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New Shocks and Asset Price Volatility in General Equilibrium[1]

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Abstract

We study equity price volatility in general equilibrium with news shocks about future productivity and monetary policy. As West (1988) shows, in a partial equilibrium present discounted value model, news about the future cash flow reduces asset price volatility. We show that introducing news shocks in a canonical dynamic stochastic general equilibrium model may not reduce asset price volatility under plausible parameter assumptions. This is because, in general equilibrium, the asset cash flow itself may be affected by the introduction of news shocks. In addition, we show that neglecting to account for policy news shocks (e.g., policy announcements) can potentially bias empirical estimates of the impact of monetary policy shocks on asset prices.

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Contents

I. INTRODUCTION

Cochrane (1994) and more recently Beaudry and Portier (2004) revived the idea that "news shocks" may be important sources of aggregate business cycle fluctuations. Cochrane (1994), in particular, noted that one reason why traditional demand and supply sources of business cycle fluctuations fared badly against the data was that economic agents may be subject to (and hence observe) shocks that are not observable to the macroeconomists or the econometricians. He then went on to conjecture that one such set of shocks may be represented by changes in expectation about the future realization of economic fundamentals (the so-called "news shocks").

While news shocks are attractive in principle, because they provide a clear and plausible example of disturbances unobservable to the econometricians but observable to the economic agents, in practice it has proven difficult to build models in which they fit the business cycles well. More recently, however, Beaudry and Portier (2004, 2007), Jaimovich and Rebelo (2009), and Schmitt-Grohe and Uribe (2008) set up dynamic stochastic general equilibrium (DSGE) models in which news shocks contribute significantly to explain aggregate fluctuations in the data.[2]

If news shocks can drive the business cycle, they should also be important for asset prices that are inherently forward looking variables. For instance, Beaudry and Portier (2006) and Gilchrist and Leahy (2002) study the interaction between asset prices and news shocks. Engel, Mark, and West (2008) also show that the main reason why fundamentals do not predict exchange rates is that currencies indeed depends heavily on expectations about the future value of the fundamentals as opposed to their current values as standard models suggest. But it is difficult to measure expectations about the future value of the fundamentals as they are not only a function of the present and the past, as it is often assumed in canonical models, but also of the future. Thus, it is useful to model the role of information about future fundamentals separately from information about current fundamentals.

Nonetheless, important theoretical results by West (1988) imply that conditioning on information sets that include also information about the future value of fundamentals should reduce the conditional variance of asset prices in present discounted value models (hereafter PVM) relative to an environment in which agents form expectations about the future conditioning only on current and past value of fundamentals.[3] Thus, one might conjecture that providing more information about future fundamentals in DSGE models (i.e., more information about the exogenous stochastic processes) would reduce asset price volatility. Since DSGE models typically generate less asset price volatility than in the data,

[2]Devereux and Engel (2006, 2007) study optimal monetary policy in the presence of news shocks in a two-country open economy model. Other recent studies include Christiano, Ilut, Motto, and Rostagno (2008), who study the implications for the conduct of monetary policy of the presence of a disturbance about the future value of the economy's fundamentals, and Fujiwara, Hirose, and Shintani (2008), who examine the role of news shocks in aggregate fluctuations for Japan and the United States.

[3]Throughout this paper, we evaluate asset price volatility using the conditional variance following West (1988).

incorporating news shocks should make the empirical performance of these models even worse with respect to this dimension of the data.

This paper incorporates news shocks about technology and monetary policy in a canonical, closed-economy DSGE model and shows that the model's ability to generate asset price volatility is not necessarily undermined. More specifically, the paper's contribution is twofold. First, the paper studies the role of news shocks for asset price volatility in a PVM. After providing a general definition of 'news', we show that the introduction of news shocks in such partial equilibrium environment always induces a fall in asset price volatility relative to the same model without news shocks.[4] However, this does not necessarily imply that, with news shocks, asset price volatility has to be low relative to that of the fundamental. In particular, we show that if news shocks are positively correlated with current shocks (which we call correlated news shocks for brevity), then the data generating process for the fundamental is serially correlated.[5] As a result, asset price volatility can increase in PVM relative to that of fundamentals with the magnitude of this correlation, holding the unconditional variance of the fundamental constant.

The fact that a persistent fundamental leads to a volatile asset price is well known in the literature.[6] The difference between a persistent fundamental process and a process with positively correlated news shocks is that, in the latter case, the asset price depends both on futute and current and past values of fundamentals, whereas in the former it depends only on current and past values of fundamentals. This distinction is important because correlated news shocks may help to explain why standard asset price models tend to fare badly against the data, consistent with the insight of Chocrane (1994) and Engel, Mark, and West (2008).

Second and more importantly, we show that, in general equilibrium, introducing news about future productivity needs not decrease asset price volatility relative to an environment without news shocks (in which agents can observe only current and past values of fundamentals).[7] That is, providing more information about the future value of the exogenous process may increase the conditional variance of asset prices significantly. The reason is that, in general equilibrium, the stochastic process for the endogenous fundamental (e.g., the cash flow from the asset) is no longer invariant to the information set. In contrast, a crucial assumption of West (1988) is that the stochastic process for the cash flow of the asset is invariant to the information set. For example, in a PVM, the dividend process would be the same regardless of

[4]In this paper, the expression "without news" means that agents do not have information about the future fundamental, but the underlying stochastic process follows exactly the same process as "with news."
[5]It is therefore impossible for the econometrician, who does not observe news shocks, to distinguish between a model in which agents observe correlated news shock and a model in which the fundamental process is persistent.
[6]See for instance Frenkel (1976) on the so-called "magnification effect" of a persistent money supply process on exchange rates volatility. More recently, interest rate smoothing has been used to explain high exchange rate volatility—e.g., Chari, Kehoe, and McGrattan (2002), Benigno (2004), Monacelli (2004), and Groen and Matsumoto (2004).
[7]We also call a model "partial equilibrium" when the cash flow process is exogenous, i.e., invariant to the information set, as in West (1988), and "general equilibrium" when the dividend process is endogenous and affected by the information assumptions.

whether agents receive news about future dividends or not. However, in general equilibrium, this may not be the case as alternative information assumptions may change the behavior of economic agents. For example, news shocks about future technology can change consumption and pricing behavior even though the exogenous stochastic process for technology is invariant to the introduction of news shocks. As a result, the profit of the firm and the dividend process can depend on whether agents receive the news about future productivity or not.

The DSGE model we set up is a simple production economy model with sticky prices. The model is simple enough to yield closed-form solutions for key variables and their conditional variances. The only model novelty is the introduction of both monetary and technology news shocks. While allowing for news shocks to aggregate technology in DGSE models is not controversial, considering monetary policy news shocks is more novel. We think about monetary policy news as the by-product of an active communication strategy aimed at guiding expectations about the future course of monetary policy, as we observe it in practice.[8] In this paper, we do not provide the rationale for an active monetary policy communication strategy, but we study its effect on asset price volatility.

While the DSGE model we set up is too simple to attempt matching asset price volatility in the data, a parameterized version of the model shows that the introduction of news shocks can indeed increase asset price volatility dramatically, measured as conditional variance of the asset price. The model also illustrates clearly the transmission mechanism of news shocks. By doing so, we can illustrate the pitfalls of empirical analyses of the impact of monetary policy shocks on asset prices that do not take the possible presence of news shocks into account. In practice, monetary policy news shocks ought to be important for asset prices as evidenced by the price of future contracts on monetary policy rates moving after monetary policy meetings and the release of communications without actual changes in policy rates. Indeed, it is often assumed (based on event studies) that new information about monetary policy plays an important role for both asset prices and macroeconomic dynamics, but there is a limited understanding of the precise transmission mechanisms at work. And a good understanding of such mechanisms should proceed any quantitative assessment of the importance of news shock for macroeconomic and asset price dynamics. In particular, as we shall see, our analysis suggests that event studies of the effect of monetary policy shocks on equity prices may be biased if they focus only on actual unanticipated policy changes.[9] Based on our analysis, which shows that it is impossible to identify news shocks by just observing fundamental data, we conjecture that including asset prices in a model that allows for news shocks may help econometricians to achieve their proper identification.

The rest of the paper is organized as follows. Section 2 provides a general definition of news shocks and a partial equilibrium example that illustrates both the result of West (1988) as well as the working of correlated news shocks. Section 3 sets up the general equilibrium model we

[8]See for instance Okina and Shiratsuka(2004), Woodford (2008), Laseen and Svensson (2009), and Blinder, Ehrmann, Fratzscher, De Haan and Jansen (2009).
[9]Rigobon and Sack (2004) is a notable exception as their empirical approach does not require the assumptions needed in the typical event study.

use and discusses its solution. Section 4 reports and discusses the main result of the paper on the impact of news shocks on equity price volatility in general equilibrium. Section 5 develops implications of the analysis in the paper for the empirical study of the impact of monetary policy shocks on asset prices. Section 6 concludes. The full solution of the model, as well as other technical details are reported in Appendices at the end of the paper.

II. A Partial Equilibrium Example

In this section, with a partial equilibrium example, we first illustrate the implications of an important result of West (1988) on asset prices and information assumptions. We then show that a positive correlation between news and current shocks can increase the conditional variance of asset price for a given variance of the fundamentals. This example also permits to illustrate why it is important to model explicitly news shocks even if they were to reduce asset price volatility relative to a model without news shocks. In the process, we establish useful notation and intuition for the general equilibrium results that we present in Section 4.

Let $\{\mathcal{F}_t\}$ be an increasing sequence (i.e., $\mathcal{F}_t \subset \mathcal{F}_{t+1}$) of linear spaces spanned by the history (current and past values) of a finite number of random variables, with $\{f_t\}$ being one of these variables. We shall call $\{f_t\}$ a fundamental variable, i.e., the cash flow of the asset. Then, let $\{\mathcal{H}_t\}$ and $\{\mathcal{I}_t\}$ be two other increasing sequences, with $\mathcal{H}_t$ being a strict subset of $\mathcal{I}_t$, which contains at least the history of $\{f_t\}$.

Consistent with the specific definitions of news shocks currently used in the DSGE literature—see for instance Jaimovich and Rebelo (2009) and Schmitt-Grohe and Uribe (2008)—we define "news" as information that helps better predict the *future value* of the fundamentals, i.e., information that reduces the conditional variance of future fundamentals. Thus, a random variable z_t can be defined as *news* about the fundamental f_{t+j} if there exists a positive integer $j > 0$ such that

$$\mathrm{Var}(f_{t+j}|\mathcal{I}_t) < \mathrm{Var}(f_{t+j}|\mathcal{H}_t) \qquad \text{with} \quad z_t \in \mathcal{I}_t \quad \text{but} \quad z_t \notin \mathcal{H}_t. \tag{1}$$

This definition characterizes a news with two attributes. First, "news" is information about the future value of fundamentals.[10] Second, it is "useful" information in the sense that it reduces the conditional variance of the future fundamental.

Consider now the following present discounted value asset pricing model (PVM)

$$x_t(\mathcal{F}_t) = \sum_{j=0}^{\infty} \beta^j \, \mathrm{P}(f_{t+j}|\, \mathcal{F}_t) \tag{2}$$

where $x_t(\mathcal{F}_t)$ is the asset price, $\mathrm{P}(f_{t+j}|\mathcal{F}_t)$ is the linear projection of f_{t+j} onto the linear space $\mathcal{F}_t$ with $j \geq 0$, and β is the discount rate. Importantly, note that the process for f_{t+j} is

[10]Empirical work sometime defines 'news' as new contemporaneous information, i.e., a surprise to current variables. We use "current shocks" to label surprises to current variables while "news" strictly refers to innovations to the future value of a variable.

invariant to the assumption made on the conditioning information set, although its expected future value and present discounted value obviously depend on this.

In such a PVM, West (1988) showed that given $\mathcal{H}_t \subset \mathcal{I}_t$,

$$\mathrm{Var}(x_t(\mathcal{I}_t)|\mathcal{I}_{t-1}) \leq \mathrm{Var}(x_t(\mathcal{H}_t)|\mathcal{H}_{t-1}), \tag{3}$$

where

$$\mathrm{Var}(x_t(\mathcal{F}_t)|\mathcal{F}_{t-1}) = \mathrm{E}[x_t(\mathcal{F}_t) - \mathrm{P}(x_t(\mathcal{F}_t)|\mathcal{F}_{t-1})]^2 \tag{4}$$

is the conditional variance of x_t given $\mathcal{F}_{t-1}$.[11] The result says that if agents receive any information (and not necessarily news) in addition to the history of the cash flows, the conditional variance of the asset price will be smaller or equal to what it would obtain if agents were to observe only the history of the cash flow at some horizon j.

We now construct an example of a PVM in which news shocks possibly correlated with current shocks (which we call correlated news shocks for brevity) can generate asset price volatility higher than the volatility of the fundamentals. Let $\mathcal{I}_t$ now be a linear space spanned by the history of $\{f_t\}$ and $\{z_t\}$ up to time t, where z_t is one of the random variables in $\{\mathcal{F}_t\}$. And let $\mathcal{H}_t$ be a linear space spanned by the history of $\{f_t\}$ up to time t and $\{z_t\}$ up only to $t-1$, with $f_0 = 0$. Thus, $z_t \in \mathcal{I}_t$, $z_t \in \mathcal{H}_{t+1}$, but $z_t \notin \mathcal{H}_t$. In other words, under these assumptions, agents in an environment with information $\mathcal{I}_t$ observe z_t at time t, while agents in an environment with information set $\mathcal{H}_t$ observe z_t only at time $t+1$. Here it is important to note that there is no agent heterogeneity in the analysis, but rather alternative information assumptions for the same homogenous representative agent model. We label the former environment "with news"and the latter "without news". Note finally that, although z_t is present in both environments, it is observed with one period delay in the model "without news."[12]

Consider now the following fundamental process that is driven by a current (ε_t) and a possibly correlated news shock (z_t):

$$f_t = f_{t-1} + \varepsilon_t + z_{t-1}, \tag{5}$$

where $(\varepsilon_t, z_t)'$ are jointly i.i.d. zero mean processes, with $\mathrm{Var}(\varepsilon_t) = \sigma_1^2$, $\mathrm{Var}(z_t) = \sigma_2^2$ and $\mathrm{Cov}(\varepsilon_t, z_t) = \varrho\sigma_1\sigma_2$ and $-1 < \varrho < 1$. These assumptions imply that

$$z_t = \varrho\frac{\sigma_2}{\sigma_1}\varepsilon_t + \eta_t, \tag{6}$$

[11]Note that this proposition requires only that one information set is a subset of the other. Of course, the proposition can be applied specifically to the case in which the difference between the two information sets is the news about the future value of the fundamental.

[12]A third environment in which, unlike the agents in the model, econometricians cannot even observe the past values of z_t (but rather only f_t), is discussed in Appendix 1.

where η_t is orthogonal to ε_t and $\mathrm{Var}(\eta_t) = (1 - \varrho^2)\sigma_2^2$. This equation characterizes z_t as a linear projection onto ε_t plus an error term, η_t. Thus η_t is the portion of z_t that is orthogonal to the current shock. Note that, strictly speaking, η_t is also "news" according to the definition we provided above as one can easily see from the special case of $\varrho = 0$ in which $z_t = \eta_t$. For illustrative purposes, however, it is preferable to consider the whole of z_t and not only η_t as news. This is because z_t represents new information arriving at time t about future fundamental f_{t+1}: $z_t = \mathrm{E}_t(\Delta f_{t+1}) - \mathrm{E}_{t-1}(\Delta f_{t+1})$. Nonetheless, the results that follow apply to both z_t and η_t.[13]

So the process for the fundamental can be rewritten as

$$
\begin{aligned}
f_t &= f_{t-1} + \varepsilon_t + z_{t-1} && (7)\\
&= f_{t-1} + \varepsilon_t + \varrho\frac{\sigma_2}{\sigma_1}\varepsilon_{t-1} + \eta_{t-1} && (8)\\
&= f_{t-1} + \theta_t + \varrho_\theta\theta_{t-1}, && (9)
\end{aligned}
$$

where θ_t and ϱ_θ are defined in Appendix 1. These three alternative representations of the process for f_t show that an 'identical' fundamental process can be expressed in three different ways depending on alternative specifications of the information set. While the economic interpretations of these alternative representations are different, it is evident that it is impossible to identify the specific information set at work observing only the time series process of the fundamental. Note in particular that the surprise component of the fundamental at time t, $f_t - \mathrm{E}_{t-1}(f_t)$, is ε_t when agents observe z_t, whereas it is $\varepsilon_t + \eta_{t-1}$ when agents observe z_{t-1} only with a lag at time t. When agents do not observe z_t at time t, they therefore attribute to "current shocks" what actually stems from news shocks. Nonetheless, agents who do not observe news shocks can still extract some information about the future value of the fundamental from the current shock ε_t as they can distinguish between ε_t and z_{t-1} in $f_t - f_{t-1}$ (because $z_{t-1} \in \mathcal{H}_t$). But when agents observe z_t at time t, they will form different expectations even though the underlying fundamental process is exactly the same.[14]

The *conditional* variance of the fundamental process with respect to these two information sets is

$$
\begin{aligned}
&\mathrm{Var}(f_t|\mathcal{I}_{t-1}) = \mathrm{Var}(\varepsilon_t) = \sigma_1^2\\
\leq\, &\mathrm{Var}(f_t|\mathcal{H}_{t-1}) = \mathrm{Var}(\varepsilon_t + \eta_{t-1}) = \sigma_1^2 + (1-\varrho^2)\sigma_2^2,
\end{aligned} \qquad (10)
$$

with the equality holding if $|\varrho| = 1$, i.e., when the current innovation reveals all the information contained in z_t.[15] When the absolute value of ϱ is close to one, the "usefulness"

[13] This implies that additional assumptions or restrictions, such as the orthogonality condition in equation (6), are required to distinguish between the two in the data.

[14] Obviously, when agents cannot even distinguish η_{t-1} from ε_t, because they do not observe even the history of z_t, like the econometrician, they will form yet different expectations for the same process. This third case (equation 9) is discussed in Appendix 1.

[15] Note that z_t is indeed "news" as it reduces the conditional variance of the fundamental.

of news (in the sense of their ability to help predicting the future fundamental) is diminishing, for given σ_1 and σ_2—i.e., holding the *unconditional* variance of the underlying fundamental $\mathrm{Var}(\Delta f_t)$ constant. The difference between the conditional variance of the fundamental with or without news depends on $1-\varrho^2$ and tends to zero as ϱ goes to one. This means that as $|\varrho|$ tends to one, agents who do not observe z_t can extract information from ε_t about future fundamentals with increasing precision. Thus, one economic interpretation of ϱ getting close to one is that the current innovation and the news shock become very similar. Note finally that the data generating process of the fundamental is invariant to the information set of the agent, but it does change depending on the value of ϱ, even though the unconditional variance of fundamentals does not change with ϱ.

Introducing news shocks explicitly in the model is useful even if it reduces asset price volatility. First, correlated news shocks can provide an economic interpretation of what may otherwise just appear to the econometrician as a "persistent" process. In other words, a stochastic process for the fundamental appearing to be persistent to the econometrician may be also due to positively correlated news shocks that are not observed by the econometrician. For instance, persistent interest rate processes may be interpreted as being generated by correlated news shocks. Monetary announcements regarding the future course of policy (monetary news shocks) tend to go in the same direction as the actual policy actions (current shocks), but they also can go in different directions, thus providing more information about the future course of policy interest rates than it can be inferred by simply assuming that interest rates are persistent. Second, as we shall see in Section 4, grounding the empirical analysis of the impact of monetary policy shocks on asset prices in a model that explicitly allows for the possible presence of news shocks may help to shed light on potential omitted variable bias problems in their estimated impacts.[16]

Let's now explore the implications for asset price. The asset price at time t conditional on $\mathcal{I}_t$ is

$$x_t(\mathcal{I}_t) = \sum_{j=0}^{\infty} \beta^j \,\mathrm{E}(f_{t+j}|\mathcal{I}_t) = \frac{1}{1-\beta} f_t + \frac{\beta}{1-\beta} z_t \tag{11}$$

while the asset price at time t conditional on $\mathcal{H}_t$ is

$$x_t(\mathcal{H}_t) = \sum_{j=0}^{\infty} \beta^j \,\mathrm{E}(f_{t+j}|\mathcal{H}_t) = \frac{1}{1-\beta} f_t + \frac{\beta}{1-\beta} \varrho \frac{\sigma_2}{\sigma_1} \varepsilon_t. \tag{12}$$

Notice here that the asset price depends not only on the current fundamental f_t but also on the news z_t if this is observed by the agents in economy. Therefore, assessing the performance of an asset price model (a PVM, for example) while making incorrect information assumptions can lead to reject the model when in fact it is the information assumption that one should reject. That is, the often lamented lack of economic understanding of asset prices may be the

[16]Rigobon and Sack (2004) point out that empirical analyses based on event studies often suffer from omitted variable bias.

result of ignoring the possible presence of news. While it is impossible to extract news from the data by just observing fundamental data, the asset price $x_t(\mathcal{I}_t)$ contains information about news that can be inferred from the data using a model that allows for such a possibility. In this respect, adding asset prices to an empirical model of the fundamental process that also allows for the possible presence of news shocks can help the econometrician to unveil a 'truer' fundamental process, and thus deepen our understanding of asset price dynamics and their determinants.[17]

Compare the conditional variances of the asset price under two alternative information environments. These are, respectively,

$$\begin{aligned} \mathrm{Var}(x_t(\mathcal{I}_t)|\mathcal{I}_{t-1}) &= \mathrm{Var}\left(\frac{1}{1-\beta}(\varepsilon_t + \beta z_t)\right) \\ &= (1-\beta)^{-2}\left(\sigma_1^2 + 2\beta\varrho\sigma_1\sigma_2 + \beta^2\sigma_2^2\right), \end{aligned} \tag{13}$$

$$\begin{aligned} \mathrm{Var}(x_t(\mathcal{H}_t)|\mathcal{H}_{t-1}) &= \mathrm{Var}\left(\frac{1}{1-\beta}(\varepsilon_t + \eta_{t-1} + \beta\varrho\frac{\sigma_2}{\sigma_1}\varepsilon_t)\right) \\ &= (1-\beta)^{-2}\left(\sigma_1^2 + 2\beta\varrho\sigma_1\sigma_2 + [\beta^2 + (1-\beta^2)(1-\varrho^2)]\sigma_2^2\right). \end{aligned} \tag{14}$$

Thus, consistent with West (1988), the conditional variance of the asset price with news shocks is smaller than that without news shocks by the factor $(1-\beta^2)(1-\varrho^2)\sigma_2^2$ (whether the news shocks are correlated with current shocks or not).

Including news shocks in the PVM, however, needs not reduce asset price volatility relative to the *unconditional* variance of the underlying fundamental. The unconditional variance of the fundamental is

$$\mathrm{Var}(\Delta f_t) = \mathrm{Var}(\varepsilon_t + z_{t-1}) = \sigma_1^2 + \sigma_2^2, \tag{15}$$

which does not depend on ϱ. Thus, a larger ϱ can increase the conditional variance of the asset price, while leaving the unconditional variance of fundamental unchanged. In fact, as ϱ gets closer to one, correlated news shocks generate higher asset price volatility, like models with persistent fundamentals in which there is the so-called magnification effect (e.g., Frenkel, 1976). This is because, as ϱ increases, the fundamental process becomes more persistent and news become less useful to predict future fundamentals (because we can predict them based on current shocks).

In practice we could increase the conditional variance of asset prices by simply assuming an MA(1) process like equation (9) above. Proceeding in this manner, however, is problematic if

[17]For instance, Rudebusch (2006) studies policy interest rate smoothing using term structure information and finds that this is better interpreted as a response to a slow moving flow of economic data than monetary policy inertia per se. Barsky and Sims (2010) identify TFP news shock by including stock prices in a otherwise standard VAR model. Following the same methodology, Kurmann and Otrok (2010) find that TFP news shocks explains most movement in the slope of term structure.

agents actually observe news about the future value of fundamentals. This is because the actual realization of news shocks may or may not be similar to the current shocks. That is, in general $\eta_t \neq 0$, meaning that agents without news always make errors in making inference about news based on ε_t even if they are "correlated" news. Unlike the fundamental process which is invariant to the information set, the realization of the asset prices will be affected by the assumption on the observability (or lack thereof) of z_t. Thus, model-based asset prices will be different depending on the inclusion or not of news, i.e., $x_t(\mathcal{I}_t) \neq x_t(\mathcal{H}_t)$. In addition, as we show in Appendix, even if the econometrician extracts the best possible information from the fundamental process without news, it is qualitatively different from the model with news shocks. While *ceteris paribus* a higher value of ϱ mitigates the problem by allowing agents without news or econometricians to extract better information from current fundamentals, a higher value of σ_2 may exacerbate this problem by increasing the importance of news about the future in the data generating process.

In sum, as shown in the seminal contribution of West (1988), the introduction of news shocks reduces asset price volatility, measured by the conditional variance of the asset price for a given univariate representation of the underlying fundamental (cash flow) process, relative to the environment in which agents do not observe news shocks. However, our simple example suggests that if news shocks are positively correlated with current shocks, asset price volatility relative to the volatility of the cash flow process can increase with this correlation for a given *variance* of the cash flow process. The reason is that correlated news shocks induce a "magnification effect" in the asset price volatility, generated by a fundamental process that appears persistent to the econometrician or the economic agents in an environment without news. As we have demonstrated (and as also implied by the proposition of West, 1988), if agents do not observe correlated news shocks, the conditional variance of the asset price is even larger in the PVM, holding constant the data generating process of the cash flow.

We have also shown that modeling news shocks explicitly can help to explain why asset prices do not simply depend on current fundamentals. Thus, the point made by Cochrane (1994) that news shocks may help to understand the business cycle also applies to asset prices. It is therefore important to allow for news shocks in asset price models even though they may reduce the conditional variance of asset prices relative to an environment without news shocks. And even more so given that, as we shall see in Section 4, this volatility reducing effect may not be necessarily present in general equilibrium.

III. A DSGE Model

We employ a relatively simple dynamic stochastic general equilibrium (DSGE) model to characterize the effects of news shocks on asset prices in general equilibrium. Except for news shocks, the model and its solution are standard. We keep the model simple to obtain analytical solutions.

The model is a production economy with unit population, nominal rigidity and news shocks. Goods prices are set one period in advance. There are two exogenous processes, for the money supply and labor productivity, and we assume that agents can receive new information about both variables one period in advance. Firms are monopolistic competitors that use a linear technology with no capital. Since agents are all alike, equity prices are simply the present discounted sum of future profits (by ruling out bubble solutions). In the rest of this section, we describe the model setup in more detail, while its full solution is reported in Appendix 2.

A. Households

The representative household j maximizes

$$\max_{C_t(j),M_t(j),L_t(j)} \mathrm{E}_t \sum_{s=t}^{\infty} \left(\frac{C_s(j)^{1-\rho}}{1-\rho} + \frac{\kappa_1}{1-\varepsilon} \left(\frac{M_s(j)}{P_s} \right)^{1-\varepsilon} - \frac{\kappa_2}{1+\psi} L_s(j)^{1+\psi} \right), \tag{16}$$

subject to a budget constraint in which we assume that asset markets are complete in nominal terms and households receive a lump-sum transfer from the national government generated by seignorage. The consumption basket is $C_t(j)$, $\frac{M_t(j)}{P_t}$ is real money balance, and $L_t(j)$ is the labor supply. The following standard parameter restrictions are assumed to hold on the inverse of the intertemporal substitution elasticity, money demand interest rate semi-elasticity, inverse of the wage elasticity of labor supply, and the weights of money balances and labor disutility in the period utility flow, respectively: $\rho > 0$, $\varepsilon > 0$, $\psi \geq 0$, κ_1 and $\kappa_2 > 0$. The consumption basket $C_t(j)$ is defined as

$$C_t(j) \equiv \left[\int_0^1 C_t(j,i)^{(\lambda-1)/\lambda} di \right]^{\lambda/(\lambda-1)}, \tag{17}$$

where $\lambda > 1$ denotes the elasticity of substitution among different varieties. Given these baskets, the aggregate price index can be written as

$$P_t = \left[\int_0^1 P_t(i)^{1-\lambda} di \right]^{1/(1-\lambda)}, \tag{18}$$

Given prices and the total consumption basket C_t, the optimal consumption allocation satisfies (since households are identical, we can suppress the index j):

$$C_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\lambda} C_t. \tag{19}$$

The other first order conditions are

$$W_t = \kappa_2 \frac{L_t^{\psi}}{C_t^{-\rho}/P_t}, \qquad \text{labor supply} \tag{20}$$

$$\left(\frac{M_t}{P_t} \right)^{\varepsilon} = \kappa_1 \frac{C_t^{\rho}}{1 - \mathrm{E}_t \beta D_{t,t+1}}, \qquad \text{money demand,} \tag{21}$$

where

$$D_{t,t+s} \equiv \frac{C_{t+s}^{-\rho}/P_{t+s}}{C_t^{-\rho}/P_t} \tag{22}$$

is the stochastic discount factor or the pricing kernel.

B. Firms

Firms are monopolistic competitors with a linear technology in labor:

$$Y_t(i) = A_t L_t(i), \tag{23}$$

where $Y_t(i)$ is firm i's production, $L_t(i)$ is firm i's labor input, and A_t is common productivity across all firms.

Firms supply goods as demanded. We assume that firm i presets its price $P_t(i)$ one period in advance. The firm's output price is set to maximize its discounted profit, given other firms' prices. The discounted profit for firm i is

$$D_{t-1,t}\Pi_t(i) = D_{t-1,t}[P_t(i)Y_t(i) - W_t L_t(i)], \tag{24}$$

where the demand for firm i's good is, respectively,

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\lambda} C_t. \tag{25}$$

Thus, the optimal preset price is

$$P_t(i) = \frac{\lambda}{\lambda - 1} \frac{\mathrm{E}_{t-1}\, D_{t-1,t}\dfrac{W_t}{A_t}C_t}{\mathrm{E}_{t-1}\, D_{t-1,t}C_t}, \tag{26}$$

Since all firms are alike, $P_t(i) = P_t$ for all i.

C. Market Clearing and Equilibrium

Labor and goods markets clear as follows:

$$Y_t = A_t L_t = C_t. \tag{27}$$

Given goods prices, households satisfy the first order conditions for their consumption. The money market clears equating money demand from the households' first order conditions and money supply as specified below. We also assume that, in the initial state, $A_0 = 1$ and $P_0 = 1$, and that there is no news about the future at time 0. Given the exogenous processes for productivity and money supply, equilibrium is then defined as usual.

D. Stochastic Processes and Information Assumptions

The assumptions we make on the stochastic processes driving the model dynamics are different from those used in the typical DSGE model, but they are now standard in the news literature. The aggregate productivity level, $\ln(A_t)$, has a unit root. Specifically, we assume that

$$a_t \equiv \ln(A_t) = a_{t-1} + \nu_{1,t} + \nu_{2,t-1}, \tag{28}$$

where $(\nu_{1,t},\ \nu_{2,t})'$ are jointly i.i.d. over time with mean zero, $\mathrm{Var}(\nu_{1,t}) = \sigma^2_{\nu_1}$, $\mathrm{Var}(\nu_{2,t}) = \sigma^2_{\nu_2}$, and $\mathrm{Cov}(\nu_{1,t}, \nu_{2,t}) = \varrho_a \sigma_{\nu_1} \sigma_{\nu_2}$. Note that $\nu_{1,t}$ is a traditional productivity shock, which we call "current shock" , while $\nu_{2,t}$ provides information about productivity one period in advance, i.e., on a_{t+1} at time t. Thus, $\nu_{2,t}$ is news about productivity as the conditional variance of a_{t+1} is smaller when we include $\nu_{2,t}$ in the information set.

To label alternative information sets, we use the notation developed in Section 2. That is $\nu_{2,t} \in \mathcal{I}_t$ and $\nu_{2,t-1} \in \mathcal{H}_t$ but $\nu_{2,t} \notin \mathcal{H}_t$. Thus, $\mathcal{I}_t$ denotes the information set when the agents can observe news, while $\mathcal{H}_t$ is the information set when agents do not observe news, i.e., agents in $\mathcal{H}_t$ do not observe $\nu_{2,t}$ until time $t+1$ even though $\nu_{2,t}$ is realized at time t. Like in the previous section, for brevity, we shall call the first environment "with news" and the second "without news"respectively. It is important to stress here that the underlying stochastic process for productivity is not affected by the introduction of news shocks, which only changes the information set of agents in the two environments.

For the money supply, we assume the following processes:

$$\ln(M_t) = \ln(M_{t-1}) + \mu_t, \tag{29}$$

where μ_t is

$$\mu_t = \nu_{3,t} + \nu_{4,t-1} + \chi_1 \nu_{1,t} + \chi_2 \nu_{2,t-1} + \chi_3 \nu_{2,t}, \tag{30}$$

with $(\nu_{3,t},\ \nu_{4,t})$ jointly i.i.d. over time, with mean zero, $\mathrm{Var}(\nu_{3,t}) = \sigma^2_{\nu_3}$, $\mathrm{Var}(\nu_{4,t}) = \sigma^2_{\nu_4}$, $\mathrm{Cov}(\nu_{3,t}, \nu_{4,t}) = \varrho_m \sigma_{\nu_3} \sigma_{\nu_4}$, and independent from $\nu_{1,t}$ and $\nu_{2,t}$.

Here, $\nu_{3,t}$ and $\nu_{4,t}$ are the traditional shock to the current period money stock and the news shock about next period's money stock, respectively, while χ_1, χ_2, and χ_3 are monetary policy responses to different productivity shocks. Specifically, χ_1 is the reaction coefficient to a current productivity shock, χ_2 is the delayed reaction to a news shock, while χ_3 is the contemporaneous reaction to a news shock. Note that while χ_2 is the monetary policy reaction to the news shock when this materializes in productivity, χ_3 is the reaction to the news shock when it arrives before its materialization in productivity. This implies that $\chi_2 \nu_{2,t-1}$ is also the anticipated monetary policy response to a productivity news shock, as agents in the economy know in advance that the monetary authority will react to this shock when it materializes in productivity in the next period. Thus, such a reaction is akin to a monetary policy news shock

($\nu_{2,t-1}$) because it does not affect the money supply until the authority actually reacts to the materialization of the productivity news shock, but it is expected one period in advance. On the other hand, $\chi_3\nu_{2,t}$ can be seen as a current monetary policy shock because agents in the economy cannot anticipate it one period in advance. Note that $\chi_3\nu_{2,t}$ can also be interpreted as a "preemptive" monetary policy reaction. In a typical model without news, it is sometimes described as reaction to an "expectation." However, the introduction of an explicit reaction to a news shock is important when expectations about future fundamentals cannot be described as a mere function of past and current fundamentals.[18]

These monetary policy responses are neither realistic nor optimal, but they permit to highlight the linkages between the monetary policy response to different shocks and asset prices. In addition, as we have shown in the previous section, asset prices carry information about future fundamentals, and the monetary authorities may react to asset prices if reaction to future fundamentals is justified and the authority does not have as good information as market participants. More generally, while monetary policy news shocks ($\nu_{4,t}$) may be novel in the DSGE literature, many policy communications can be easily interpreted as monetary policy news shocks.[19]

Note finally that, for ease of interpretation of the results in the next section, it is useful to define the following auxiliary variables:

$$\mu_{1,t} \equiv \nu_{3,t} + \chi_1\nu_{1,t} + \chi_3\nu_{2,t}, \quad \mu_{2,t} \equiv \nu_{4,t} + \chi_2\nu_{2,t}, \tag{31}$$

so that $\mu_t = \mu_{1,t} + \mu_{2,t-1}$ where $\mu_{1,t}$ are the surprise components of the money supply (i.e., the policy reaction to the current productivity shock and/or the current shock to the money supply), and $\mu_{2,t}$ is news about future money supply plus the delayed (thus anticipated) policy response to the news about future productivity.

E. Solution

We solve the model by log-linearizing around an initial steady state. For any variable, lower case notation stands for its log-deviation from the initial steady state. The Appendix 2 reports a complete model solution. In the rest of this section, we discuss the implications of the model's solution for equity price volatility.

We solve the model assuming that agents observe news, but it is simple to obtain the solution when agents do not observe news. This is because the model with news shocks nests the standard model without news shocks. The difference between the two models is that news shocks have specific effects when agents observe them, which are not present without news. However, the effects of current shocks (ν_1, μ_1) is the same whether agents observe news or not, assuming no correlation between news shocks and current shocks. The solutions in both

[18]Christiano et.al. (2008) find that a Taylor rule that does not react to productivity news shock when it occurs (e.g., $\chi_3 = 0$) can generate asset price booms and busts in their model.
[19]Sekine and Teranishi (2008), for example, discuss the effect of policy communication on the volatility of inflation. Okina and Shiratsuka (2004) study the effect of monetary policy commitment on the yield curve.

environments depend on two types of shocks, current and news shocks to the underlying processes (i.e., ν_1, ν_2, and μ_1, μ_2 respectively). When agents do not observe news, they are surprised by news only one period after the news has arrived. And hence the effect of a unit 'news shock' when agents do not observe them is the same as that of a unit current shock.

IV. General Equilibrium Results

In this section, we study the volatility impact of the introduction of news shocks in general equilibrium. Specifically, we provide an example in which the introduction of news about future productivity leads to an increase in the conditional variance of the equity price. Then we discuss monetary policy news shocks and the interaction of news shocks with a stochastic discount factor. Finally, we introduce a correlation between current and news shocks to show that the magnification effect that we discussed in Section 2 may not be operative in general equilibrium. Before proceeding, recall that when we compare asset price volatility with or without news shocks, we keep the underlying stochastic process unchanged, and only change the information set of the agents.

A. News Shocks and Equity Prices

In the model, equity prices are discounted present values of dividends. In general equilibrium, however, dividends depend not only on the realization of the underlying exogenous stochastic processes for productivity and money supply, but also on the expected future values of these processes. This implies that alternative information assumptions can affect the dividend process itself unlike in the present discounted value example of section 2, in which the dividend process is invariant to the assumptions on the information set.[20] This is because, in general equilibrium, consumption, the wage rate, sales, pricing, and hence profits all depend on current as well as news shocks to the exogenous processes.

The reason why consumption is different when the information set is different is very intuitive: if agents know today (via news shocks) that tomorrow is going to be a good time, then they start to adjust today. This in turn affects sales and firms' profits. At the same time, because of price rigidity, some variables cannot adjust immediately in response to shocks. As a result, in a general equilibrium model with news shocks, it is possible to obtain a more volatile equity price than in the environment without news for certain parameter values.

Equities in our model are claims that pay off the firm's profit every period. Firms do not have physical capital, but they have monopolistic power that generates profits.[21] Given the assumption of complete asset markets and the discount factor, the pre-dividend price of a

[20] As we have already noted, exogenous processes are invariant to alternative assumptions on the information set.
[21] This specification is isomorphic to the case in which firms are endowed with a fixed stock of capital that does not depreciate. We do not model investment decisions for simplicity and to obtain analytical solutions. An even simpler endowment economy, however, would not generate the results we report as the firm cash flow would not exist in this case.

claim on the firm's profit can be written as

$$Q_t = \Pi_t + \mathrm{E}_t\left[\beta D_{t,t+1} Q_{t+1}\right]. \tag{32}$$

Thus, the linearized equity price[22] is

$$q_t = \beta\, \mathrm{E}_t\, q_{t+1} + (1-\beta)\pi_t - \beta i_t, \tag{33}$$

where $i_t = E_t(-d_{t,t+1})$ is the (linearized) nominal interest rate between period t to $t+1$.[23] Then, it is straightforward to derive the following expression for the return on equity, r_t:

$$r_{t+1} = i_t + (q_{t+1} - \mathrm{E}_t\, q_{t+1}). \tag{34}$$

This expression shows that the excess return on equity over the nominal interest rate, $r_{t+1} - i_t$, is equal to the surprise component of equity prices, $q_{t+1} - \mathrm{E}_t\, q_{t+1}$. Note also that the return on equity is not i.i.d., as the nominal interest rate is known at time t, i.e., $\mathrm{E}_t(r_{t+1}) = i_t$, but its excess return is indeed an i.i.d. process as one would expect. This equation also implies that the variance of the excess return is the same as the conditional variance of the equity price innovation, which is the focus of our analysis.[24] Note finally that, in our model, good prices are set one period in advance and hence surprise components or excess returns are the same in both nominal and real terms.

The surprise component of the equity price is

$$\begin{aligned} &q_{t+1} - \mathrm{E}_t\, q_{t+1} = r_{t+1} - i_t \\ =&(\Lambda_1 + \Lambda_2)\nu_{1,t+1} + \Lambda_2 \nu_{2,t+1} \\ &+ \Lambda_m \left\{\left[(1-\beta)\varepsilon + \beta\right](\mu_{1,t+1}) + \beta\mu_{2,t+1}\right\}, \end{aligned} \tag{35}$$

where

$$\begin{aligned} \Lambda_1 \equiv&(1-\beta)\frac{\zeta}{1-\zeta}(\psi+1), \\ \Lambda_2 \equiv&\left\{\left[1 + (1-\beta)\left(\frac{1-\rho}{\rho} - \frac{\zeta}{1-\zeta}\frac{\rho+\psi}{\rho}\right)\right]\rho\left(1-\frac{1}{\varepsilon}\right) + (1-\rho)\right\}\beta\frac{\psi+1}{\rho+\psi}, \\ \Lambda_m \equiv&1 + (1-\beta)\left(\frac{1-\rho}{\rho} - \frac{\zeta}{1-\zeta}\frac{\rho+\psi}{\rho}\right), \end{aligned}$$

and $\zeta = (\lambda-1)/\lambda$ is the steady state labor share of revenue. We can now study the volatility impact of introducing news shocks.

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[22] **As we use the standard linear approximation, the covariance terms drops.**

[23] Note that i_t is the log deviation from the steady state net interest rate, $\frac{1-\beta}{\beta}$.

[24] We use "excess return," "unexpected return," and "surprise component of the equity price return" interchangeably.

B. Productivity News Shocks

From equation 35, we can see that productivity news shocks, $\nu_{2,t+1}$, affect the excess return unless $\Lambda_2 = 0$ (i.e., both $\varepsilon = 1$ and $\rho = 1$). Let $q_t(\mathcal{I}_t)$ be the equity price when agents observe a news shock ($\nu_{2,t}$) at time t, and $q_t(\mathcal{H}_t)$ be the equity price when agents do not observe at time t (i.e., they observe it only at time $t+1$ together with the current shock $\nu_{1,t+1}$). Further, to isolate the general equilibrium effect of news shocks, we assume $\varrho_a = 0$. Assuming $\varrho_a = 0$ also simplifies the analysis because the surprise component of productivity for the agents who do not observe news is the same as the actual productivity change. That is, when agents observe news shocks $\nu_{2,t}$ only at time $t+1$, $a_{t+1} - \mathrm{E}(a_{t+1}|\mathcal{H}_t) = \Delta a_{t+1} = \nu_{1,t+1} + \nu_{2,t}$. In contrast, the surprise component of productivity for agents who do observe news shocks is $a_{t+1} - \mathrm{E}(a_{t+1}|\mathcal{I}_t) = \nu_{1,t+1}$.

First, ignoring monetary shocks and the monetary reaction to the technology shocks for simplicity, we can rewrite the surprise component of the equity price with news shocks as follows:

$$q_{t+1}(\mathcal{I}_{t+1}) - \mathrm{E}(q_{t+1}(\mathcal{I}_{t+1})|\mathcal{I}_t) = (\Lambda_1 + \Lambda_2)\nu_{1,t+1} + \Lambda_2 \nu_{2,t+1}. \tag{36}$$

When agents do not observe news shocks we can replace $\nu_{2,t+1}$ with zero and $\nu_{1,t+1}$ with $\nu_{1,t+1} + \nu_{2,t}$ in the above equation.[25] Thus, without news shocks, we have

$$q_{t+1}(\mathcal{H}_{t+1}) - \mathrm{E}(q_{t+1}(\mathcal{H}_{t+1})|\mathcal{H}_t) = (\Lambda_1 + \Lambda_2)\left(\nu_{1,t+1} + \nu_{2,t}\right). \tag{37}$$

Now it is easy to see that the difference in the conditional variances of these two surprise components is given by the following expression:

$$\begin{aligned} &\mathrm{Var}(q_{t+1}(\mathcal{I}_{t+1})|\mathcal{I}_t) - \mathrm{Var}(q_{t+1}(\mathcal{H}_{t+1})|\mathcal{H}_t) \\ &= -\left(\Lambda_1 + 2\Lambda_2\right)\Lambda_1 \sigma_{\nu 2}^2. \end{aligned} \tag{38}$$

Asset price volatility with news shocks is larger than without news shocks—i.e., the sign of this expression is positive—when $\Lambda_1 + 2\Lambda_2 < 0$ as $\Lambda_1 > 0$. In general, $\Lambda_1 + 2\Lambda_2$ can be either positive or negative. However, it is possible to find cases in which its value is negative for plausible assumptions on the parameter values. For instance, suppose $\varepsilon = 1$ and $\psi = 0$ (i.e., unit interest rate elasticity of money demand ($1/\varepsilon$) and linear disutility of labor, as often assumed in the literature because of lack of direct empirical evidence on this parameter). The above equation then simplifies to

$$\begin{aligned} &\mathrm{Var}(q_{t+1}(\mathcal{I}_{t+1})|\mathcal{I}_t) - \mathrm{Var}(q_{t+1}(\mathcal{H}_{t+1})|\mathcal{H}_t) \\ &= -\left[2\beta\frac{1-\rho}{\rho} + (1-\beta)\frac{\zeta}{1-\zeta}\right](1-\beta)\frac{\zeta}{1-\zeta}\sigma_{\nu 2}^2, \end{aligned} \tag{39}$$

which, for instance, is positive if the labor share $\zeta = 2/3$, the discount factor $\beta = .95$, and the inverse of elasticity of intertemporal substitution $\rho \geq (1 - \frac{1-\beta}{2\beta}\frac{\zeta}{1-\zeta})^{-1} \approx 1.06$.[26]

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[25]It is easy to see that if $\varrho_a \neq 0$, then we have to replace $\nu_{2,t+1}$ with $\varrho_a \sigma_2/\sigma_1 \nu_{1,t+1}$ and $\nu_{1,t+1}$ with $\nu_{1,t+1} + \eta_t$ where $\eta_t \equiv \nu_{2,t} - \varrho_a \sigma_2/\sigma_1 \nu_{1,t}$.

[26]Note that if $\rho = 1$, the expression (38) is positive for $\varepsilon = .8$, $\zeta = 2/3$, and $\beta = .95$.

Note that, in this example, contrary to the empirical evidence presented by Beaudry and Portier (2006) and Barsky and Sims (2010), the equity return falls with a positive productivity news shock. This is because $\Lambda_2 < 0$ when $\Lambda_1 + 2\Lambda_2 < 0$. In fact, our simple model cannot generate simultaneously an increase in the equity return in response to a positive productivity news shock and higher equity price volatility with the introduction of news shocks, unless monetary policy reacts to these shocks in specific ways. As we shall see below, however, with a specific monetary policy reaction to productivity news shocks, the model can generate both the right comovement and higher volatility.

Why is the equity price more volatile when agents observe news in this general equilibrium example? As equations (36) and (37) show, the difference in the equity price response to news shocks is due to ν_2 as the effect of current shocks ν_1 is the same in the two model environments. So let's consider how $\nu_{2,t}$ affects asset prices. When agents do not observe news, $\nu_{2,t}$ surprises them only one period later, at time $t+1$, when the news materializes in productivity. In contrast, when agents observe news, $\nu_{2,t}$ surprises them when it arrives, at time t. Also, since $\nu_{2,t}$ has a permanent effect on productivity, agents update their expectations about future productivity when they are surprised (either at time t or $t+1$ depending on the information environment). In turn, in both environments, higher expected future productivity reduces the future good price and hence the future nominal profit for the parameter values we assumed.

However, today's profit increases only if agents are surprised, by either the realization of a current productivity shock in both environments or by the materialization of a past news shock in the environment without news shocks. A positive surprise in current productivity thus has two offsetting effects on the equity prices—a positive effect via the impact on today's profit and a negative effect via the impact on future nominal profits. Since the effect on future profits is larger, such a shock depresses equity price.

In contrast, when agents observe news shocks, the only effect of a positive productivity news shock on the equity price is via a reduction in the nominal future profits with no offsetting impact on today's profit (because the current profit does not change in response to the news shock with this parametrization.)[27] As a result, the equity price decreases more with a news shock than with a current shock in both environments (or with the materialization of a past news shock in the $\mathcal{H}_t$ environment). That is, the impact of ν_2 on the equity price is bigger when agents observe news than when agents do not.

Trying to match asset price volatility in the data is beyond the scope of the simple model we set up; however, it is still possible to quantify the impact of the introduction of news shocks on asset price volatility in our model, for plausible parameter values. Figure 1 plots the conditional variance of equity prices with or without news shocks as a function of ρ (inverse of the intertemporal elasticity of substitution, or the coefficient of relative risk aversion) for

[27]When $\varepsilon \neq 1$, current profit will be affected by news shocks via a consumption smoothing channel, but the quantitative impact is small as far as $\varepsilon \approx 1$.

three different values of ε (the inverse of real money demand elasticity to the interest rate) to illustrate how the impact on the asset price volatility depends on the various parameters. Figure 2 plots the log difference of these conditional variances in the two model environments, $\ln \mathrm{Var}(q_{t+1}(\mathcal{I}_{t+1})|\mathcal{I}_t) - \ln \mathrm{Var}(q_{t+1}(\mathcal{H}_{t+1})|\mathcal{H}_t)$. Note that, in these computations, we assume no monetary policy shock as well as no monetary policy response to any productivity shock. The variances of the productivity news shocks and current shocks are unity with no correlation between current and news shocks. Other parameter values are the same we assumed above: $\psi = 0$, $\beta = .95$, $\zeta = 2/3$.

Introducing news shocks in the model, under these parameter assumptions, can have a potentially large impact on the conditional variance of asset prices. While the absolute values of the conditional variances are small in this simple model (Figure 1), the log difference between the model with and without news shocks is very large (Figure 2). When $\Lambda_1 + 2\Lambda_2 = 0$, the two conditional variances are the same, while the log difference goes to infinity when $\Lambda_1 + \Lambda_2 = 0$, as the equity price does not respond when agents do not observe news (see equation 37). As explained above, this is the crucial distinction in the transmission of current and news shocks. While this example inevitably reflects the simplicity of the model and the specific assumptions made on parameter values, it shows that the effect of news shocks on asset price volatility in general equilibrium can be potentially large.

C. Monetary Policy News Shocks

We now consider monetary policy news shocks. Recall that

$$\mu_{1,t} \equiv \nu_{3,t} + \chi_1 \nu_{1,t} + \chi_3 \nu_{2,t}, \quad \mu_{2,t} \equiv \nu_{4,t} + \chi_2 \nu_{2,t}, \tag{40}$$

Consider first the case in which there is no monetary policy response to productivity shocks. Monetary policy news shocks alone do not generate higher asset price volatility in this simple model. In fact,

$$\begin{aligned} &\mathrm{Var}(q_{t+1}(\mathcal{I}_{t+1})|\mathcal{I}_t) - \mathrm{Var}(q_{t+1}(\mathcal{H}_{t+1})|\mathcal{H}_t) \\ &= -\,\Lambda_m^2 (1-\beta)\varepsilon \left[(1-\beta)\varepsilon + 2\beta\right] \sigma_{\nu 4}^2. \end{aligned} \tag{41}$$

Since $\varepsilon > 0$, this expression is always negative, meaning that a monetary policy announcement alone cannot increase the conditional variance of equity price.

Consider now a more realistic situation in which monetary policy reacts to productivity news shocks, assuming for simplicity that there are no monetary policy news shocks (i.e., $\nu_{4,t}$ is zero). Specifically, assume that

$$\mu_t(\mathcal{I}_t) = \chi_1 \nu_{1,t} + \chi_2 \nu_{2,t-1} + \nu_{3,t}, \tag{42}$$

$$\mu_t(\mathcal{H}_t) = \chi_1 (\nu_{1,t} + \nu_{2,t-1}) + \nu_{3,t}, \tag{43}$$

with $\chi_3 = 0$, so that monetary policy responds only to the materialization of a previous period news shock or to the realization of a current shock in productivity.[28] With this monetary reaction function, we have that

$$\begin{aligned} & q_{t+1}(\mathcal{I}_{t+1}) - \mathrm{E}(q_{t+1}(\mathcal{I}_{t+1})|\mathcal{I}_t) \\ = & \left\{\Lambda_1 + \Lambda_2 + \Lambda_m\chi_1\left[(1-\beta)\varepsilon+\beta\right]\right\}\nu_{1,t+1} \\ & \qquad + (\Lambda_2 + \Lambda_m\chi_2\beta)\nu_{2,t+1} + \Lambda_m\left[(1-\beta)\varepsilon+\beta\right]\nu_{3,t}, \end{aligned} \tag{44}$$

$$\begin{aligned} & q_{t+1}(\mathcal{H}_{t+1}) - \mathrm{E}(q_{t+1}(\mathcal{H}_{t+1})|\mathcal{H}_t) \\ = & \left\{\Lambda_1 + \Lambda_2 + \Lambda_m\chi_1\left[(1-\beta)\varepsilon+\beta\right]\right\}(\nu_{1,t+1}+\nu_{2,t}) + \Lambda_m\left[(1-\beta)\varepsilon+\beta\right]\nu_{3,t}. \end{aligned} \tag{45}$$

Therefore, in order to have higher conditional variance by introducing news shocks with the specific monetary reaction above, the following inequality has to hold:

$$\begin{aligned} & \mathrm{Var}(q_{t+1}(\mathcal{I}_{t+1})|\mathcal{I}_t) - \mathrm{Var}(q_{t+1}(\mathcal{H}_{t+1})|\mathcal{H}_t) \\ = & -\left\{\Lambda_1 + 2\Lambda_2 + \Lambda_m\chi_1\left[(1-\beta)\varepsilon+\beta\right] + \Lambda_m\beta\chi_2\right\} \\ & \quad \times \left\{\Lambda_1 + \Lambda_m\chi_1\left[(1-\beta)\varepsilon+\beta\right] - \Lambda_m\beta\chi_2\right\}\sigma_{\nu 2}^2 > 0. \end{aligned} \tag{46}$$

Depending on the sign and values of χ_1 and χ_2 and the other parameter values, this last expression can be satisfied.[29] In order to quantify the difference between these two expressions, assume $\varepsilon = 1$ and $\psi = 0$ as before, and consider an optimal monetary policy reaction in the sense that it replicates the flexible price equilibrium (i.e., $\chi_1 = 1$ and $\chi_2 = 0$).[30] In this case, we find that

$$\begin{aligned} & \mathrm{Var}(q_{t+1}(\mathcal{I}_{t+1})|\mathcal{I}_t) - \mathrm{Var}(q_{t+1}(\mathcal{H}_{t+1})|\mathcal{H}_t) \\ = & -(\Lambda_1 + 2\Lambda_2 + \Lambda_m)(\Lambda_1 + \Lambda_m)\sigma_{\nu 2}^2 \\ = & -\left[(1+\beta)\frac{1}{\rho} - \beta\right]\left[\beta + (1-\beta)\frac{1}{\rho}\right]\sigma_{\nu 2}^2, \end{aligned} \tag{47}$$

implying that news shocks can increase equity price volatility for $\rho > 1 + 1/\beta$ (a plausible value, slightly larger than 2, for the assumed values of the other parameters and $\beta = .95$). Thus, this example shows that, even when monetary policy responds optimally, the introduction of news shocks can indeed increase asset price volatility.[31]

With this monetary policy reaction, however, the model cannot generate the positive comovement between the equity price and the productivity news shock documented by

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[28] Assuming $\chi_3 \neq 0$ is not plausible when agents do not observe news. Therefore, environments with and without news shocks cannot be compared if $\chi_3 \neq 0$. Note also that when agents and the monetary policy authority do not observe productivity news shocks, then the whole term $(\nu_{1,t} + \nu_{2,t-1})$ is a current productivity policy shock consistent with the discussion above.

[29] Recall that we have not imposed sign restrictions on these coefficients.

[30] The flexible price consumption level is $\frac{\psi+1}{\rho+\psi}a_t$.

[31] Note that studying how alternative monetary policy reactions to news shocks may affect asset price dynamics for a given information set such as $\mathcal{I}_t$ is a related but different question than we address in the paper. Christiano et. al. (2008) investigate this question in a more realistic model. One could start to address this question in our model by examining equation (35).

Beaudry and Portier (2006) and Barsky and Sims (2010). This property of our model is consistent with the theoretical findings of Gilchrist and Leahy (2002). That study shows that a simple real business cycle model (RBC) cannot generate positive comovement between stock prices and productivity news shocks, but a sticky-price model with a Taylor rule with interest rate smoothing (which does not necessarily represent an optimal monetary policy rule) could generate such a correlation. Effectively, our "optimal" monetary policy is such that consumption and labor replicates a flexible price allocation (i.e., the allocation that would prevail in a simple RBC allocation), which explains why our model displays properties similar to those of an RBC model.

In order to generate a positive correlation between the news shock and equity price in our model, we need a specific monetary policy reaction to productivity news shocks. Specifically, we need to assume that the coefficient on the news shocks in equation (44) is positive. Thus, we can obtain a positive correlation between equity price and news shocks if $\Lambda_2 + \Lambda_m \chi_2 \beta > 0$, which in turn is true if and only if

$$\left[1 + (1-\beta)\left(\frac{1-\rho}{\rho} - \frac{\zeta}{1-\zeta}\frac{\rho+\psi}{\rho}\right)\right]\left[\rho\left(1-\frac{1}{\varepsilon}\right)\frac{\psi+1}{\rho+\psi} + \chi_2\right] + (1-\rho)\frac{\psi+1}{\rho+\psi} > 0. \tag{48}$$

More simply, assuming a positive response of the equity price to a monetary policy shock, i.e., $\Lambda_m > 0$ (which in the model is true for plausible parameter values), we can satisfy the above condition if $\chi_2 > -\frac{\Lambda_2}{\beta\Lambda_m}$.

It is now evident that to generate higher volatility with the introduction of news shocks and a positive correlation between the news shock and equity price, the inequalities (46) and (48) must hold at the same time. Assuming that the first term of the left hand side of inequality (46) is positive, which is true under reasonable parameter values, we need the second term to be negative; therefore, we need

$$\chi_1 < \frac{-\boldsymbol{\Lambda_1} + \boldsymbol{\Lambda_m}\beta\chi_2}{\boldsymbol{\Lambda_m}\left[(\mathbf{1}-\beta)\varepsilon + \beta\right]}. \tag{49}$$

Using this condition together with the inequality (48) we can obtain sufficient conditions for higher equity price volatility and a positive correlation between the news shock and equity price. For example, if $\varepsilon = 1$, $\psi = 0$, $\rho = 1$, $\zeta = 2/3$, $\beta = .95$, and $\chi_1 = .4$ and $\chi_2 = .6$ then the two conditions for the higher volatility and positive comovement are indeed satisfied.[32]

D. Stochastic Discount Factor and News Shocks

As we know from the empirical finance literature—e.g., Campbell (1991) or Lettau and Ludvigson (2005)—the properties of stochastic discount factor affects the behavior of equity

[32]The value of ρ can be as large as 2 in this example. **Adopting monetary reaction can allow us to set ρ even below the value discussed in the previous section as shown in equation 39 However, condition for comovement limits the value of ρ not exceeding certain value given chi_2.** Alternatively one can choose a larger χ_2 to allow larger ρ.

return. In this section we discuss the role of the stochastic discount factor in the main general equilibrium results of the previous two subsections on productivity and monetary policy news shocks, respectively.

To do this, split the surprise component of the equity return in two parts:

$$\begin{aligned} & r_{t+1} - \mathrm{E}_t\, r_{t+1} = q_{t+1} - \mathrm{E}_t\, q_{t+1} \\ &= \sum_{s=0}^{\infty} \beta^s [(1-\beta)(\mathrm{E}_{t+1} - \mathrm{E}_t)\pi_{t+s+1} + \beta(\mathrm{E}_{t+1} - \mathrm{E}_t) d_{t+s+1,t+2+s}] \\ &= \sum_{s=0}^{\infty} \beta^s [(1-\beta)(\mathrm{E}_{t+1} - \mathrm{E}_t)\pi_{t+s+1} - \beta i_{t,t+1}. \end{aligned} \tag{50}$$

The first part is the present discounted value of the expectation change in future dividends. The second part is the present discounted value of the expectation change in future discount factors, which reduces to the nominal interest rate at time $t+1$ (because $\mathrm{E}_t\, d_{t+s+1,t+2+s} = 0$ for $s > 0$ and $\mathrm{E}_{t+1}\, d_{t+1,t+2} = -i_{t+1}$).[33]

To analyze the role of the discount factor for our results, we need to show how the introduction of news shocks affects i_{t+1}. The solution for i_{t+1} with and without news shocks is given by, respectively,

$$i_{t+1}(\mathcal{I}_{t+1}) = (1-\beta)\left\{[(1-\varepsilon)\mu_{1,t+1} + \mu_{2,t+1}] + \frac{\psi+1}{\rho+\psi}\rho\left(1-\frac{1}{\varepsilon}\right)(\nu_{1,t+1} + \nu_{2,t+1})\right\}, \tag{51}$$

$$i_{t+1}(\mathcal{H}_{t+1}) = (1-\beta)\left\{(1-\varepsilon)(\mu_{1,t+1} + \mu_{2,t}) + \frac{\psi+1}{\rho+\psi}\rho\left(1-\frac{1}{\varepsilon}\right)(\nu_{1,t+1} + \nu_{2,t})\right\}. \tag{52}$$

From these equations we can see that introducing productivity news shocks has no impact on the volatility of the equity price *through* the stochastic discount factor in our model. This is because the coefficients on $\nu_{2,t}$ and $\nu_{2,t+1}$ are identical in the two equations above. The stochastic discount factor therefore plays no role in our main result on the impact of introducing productivity news shocks on equity price volatility. Thus, if we focus only on productivity news shocks without a monetary policy reaction to them, the higher equity price volatility that may arise must be stemming entirely from the behavior of dividends (the first part of equation (50) above).

In contrast, introducing monetary policy news shocks and/or a monetary policy reaction to the productivity news shocks changes the volatility of the equity price through the behavior of the stochastic discount factor in our model. Recall however that introducing pure monetary policy news shock cannot increase equity price volatility in our simple model. The stochastic

[33] Note that the comovement of $i_{t+1}(\mathcal{I}_{t+1})$ and the update in the expected dividend path affects the conditional variance of equity return in a manner that is similar to the findings in Lettau and Ludvigson (2005).

discount factor therefore can play a role only if monetary policy reacts to productivity news shocks. For example, it is easy to see that, if $\varepsilon = 1$, the stochastic discount with and without news shocks is

$$i_{t+1}(\mathcal{I}_{t+1}) = (1-\beta)\mu_{2,t+1}, \qquad i_{t+1}(\mathcal{H}_{t+1}) = 0.$$

and hence can affect equity price volatility when we introduce productivity news shocks with a monetary reaction to them.

To conclude, while productivity news shocks do not directly affect the stochastic discount factor in our model, they do so via a plausible monetary policy reaction to them. In this sense, modeling the monetary policy response to productivity news shocks may be key for matching the empirical features of asset prices in a DSGE model with news shocks.

E. Correlated News Shocks

We now consider the effects of correlated news shocks on the conditional variance of equity prices holding the unconditional variance of productivity shocks constant. In general equilibrium, unlike in the simple present discounted value model of section 2, correlated news shocks do not always induce higher conditional variance. While the unconditional variance of productivity growth,$\mathrm{Var}(\Delta a_{t+1}) = \mathrm{Var}(\nu_{1,t+1} + \nu_{2,t}) = \sigma^2_{\nu_1} + \sigma^2_{\nu_2}$, does not depend on the correlation between $\nu_{1,t+1}$ and $\nu_{2,t+1}$ (ϱ_a), the conditional variance of the equity price, $\mathrm{Var}_t\, q_{t+1}$, does depend on ϱ_a. Again ignoring for simplicity monetary shocks and the monetary response to productivity shocks, we have

$$\mathrm{Var}_t\, q_{t+1} = (\Lambda_1 + \Lambda_2)^2 \sigma^2_{\nu_1} + 2\Lambda_1\Lambda_2\varrho_a\sigma_{\nu_1}\sigma_{\nu_1} + \Lambda_2^2\sigma^2_{\nu_2}. \tag{53}$$

So increasing the correlation between news and current shocks can either increase equity price volatility (if $\Lambda_2 > 0$) or decrease it (if $\Lambda_2 < 0$ since $\Lambda_1 > 0$), the more so the larger ϱ_a. Again, the reason why the 'magnification effect' does not always operate here is that, in general equilibrium, information about the future can indeed change the behavior of agents. Note here that, by the same token, even if agents do not observe news shocks, a positively serially correlated productivity process can also reduce the conditional variance of the equity price. This is because information about future productivity conveyed by a persistent current productivity shock is similar to that carried by correlated news shocks, thus affecting the behavior of agents in the same manner in general equilibrium.

V. The Impact of Monetary Policy Shocks on Equity Prices

The solution for the excess return in equation (35) also illustrates the transmission mechanism of monetary policy news to equity prices. In our simple model, monetary policy news shocks affect the excess equity return if and only if current monetary policy shocks also affect the excess return at the same time. This is because $\mu_{1,t+1}$ and $\mu_{2,t+1}$ share the same coefficient in equation (35), and for either of them to have an impact it must be the case that $\left[1 + (1-\beta)\left(\frac{1-\rho}{\rho} - \frac{\zeta}{1-\zeta}\frac{\rho+\psi}{\rho}\right)\right] \neq 0$. This has the important implication that it is difficult to measure the impact of monetary policy shocks on equity prices through event studies of actual policy changes.

The typical event study with US data uses the change in the adjusted federal funds rate futures at the time of a FOMC announcement on the right hand side of the estimated econometric equation. This, in principle, should measure current policy shocks, or $\mu_{1,t+1}$. FOMC announcements, however, often contain information about future interest rates as well, $\mu_{2,t+1}$, and equity returns must reflect that information as well. If one regresses equity returns onto changes in the federal funds rate futures, the estimate of the effect of current shocks on the equity return may be biased because the effect of news about the future is omitted from the econometrician's specification. Indeed, Rigobon and Sack (2004) investigate the impact of monetary policy shocks on equity prices without relying on an event study and find that the typical event study is biased because of omitted variable problems.

While there are many studies that focus on the effect of current monetary policy shocks on equity prices using an event study approach, the effect of policy announcements is rarely investigated. Obviously monetary policy announcements are difficult to quantify. Okina and Shiratsuka (2004) assess the impact of monetary policy news shocks on the Japanese yield curve during 2001. At the time, the Bank of Japan announced a commitment to target the "current account balance" until CPI inflation would have stabilized at or above zero percent. Interestingly, they find that this policy announcement had an effect on the long end of the curve, and thus provide an example of a quantitatively significant effect of news shocks on asset prices.

VI. Conclusions

In this paper, we study the role of news shocks for equity price volatility in general equilibrium. Specifically, we investigate how news about future money supply and productivity affect equity price volatility in a standard DSGE model with complete asset markets and nominal rigidity. To relate our contribution to the previous literature, and also to highlight the fundamental difference between introducing news shocks in partial and general equilibrium, we also analyze in detail a PVM example.

First and most importantly we show that, in general equilibrium, news shocks about future productivity can significantly increase the volatility of equity prices relative to a set up in which agents do not observe news under plausible assumptions on parameter values. This is in stark contrast to the volatility reducing effect of introducing news shocks in a PVM, as the seminal analysis of West (1988) implies. This is because, in general equilibrium, agents can change their behavior if they observe news shocks compared to an environment in which they do not, thereby affecting the cash flow stream on which asset prices are defined. This mechanism is not present in the typical PVM because the asset cash flow is exogenous in that set up. Our result implies that, in general equilibrium, the volatility of endogenous variables does not necessarily fall when agents have more information about the underlying, exogenous stochastic processes.

Second, in a simple PVM example, we also show that the conditional variance of asset prices can increase with the correlation between news shocks and current shocks, holding the variance of underlying exogenous process constant, with effects similar to those induced by more persistent exogenous processes. However, unlike in this PVM example, in general equilibrium, correlated news shocks can either reduce or increase the variance of asset prices depending on the specific assumptions on parameter values.

Third and finally, the theoretical analysis in the paper has important implications for estimation of the impact of monetary policy shocks on asset prices. We show in a PVM example that correlated news shocks can be observationally equivalent to a serially correlated fundamental process from the econometrician's perspective. However, while correlated news shocks can explain why an asset price model cannot fit the data, a model with persistent fundamentals cannot do so—a point that is consistent with Cochrane's (1994) observation that news shocks may help to explain models' empirical inability to explain the business cycle. As a result, econometric specifications of the analysis of the impact of fundamental shocks on asset prices that omit explicit considerations of news shocks may be biased, as we show analytically in our DSGE model. This is notwithstanding the fact that the data generating process for the fundamentals is the same with and without news shocks. The analysis in the paper thus stresses the usefulness and the challenges of introducing news shocks when modelling asset prices.

Our general equilibrium model is too simple for a full fledged quantitative evaluation exercise against the data. Nonetheless, we find that the general equilibrium effects uncovered can be numerically sizable. We therefore regard the quantitative analysis of asset price volatility in DSGE models with news shocks, as well as the development of the implications of such analyses for the empirical identification and measurement of the effects of news and current shocks on asset prices, as two interesting areas of future research.

I. APPENDIX 1

In this section, we derive the implications for the partial equilibrium analysis of section 2 of assuming that news are not observable to the econometricians. That is, not only the current value of z_t but also the past values of z_t are not in the information set of the econometrician. So define $\mathcal{H}'_t$ a linear space spanned by only the history of $\{f_t\}$ up to time t and recall that

$$\Delta f_t = \varepsilon_{1,t} + \varrho \frac{\sigma_2}{\sigma_1} \varepsilon_{t-1} + \eta_{t-1}. \tag{A.1}$$

Since the econometricians cannot distinguish ε_t and η_{t-1}, the process must be appearing as

$$\Delta f_t = \theta_t + \varrho_\theta \theta_{t-1}. \tag{A.2}$$

where ϱ_θ is a root of the quadratic function:

$$\frac{\rho_\theta}{1+\varrho_\theta^2} = \frac{\varrho \sigma_1 \sigma_2}{\sigma_1^2 + \sigma_2^2} \left(= \frac{Cov(\Delta f_t, \Delta f_{t-1})}{\mathrm{Var}(\Delta f_t)} \right) \tag{A.3}$$

and θ_t is an i.i.d shock with mean zero and variance, $\frac{\sigma_1^2+\sigma_2^2}{1+\varrho_\theta{}^2}$. As $\frac{\sigma_1 \sigma_2}{\sigma_1^2+\sigma_2^2} \leq 1/2$, it is easy to see that one of the root lies inside the unit circle and the other outside. Using the root with $|\varrho_\theta| < 1$, we have

$$\theta_t = \sum_{j=0}^{\infty} (-\varrho_\theta)^j \Delta f_{t-j} = \sum_{j=0}^{\infty} (-\varrho_\theta)^j (\varepsilon_{t-j} + z_{t-1-j}). \tag{A.4}$$

Thus, the theoretical asset price modeled by econometricians is

$$x_t(\mathcal{H}'_t) = \sum_{j=0}^{\infty} \beta^j \, \mathrm{E}(f_{t+j} | \mathcal{H}_t) = \frac{1}{1-\beta} f_t + \frac{\beta}{1-\beta} \rho_\theta \theta_t. \tag{A.5}$$

II. APPENDIX 2

In this appendix we report the complete solution of the model described in section 3 and used in Section 4.

A. Notation

We denote the log deviation of any variables from the initial steady state with lower case letters. That is

$$z_t \equiv \ln(Z_t) - \ln(Z_0). \tag{B.6}$$

B. Model Equilibrium Conditions

The log-linear version of the model can be summarized by the following equations:

$$\varepsilon(m_t - p_t) = \rho c_t + \frac{\beta}{1-\beta} \mathrm{E}_t\, d_{t,t+1} \tag{B.7}$$

$$d_{t,t+s} = \rho c_t + p_t - \rho c_{t+s} - p_{t+s} \tag{B.8}$$

$$i_t = -\mathrm{E}_t\, d_{t,t+1} \tag{B.9}$$

$$w_t = \psi l_t + \rho c_t + p_t \tag{B.10}$$

$$p_t = \mathrm{E}_{t-1}(w_t - a_t) \tag{B.11}$$

$$a_t + l_t = c_t \tag{B.12}$$

The pre-dividend equity price and the equity return are, respectively:

$$q_t = (1-\beta) \sum_{s=0}^{\infty} \mathrm{E}_t\, \beta^s (d_{t,t+s} + \pi_{t+s}), \tag{B.13}$$

$$r_{t+1} = q_{t+1} - \frac{1}{\beta} q_t + \frac{1-\beta}{\beta} \pi_t. \tag{B.14}$$

C. Model Solution

Using the assumptions made in section 3 on the underlying shocks, the solution is given by the following equations:

$$p_t = -\operatorname{E}_{t-1} \frac{\rho}{\varepsilon} \frac{\psi+1}{\rho+\psi} a_t + \operatorname{E}_{t-1} m_t \tag{B.15}$$

$$\begin{aligned} c_t =& \frac{1}{\rho} \left[(1-\beta)\varepsilon(\mu_{1,t}) + \beta(\mu_{1,t} + \mu_{2,t})\right] \\ &+ \frac{\psi+1}{\rho+\psi} \left[\operatorname{E}_{t-1} a_t + \beta \left(1 - \frac{1}{\varepsilon}\right)(\nu_{1,t} + \nu_{2,t})\right] \end{aligned} \tag{B.16}$$

$$l_t = c_t - a_t \tag{B.17}$$

$$w_t = \psi l_t + \rho c_t + p_t \tag{B.18}$$

$$\begin{aligned} i_t =& \frac{1-\beta}{\beta} [\rho c_t - \varepsilon(m_t - p_t)] \\ =& (1-\beta)\left[(1-\varepsilon)\mu_{1,t} + \mu_{2,t}\right] + (1-\beta) \frac{\psi+1}{\rho+\psi} \rho \left(1 - \frac{1}{\varepsilon}\right)(\nu_{1,t} + \nu_{2,t}) \end{aligned} \tag{B.19}$$

$$\pi_t = p_t + c_t + \frac{\zeta}{1-\zeta} \left[(\psi+1)(a_t - \operatorname{E}_{t-1} a_t) - (\rho+\psi)(c_t - \operatorname{E}_{t-1} c_t)\right] \tag{B.20}$$

$$q_t = (1-\rho)\beta(\operatorname{E}_t c_{t+1} - c_t) + c_t + p_t + (1-\beta) \frac{\zeta}{1-\zeta} \left[(\psi+1)\, a_t - (\rho+\psi)\, c_t\right] \tag{B.21}$$

$$\begin{aligned} r_{t+1} =& \Delta p_{t+1} + \rho(\operatorname{E}_t c_{t+1} - c_t) \\ &+ \beta(1-\rho)\left(\operatorname{E}_{t+1} c_{t+2} - \operatorname{E}_t c_{t+1}\right) + [\rho + (1-\beta)(1-\rho)](c_{t+1} - \operatorname{E}_t c_{t+1}) \\ &+ (1-\beta) \frac{\zeta}{1-\zeta} [(\psi+1)\left(a_{t+1} - \operatorname{E}_t a_{t+1}\right) - (\rho+\psi)\left(c_{t+1} - \operatorname{E}_t c_{t+1}\right)]. \end{aligned} \tag{B.22}$$

where $\zeta \equiv \frac{\lambda-1}{\lambda}$ is labor share of the economy.

Figure 1. Log Difference of Conditional Variance of Equity Price

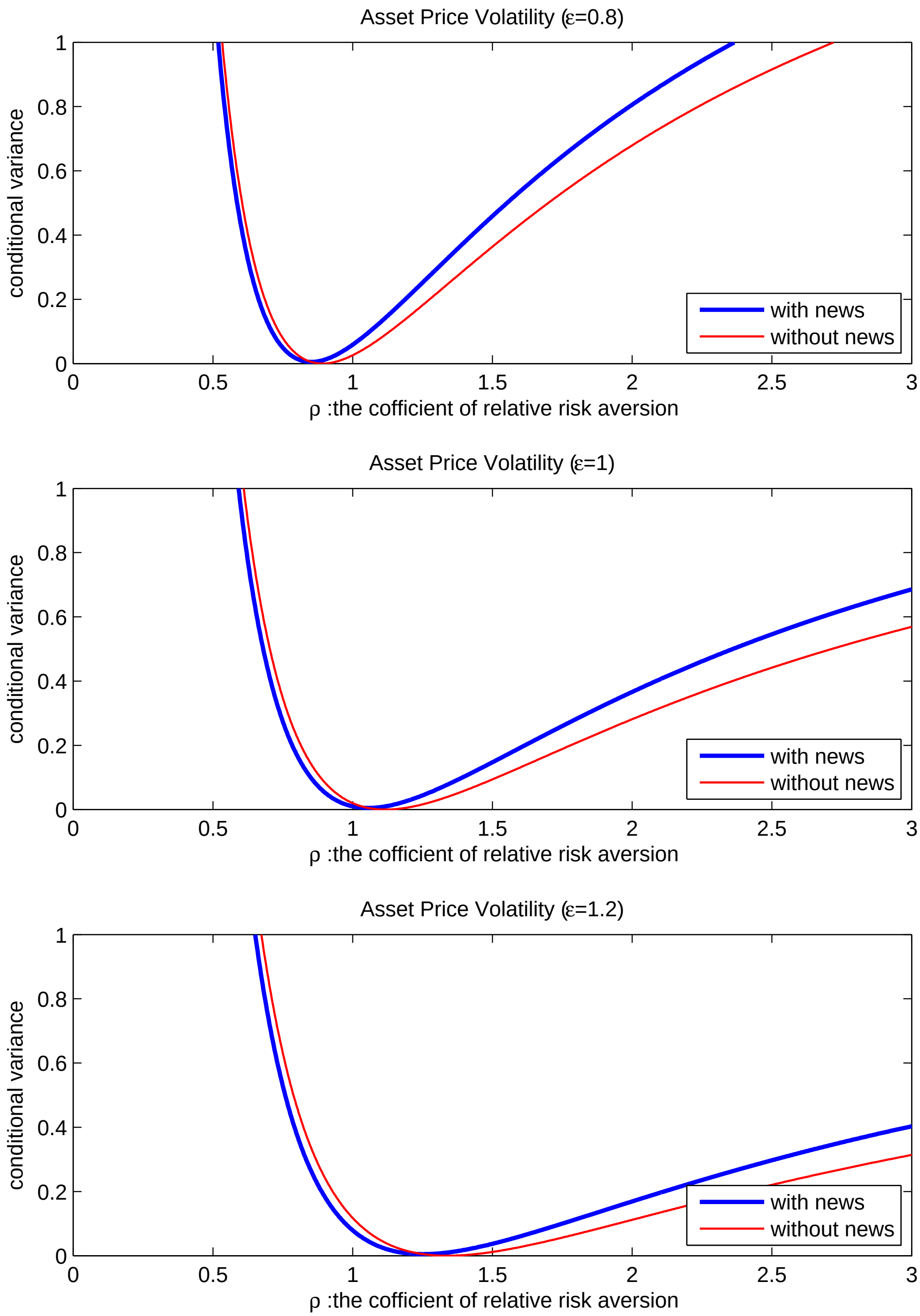
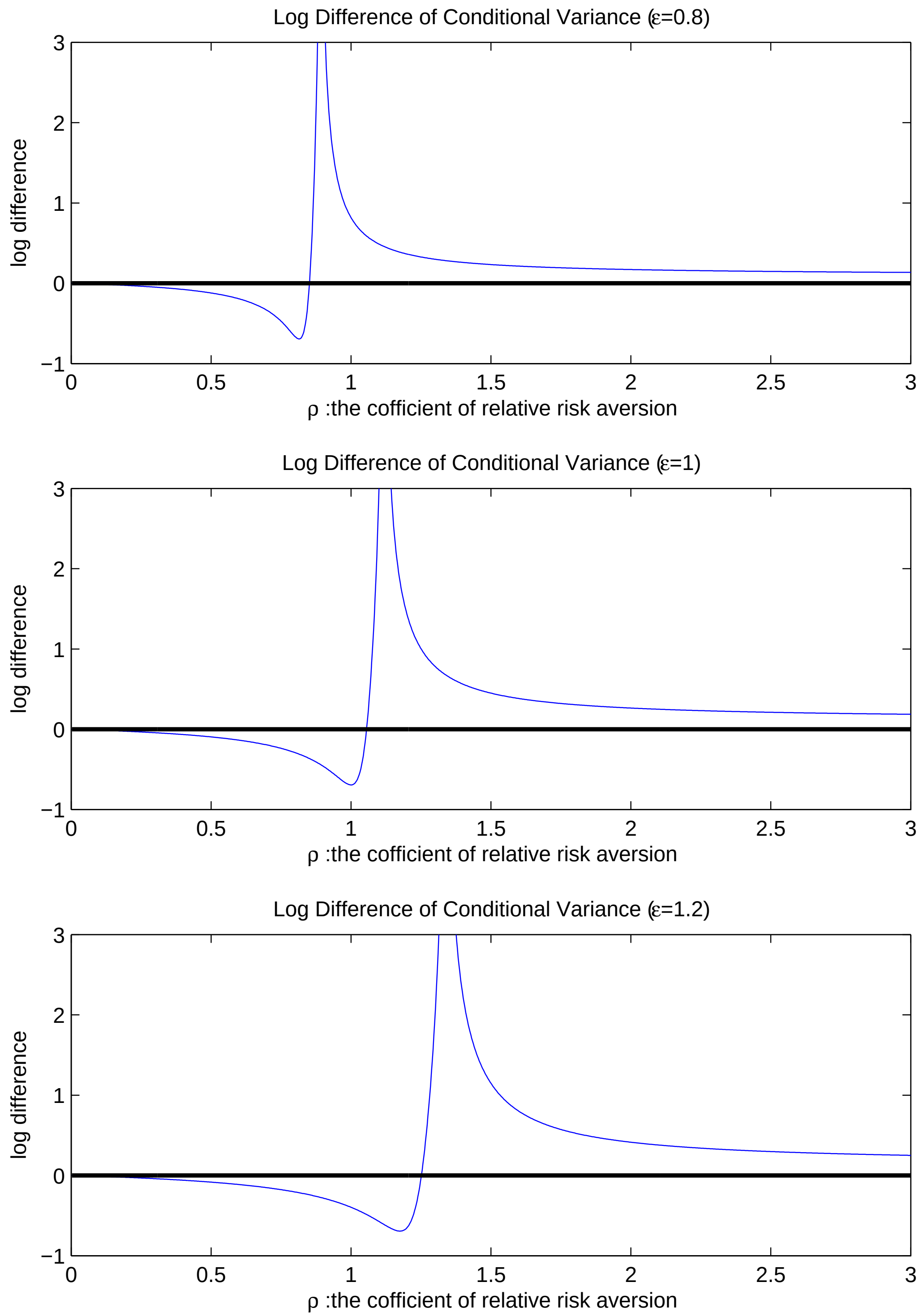


Figure 2. Log Difference of Conditional Variance of Equity Price



REFERENCES

[1] Backus, David K., Patrick J. Kehoe, and Finn E. Kydland,, 1992, "International Real Business Cycles," *Journal of Political Economy*, University of Chicago Press, Vol. 100 (4), 745-75, August.

[2] Barsky, Robert B. and Eric R. Sims, 2009, "News Shocks," NBER Working Papers 15312, National Bureau of Economic Research, Inc.

[3] Beaudry, Paul and Franck Portier, 2004, "An Exploration into Pigou'S Theory of Cycles," *Journal of Monetary Economics*, vol. 51(6), 1183-1216.

[4] ———, 2006, "Stock Prices, News, and Economic Fluctuations," *American Economic Review*, Vol. 96 (4), 1293-1307.

[5] ———, 2007, "When can Changes in Expectations Cause Business Cycle Fluctuations in Neo-Classical Settings?," *Journal of Economic Theory*, vol. 135(1), 458-477.

[6] Benigno, Gianluca, 2004, "Real Exchange Rate Persistence and Monetary Policy Rules" *Journal of Monetary Economics*, Vol. 51, 473-502

[7] Blinder, Alan S., Michael Ehrmann, Marcel Fratzscher, Jakob De Haan, and David-Jan Jansen, 2009, "Central Bank Communication And Monetary Policy: A Survey Of Theory And Evidence," *Journal of Economic Literature*, vol. 46(4), 910-45.

[8] Campbell, John Y., 1991, "A Variance Decomposition for Stock Returns," *Economic Journal*, Vol. 101(405), 157-79.

[9] Chari, V. V., Patrick J. Kehoe, and Ellen R. McGrattan, 2002. "Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates?," *Review of Economic Studies*, Blackwell Publishing, Vol. 69 (3), 533-63.

[10] Christiano, Lawrence, Cosmin Ilut, Roberto Motto and Massimo Rostagno, 2008, "Signals: Implications for Business Cycles and Monetary Policy," unpublished paper.

[11] Cochrane, John H., 1994, "Shocks," *Carnegie-Rochester Conference Series on Public Policy*, Vol. 41(1), 295-364.

[12] Devereux, Michael B. and Charles Engel 2006, "Expectations and Exchange Rate Policy," NBER Working Paper No. 12213 (Cambridge, Massachusetts: National Bureau of Economic Research).

[13] ———, 2007, "Expectations, Monetary Policy, and the Misalignment of Traded Goods Prices," International Seminar on Macroeconomics 2007, 131-157.

[14] Engel, Charles, Nelson C. Mark, and Kenneth D. West, 2008, "Exchange Rate Models Are Not as Bad as You Think," *NBER Macroeconomics Annual 2007* (Cambridge, Massachusetts: National Bureau of Economic Research).

[15] ——— and Akito Matsumoto, 2009, “The International Diversification Puzzle When Goods Prices Are Sticky: It’s Really about Exchange-Rate Hedging, Not Equity Portfolios,” *American Economic Journal: Macroeconomics*, Vol 1(2), 155-88.

[16] ——— and Kenneth D. West, 2006, “Exchange Rates and Fundamentals,” *Journal of Political Economy*, Vol. 113 (3), 485-517.

[17] Fujiwara, Ippei, Yasuo Hirose, and Mototsugu Shintani, 2008, “Can News Be a Major Source of Aggregate Fluctuations? A Bayesian DSGE Approach,” IMES Discussion Paper Series, 08-E-16, Institute for Monetary and Economic Studies, Bank of Japan.

[18] Frenkel, Jacob A. 1976, “A Monetary Approach to the Exchange Rate: Doctrinal Aspects and Empirical Evidence,” *The Scandinavian Journal of Economics*, Vol 78 (2), 200-224.

[19] Gilchrist, Simon and John V. Leahy, 2002, “Monetary Policy and Asset Prices,” *Journal of Monetary Economics*, vol. 49(1), 75-97.

[20] Groen, Jan J. J. and Akito Matsumoto, 2004, “Real exchange rate persistence and systematic monetary policy behaviour,” Bank of England working papers 231, Bank of England.

[21] Heathcote, Jonathan and Fabrizio Perri, 2002, “Financial autarky and international business cycles,” *Journal of Monetary Economics*, 49(3), 601-627.

[22] Jaimovich, Nir and Sergio Rebelo, 2009, “Can News about the Future Drive the Business Cycle? ,” *American Economic Review*, Vol. 99 (4), 1097-1118.

[23] Kurmann Andre and Christopher Otrok, 2010, “News Shocks and the Slope of the Term Structure of Interest Rates,” mimeo, University of Vriginia

[24] Laséen, Stefan and Lars E.O. Svensson, 2009, “Anticipated Alternative Instrument-Rate Paths in Policy Simulations,” NBER Working Papers 14902, National Bureau of Economic Research, Inc.

[25] Lettau, Martin and Sydney C. Ludvigson, 2005. “Expected returns and expected dividend growth,” *Journal of Financial Economics*, vol. 76(3), pages 583-626

[26] Meese, Richard A. and Kenneth Rogoff, 1983, “Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?,” *Journal of International Economics*, Vol. 14, 3-24.

[27] Monacelli, Tommaso, 2004, “Into the Mussa Puzzle: Monetary Policy Regimes and the Real Exchange Rate in a Small Open Economy,” *Journal of International Economics*, Vol. 62, 191-217.

[28] Okina, Kunio, and Shigenori Shiratsuka, 2004, “Policy commitment and expectation formation: Japan’s experience under zero interest rates” *The North American Journal of Economics and Finance*, vol. 15(1),75-100.

[29] Rigobon, Roberto and Brian Sack , 2004, “The Impact of Monetary Policy on Asset Prices, ” *Journal of Monetary Economics*, November, Vol. 51 (8), 1553-75.

[30] Rudebusch, Glenn D., 2006, “Monetary Policy Inertia: Fact or Fiction?,” *International Journal of Central Banking*, Vol. 2(4), 85-134.

[31] Schmitt-Grohé, Stephanie and Martín Uribe, 2008, “What’s News in Business Cycles,” unpublished paper,

[32] Sekine, Toshitaka, and Yuki Teranishi, 2008, “Inflation Targeting and Monetary Policy Activism,” IMES Discussion Paper Series 2008-E-13, Bank of Japan.

[33] West, Kenneth D, 1988, “Dividend Innovations and Stock Price Volatility,” *Econometrica*, Vol. 56 (1), 37-61

[34] Woodford, Michael, 2008, “The Fed’s ‘Enhanced’ Communication Strategy: Work in Progress,” mimeo, Columibia University