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News-Driven Business Cycles: Insights and Challenges[†]

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There is a widespread belief that changes in expectations may be an important independent driver of economic fluctuations. The news view of business cycles offers a formalization of this perspective. In this paper we discuss mechanisms by which changes in agents' information, due to the arrival of news, can cause business cycle fluctuations driven by expectational change, and we review the empirical evidence aimed at evaluating their relevance. In particular, we highlight how the literature on news and business cycles offers a coherent way of thinking about aggregate fluctuations, while at the same time we emphasize the many challenges that must be addressed before a proper assessment of the role of news in business cycles can be established. (*JEL* D83, D84, E13, E32, O33)

1. *Introduction*

Why do market economies exhibit business cycle phenomena; that is, why do they exhibit recurring boom periods with higher-than-average growth in investment, consumption, and employment, followed by recessions characterized by declines in these same macroeconomic aggregates? The news view of business cycles suggests that these phenomena are mainly the result of agents having incentives to continuously anticipate the economy's future demands. If an agent can properly anticipate a future need, he can gain by trying to preempt the market and invest early as to make goods readily available when the predicted needs eventually appear. If many agents adopt similar behavior because they receive related news about future developments, this will lead to a boom period. However, by the very fact that such behavior involves speculation, it will be subject to errors. In the cases of error, the economy will have overinvested, as the anticipated demand will not materialize. This will cause a recession and a process of liquidation. Hence, according to the news view of the business cycle, both the boom and the bust are direct consequences of people's incentive to speculate on information related to future developments of the economy.

An interesting example of anecdotal evidence for such speculative cycles is given by

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the satellite industry. In the early 1980s, in anticipation of long-distance telephone service, video teleconferencing, and other forms of sophisticated electronic communications, the launching of telecommunication satellites exploded. A couple of years later, the market realized that the increase in demand failed to materialize, which caused severe capacity underutilization. On a weekday afternoon in December 1983, the Federal Communications Commission observed that only 54 percent of capacity on communications satellites was in use. Of the 14 satellites studied, 143 of 312 transponders were idle. Six months earlier, before forty-eight new transponders had been introduced, thirty-six fewer were idle and capacity utilization reached 59 percent.[1] This "transponder glut" repeated in the early 2000s. During the "dot com" boom of the 1990s, prospective demand for data transmission led the market to increase dramatically the number of launched satellites. In 1998, the satellite industry launched 150 satellites, a nearly 300 percent growth compared to 1993 (Hague 2003). It was not a radical change in the launching technology that caused such a boom, nor the current demand for data transmission,[2] but the perceived future profitability of satellite operation associated with the development of the IT economy. With the bust of year 2000, the number of satellites launched went down to seventy-five in 2001 and sixty-nine in 2003, against 150 in 1998 (OECD 2004). The sector then went to a period of liquidation and falling prices. As described by the magazine *Satellite News* of November 4, 2002, "Companies that purchased satellite transponder capacity during the industry's halcyon days are now struggling to resell the capability in the face of falling market prices."

While the idea of news-driven business cycles is rather simple and echoes commonly found narratives in the business press, as illustrated above, evaluating its relevance is quite challenging. Difficulties arise on two main fronts. On the one hand, since the main driving force is agents' perceptions about the economy's future needs, it implies that the business cycle is driven by a force difficult to measure. This generally makes empirical evaluation depend on subtle identification assumptions, and therefore subject to debate. On the other hand, even if the underlying story appears intuitive, it turns out that it is quite challenging to build a simple macroeconomic model that captures in a robust way the idea that changes in agents' perceptions about the economy's future needs can cause business-cycle-type fluctuations. In fact, we will show why one generally needs to depart at least from some standard modeling assumption to be able capture the notion of news-driven business cycles within the confines of a dynamic general equilibrium framework. These two issues, modeling and evaluating news-driven business cycles, will be at the heart of this article. In particular, the goal of this article will be to highlight both the promising paths and the difficulties in building and evaluating the news view of business cycles.

The idea of business cycles driven by expectations can be traced back to writing such as that of Pigou (1927), where he states, "The varying expectations of business men . . . constitute the immediate cause and direct causes or antecedents of industrial fluctuations." According to Pigou, the very source of fluctuations is the "wave-like swings in the mind of the business world between errors of optimism and errors of pessimism."[3] This view is also closely related to Keynes' 1936 notion of

[1] "Satellites outpace customers," *The New York Times*, April 10, 1984.

[2] The growth rate for demand for satellite bandwidth has been 31 percent between 1995 and 2003, while the supply of satellite bandwidth grew by 54 percent during this same time frame (Futron Corporation 2004).

[3] See Collard (1983, 1996) on the business cycle theory of Pigou.

animal spirits as it relates to these waves of optimism and pessimism as important driving forces behind economic fluctuations. There are at least three different ways of interpreting optimism and pessimism in business cycles. At one extreme is the view that such waves are an entirely psychological phenomenon, with no grounding in economic reality. According to such a perspective, any expansion driven by optimism must eventually lead to a crash, as the expansion is not supported by any change in fundamentals. At the other extreme is the view that the macroeconomy is inherently unstable as it admits self-fulfilling fluctuations. In this perspective, a wave of optimism creates a boom that renders the initial optimism rational, and the same is true of waves of pessimism. A third possibility is the news view whereby agents in the economy are continually trying to predict future needs, but likely do so imperfectly. In this interpretation, a boom driven by a wave of optimism arises when agents have gathered information suggesting that future fundamentals favor high investment demand today. If their information is valid and expectations are realized, then the boom needs not be followed by a crash. In contrast, if agents have made an error and have been overly optimistic, then there will be a crash. This type of recurrent boom and occasional bust phenomena, driven by information and possible errors, is the defining property of news-driven business cycles.[4] The empirical evidence we will review in this survey lead us to favor this third possibility.

One important issue that arises when considering any theory of business cycles is whether it implies that cycles are efficient or not. While we agree on the relevance of this issue, it will not be a major focus of this article. At this point in time we see the news view of business cycles as primarily proposing a positive theory of fluctuations where, depending on the details, the fluctuations may or may not be efficient. In the literature we will review, some of the models imply that the resulting cycles are efficient, while others imply they are not. We will point out these differences as they arise.

1.1 *Overview*

The survey is structured as follows. In section 2, we begin by presenting the general idea of news in terms of innovations in agents' information sets that are useful for predicting future fundamentals. The fundamentals of interest could be from many difference sources, but in much of the applied news literature the fundamental being predicted is productivity. We emphasize the difference between two information structures, one where the news can be wrong and one where the news is right but incomplete. The case where the news can be wrong is generally referred to as the noise formulation. Recognizing the difference between these two formulations is important when bringing the idea of news to the data.

In section 2.1, we present a baseline general equilibrium model where booms are driven by optimistic news that favors current investment, while a bust arises if and when news is recognized to be wrong. This baseline model abstracts from many important features, but for illustrative purposes is very helpful, since it offers a closed-form solution in which optimistic news are expansionary, and where revisions can lead to busts. The environment considered consists of a final good consumption sector produced by intermediate goods. Investment in each sector depends on the future prices. We allow agents to receive news about the future productivity in each of the intermediate good sectors. When all the intermediate goods are substitutable in the production of the final good, we show that only the expectation of the aggregate level of productivity matters at

[4] The word "news" is used here to represent exogenous changes in the information sets that agents use to form their perceptions regarding future economic activity.

the symmetric equilibrium for determining investment. In this case, we can formalize the information process in the following way: in period t, agents receive a noisy signal about aggregate productivity of period $t + q$. Then in period $t + q$, information is revealed. The arrival of positive news is shown to cause a boom period as expectations about the future are optimistic, with investment and hours worked increasing immediately and consumption increasing with a lag. If at $t + q$ productivity growth meets expectations, which happens, on average, when agents are Bayesian, then the boom period continues and the economy converges to its new steady state. If, however, expectations are not met because the signal was wrong, then the economy enters a recessionary period with macroeconomic aggregates going down. We discuss the conditions under which the economy actually enters a liquidation phase after the misinterpretation of a news shock, with investment dropping drastically and staying below its steady state on the convergence path back to the steady state. We then use this basic model to discuss various information structures and interpretations of the shocks. For example, we examine a case where information is dispersed and each firm receives an idiosyncratic noisy signal. We show that this problem exhibits a complementarity structure whereby firms in one sector will want to increase their production if they expect others to increase their production, regardless of the actual news received. This baseline model has some undesirable features, as consumption responds to news only with a lag and the real wage is constant. In later sections, we discuss more complicated models that do not have these features. An important feature on this baseline model is that it offers an explicit framework in which the empirical exercises reviewed in section 3 can be interpreted.

In section 3, we start by providing some simple reduced-form evidence that is suggestive of the news view of business cycles and then we summarize vector autoregressive (VAR) evidence, which has been presented as both supportive and dismissive of the news view. The reduced-form evidence is based on the cyclical property of the ratio of the capital stock to total factor productivity (TFP). Positive deviations of this variable from its long-run level indicate periods of capital "excess," in the sense that capital is above the level that current productivity would support in steady state. We show that U.S. recessions are almost always preceeded by periods of capital excess, while on average a high value of $\frac{K}{TFP}$ does not predict future low growth. We argue that such evidence is suggestive of a news view in which recessions are most often the consequence of previous period of high accumulation driven by rosy expectations, but that rosy expectations do not, on average, predict recessions, as expectations are often right. In contrast, if an economy is driven by technological surprise, booms should be associated with high investment but low values of this ratio, as capital accumulation is trying to catch-up with TFP. Such a view of cycles therefore predicts a strong negative correlation between a measure of the business cycle, say hours worked, and the ratio of capital to TFP. On the other hand, if some type of pure demand shock drives the cycle, there should a strong positive correlation between hours and the capital to TFP ratio, since capital accumulation is being driven by a force other than TFP. The news view lies between these two extremes, with capital sometimes proceeding TFP growth when agents are acting on news and sometimes lagging if agents are reacting to realizations. We show that the U.S. business cycle exhibits a very modest correlation (0.3) between hours and $\frac{K}{TFP}$, which is consistent with the news view.[5]

[5] We also discuss in this section the extent to which the cyclical properties of the relative price of capital are consistent or not with a news view of business cycles.

In the second part of section 3, we discuss how structural VAR methods have been used to evaluate the news view of business cycles. However, before discussing the empirical results from this literature, we first need to discuss the extent to which the problem of nonfundamentalness can render such exercises meaningless. The problem of nonfundamentalness arises if news shocks cannot be expressed as linear combinations of the current and past observables that are in the econometricien's information set. If such is the case, VARs methods will not properly identify news shocks. To explore this issue, we begin by defining a set of *news-rich* processes, and show when nonfundamentalness may arise. Then we show that even when it arises, it may still be possible to approximatively recover news shocks, provided that the nonfundmentalness is not too serious (where we give a precise definition of what we mean by serious). For example, we discuss and illustrate how adding more variables to a VAR can reduce the nonfundamentalness problem. The results presented in this section nicely illustrate why the empirical literature, starting with Beaudry and Portier (2006), have been wise to choose forward-looking variables such as stock prices or expectation surveys when trying to identify news shocks. Once aware of the potential caveats with using VAR methods to identify the effects of news shocks, we turn to reviewing the relevant applied literature. Since this literature is quite vast, and arrives at different conclusions, we try to offer a systematic analysis using a common set of updated data. Although there are some sensitivities, we find that once a common data set is used, the impulse responses implied by VAR methods generally suggest news create aggregate booms in the short run and increase TFP in the long run.

In section 4 we examine more structural approaches that have been used to evaluate the importance of news in driving fluctuations. We begin by discussing a set of theoretical issues related to building general equilibrium models where business cycles can be driven by news-induced changes in expectations. It appears intuitive to many that if agents in an economy wake up to news about new market opportunities developing on the horizon, this will likely cause increased activity immediately as agents both start to invest early to be ready when the new demand patterns materialize and start to consume early as they feel richer. We have shown in the previous section that such an intuitive pattern generally emerges from the VAR literature that aims at identifying the effect of TFP news shocks. However, it turns out that such patterns are difficult to generate in the two benchmark models of modern macroeconomics, namely the RBC model and the New-Keynesian model.[6] The difficulties arise on two fronts, which we will refer to as the dynamic front and the static front. On the dynamic front, as we shall show, in many simple dynamic models it is difficult for positive technological news to cause an increased desire to invest today. On the static front, we will show that even if positive technological news causes increased desire to invest, in many models this will not be translated into increased consumption and investment today. Instead, it is more commonly associated with either consumption or investment decreasing today. We then show how the literature has proposed models that address these two challenges. We complete the section by reviewing the literature that has used fully specified structural model with many shocks to examine the relevance of news shocks. In general, these structural estimation techniques find that news shocks play a significant but modest role in explaining the fluctuations. Finally, section 5 briefly describes the potential future avenues of research and offers concluding comments.

[6] In the case of the New-Keynesian model, the failure is not systematic, as allocations are very much dependent on the assumption made for monetary policy.

2. *The Basic Framework*

The basic idea in the news view of business cycles, as for example presented in Beaudry and Portier (2004), is that agents repeatedly receive advanced information that relates to future developments in the economy. This information, or signals, are referred to as news and in general are assumed to be noisy; that is, the news may turn out to be validated by future events, or may be wrong in the sense that future developments may not conform to the content of the original information. The link between current news and agents' perception regarding the distribution of future events could take many forms. However, in practice it has most often been given a rather simple parametric formulation in the spirit of signal extraction problems. For example, it is generally assumed that there is some exogenous driving force in an economy that may be predicted by news. The driving force, which we can denote by θ_t, is usually modeled as an autoregressive integrated moving average (ARIMA) stochastic process, where we can denote innovations to the process by ϵ_t. The news that agents receive at time t is then modeled as a signal regarding the value of ϵ_{t+q}, that is, the agents receive information at time t regarding the innovation in θ that will arise at time $t+q$. The news can then be modeled as a signal S_t of ϵ_{t+q} as given by

$$(1) \qquad S_t = \epsilon_{t+q} + \nu_t,$$

where ν_t is the noise in the agents' signal, σ_ν^2 is the variance of ν_t and σ_ϵ^2 is the variance in ϵ_t. If we further assume that the processes are Gaussian, from the point of view of agents, the conditional expectation of ϵ_{t+q} at time t is then given by

$$(2) \quad E[\epsilon_{t+q} \mid \Omega_t = S_t] = \frac{\sigma_\epsilon^2}{\sigma_\epsilon^2 + \sigma_\nu^2} S_t,$$

where Ω_t is the information set of agents at time t.[7] This formulation is, for example, used in Beaudry and Portier (2004).

A close alternative to this formulation of news is to model the innovation in θ_t as being composed of two elements, say $\epsilon_{1t} + \epsilon_{2t}$. The news is then modeled as a signal without error S_t of the first component of ϵ_{t+q}, such that $S_t = \epsilon_{1t+q}$. Therefore, the expectation of ϵ_{t+q} at time t is given by

$$(3) \quad E[\epsilon_{t+q} \mid \Omega_t = S_t] = S_t = \epsilon_{1t+q}.$$

This formulation is, for example, used in Davis (2007), Christiano et al. (2010), and in one of the examples of Beaudry and Portier (2006).

While these two formulations may appear almost identical, they are actually quite different, as we will emphasize when discussing VAR approaches to the identification of news shocks. To give an idea of the difference, in the first formulation, there is a shock ν_t, which can be referred to as a noise or error shock, and one can be interested in knowing how the economy responds to such a noise shock. In the second formulation there is no direct counterpart: there is an anticipated shock ϵ_1 and an unanticipated shock ϵ_2, but no noise shock.

The main question addressed in the news view of business cycles is whether signals of the type described above could be important forces driving macroeconomic fluctuations through their effect on incentives to invest, either by starting or expanding firms, or by directly accumulating certain capital goods. In principle, the content of the news could be about many diverse objects. It could be related to information about future policy,

[7] In this formulation, we could easily allow the noise-to-signal ratio to vary over time as to reflect that in some periods agents may believe signals are more reliable than in other periods. Conceptually, this is very easy and reasonable, but it makes empirical evaluation much more difficult.

news about demographic trends, news about energy prices or news about future technological developments, since any one of these forces will affect the economy's future needs. While all these different avenues have received some attention, the bulk of the literature on news and business cycles has focused on the role of technological news; that is, news regarding future developments in productivity. Accordingly, we will focus mainly on the role of technology-related news in driving business cycles in this paper.

2.1 *A Baseline Dynamic General Equilibrium Model with Technological News*

According to the news view of business cycles, booms arise mainly as the result of speculation; that is, booms are not initially driven by contemporaneous changes in technology or preferences, but instead are driven by agents' anticipation of the economy's future developments. If agents get news regarding potential technological change in some sector of the economy, then they may want to take advantage of such news in at least two ways. First, they may want to directly invest in the sector being affected by the change, or, alternatively, they may want to invest in complementary sectors that will benefit only indirectly from the change. The following illustrative model of news-driven business cycles will allow both these forces to be present, with the qualitative aspects of the model being invariant to which one of the channels dominates. In this baseline model, we choose functional forms that allow for an analytical solution for ease of presentation. Later we discuss how the structure of the economy can be generalized as to maintain the same types of results.

Let us consider an environment populated by a representative household with preferences given by

$$(4) \quad E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(C_t) + \nu \cdot \left(\tilde{L} - L_t\right)\right],$$

where C_t is total consumption, L_t is the total time worked, $\tilde{L}$ is total time endowment, ν is a parameter, and E_0 is the expectation operator based on the information set Ω_0. The household can buy some or all of its consumption on the market, it can supply labor time to the market, it can produce household consumption, it can buy one-period bonds and it can trade in firm shares. The household budget constraint is given by

$$(5) \quad C_t^M + B_{t+1} + \sum_{i=1}^{N}(P_{it}^s - d_{it})Z_{it+1} = w_t L_t^M + (1 + r_t)B_t + \sum_{i=1}^{N} P_{it}^s Z_{it},$$

where C_t^M is amount of consumption goods acquired on the market, L_t^M is the amount of time supplied to the market, B_t is the household's bond holdings, Z_{it} is the number of shares held in sector i firms, w_t is the wage rate, r_t is the interest rate on bonds, d_{it} are dividends and P_{it}^s is the price of shares before dividends. Total consumption is made up of market consumption and household production goods, C_t^H, where household goods are produced with time according to the $C_t^H = \alpha L_t^H$, where α is the productivity of household labor.[8] Hence, total consumption is equal to $C_t^M + C_t^H$ and total time not enjoyed as leisure is equal to $L_t^M + L_t^H$. The household maximizes utility by choosing $\{C_t^M, C_t^H, Z_{it+1}, B_{t+1}, L_t^M, L_t^H\}$.

The production side of the economy consists of a set of intermediate sectors $i = 1, \ldots, N$ and a final good sector that aggregates the intermediate goods into a market consumption good according to:

$$(6) \quad C_t^M = \left[\sum_{i=1}^{N} \frac{1}{N}(\theta_{it} X_{it})^{\phi}\right]^{\frac{1}{\phi}}, \quad \phi < 1,$$

[8] Home production with linear technology is introduced here for analytical tractability, as it allows us to easily determine the wage rate and the interest rate.

where X_{it} are the quantities of intermediate goods (or services) used in the production of the market consumption good and θ_{it} is a technology shifter in sector i. Both the intermediate sectors and the final market consumption good sector are assumed to be competitive. The price of the market consumption good is the numeraire and the prices of the intermediate goods are denoted by P_{it}.

The representative firm in sector i produces the intermediate good X_{it} using services from its capital stock K_{it} combined with labor it directs toward production, denoted L_{it}^{P}. The firm also hires labor L_{it}^{I} to build up its capital stock. The production of the intermediate good is given by $X_{it} = K_{it}^{\gamma}(L_{it}^{P})^{1-\gamma}$, $0 < \gamma \leq 1$. The firm's capital stock accumulates according to $K_{it+1} = I_{it} + (1-\delta)K_{it}$, with $I_{it} = \ln(L_{it}^{I})$.[9] Here we can interpret that capital stock as representing physical capital, organizational capital, or a combination of both. So the firm's problem can be stated as choosing labor as to maximize the present discounted value of dividends $d_{it} = P_{it}X_{it} - w_t L_{it}^{M}$ or, stated explicitly, as solving

$$\max_{\{L_{it}^{P}, L_{it}^{I}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \frac{\beta^t C_0}{C_t}(P_{it}X_{it} - w_t L_{it}^{M}),$$

$$\text{s.t. } X_{it} = K_{it}^{\gamma}(L_{it}^{P})^{1-\gamma},$$

$$K_{it+1} = \ln(L_{it}^{I}) + (1-\delta)K_{it}$$

$$L_{it}^{M} = L_{it}^{P} + L_{it}^{I}.$$

In this formulation, firms are assumed to finance themselves by retained earnings and the total number of shares in each sector is normalized to one.

The Walrasian equilibrium for this economy takes a particularly simple form if the household problem has an interior solution, i.e., $L_t^{M} + L_t^{H} < \tilde{L}$. In this case, which we will focus upon, it can be easily verified that the equilibrium will be characterized by a fixed wage rate $w_t = \alpha$ and a fixed interest rate $(1+r_t) = \frac{1}{\beta}$. The optimal choices of labor and investment for the firm are then given by

$$(7)\quad L_{it}^{M} = L_{it}^{P} + L_{it}^{I} = K_{it}\left(\frac{(1-\gamma)P_{it}}{\alpha}\right)^{\frac{1}{\gamma}} + \frac{\beta}{\alpha}\gamma(1-\gamma)^{\frac{1-\gamma}{\gamma}} E_t \sum_{s=0}^{\infty}(\beta(1-\delta))^{j} P_{it+s+1}^{\frac{1}{\gamma}}$$

and[10]

$$(8)\quad I_{it} = \ln\left(\frac{\beta}{\alpha}\gamma(1-\gamma)^{\frac{1-\gamma}{\gamma}} \times E_t \sum_{s=0}^{\infty}(\beta(1-\delta))^{j} P_{it+s+1}^{\frac{1}{\gamma}}\right),$$

and the price of shares $\mathcal{P}_{it}$ will be given by

$$(9)\quad \mathcal{P}_{it} = E_t \sum_{s=0}^{\infty} \beta^s d_{it+s} = E_t \sum_{s=0}^{\infty} \beta^s \left(P_{it+s}^{1+\frac{1-\gamma}{\gamma}} K_{it+s}\left(\frac{1-\gamma}{\alpha}\right)^{\frac{1-\gamma}{\gamma}} - \alpha_t L_{it+s}^{M}\right).$$

The key equation here is (7), as it emphasizes the forward aspect of the firm's labor demand. There are two components to this labor demand. The first component captures

[9] We could allow the firm's production technology for investment goods to take a much more general form, including allowing the firm's capital stock to also enter the production function of investment goods. Analytical tractability has dictated the current choice.

[10] Note that investment expenditures by the firm are $w_t L_{it}^{I} = \beta\gamma(1-\gamma)^{\frac{1-\gamma}{\gamma}} E_t \sum_{s=0}^{\infty}(\beta(1-\delta))^{s} P_{it+s+1}^{\frac{1}{\gamma}}$, so that total market output in the economy is measured as $C_t^{M} + \alpha L_{it}^{I}$.

the demand for labor directed at the current production of X_{it}, while the second component captures the labor that is hired for investment purposes; that is, in order to build capacity in anticipation of the economy's future needs. In order to determine their optimal employment, firms need to form expectations about the future price of their output. In this model, the price at time $t+j$ in sector i can be written as

$$P_{it+j} = \frac{1}{N}\left(\frac{C^M_{t+j}}{X_{it+j}}\right)^{1-\phi} \theta^{\phi}_{it+j}.$$

So to form expectations of future prices, firms will want to have information relevant for predicting aggregate consumption, aggregate production in their sector, and technological change in their sector. Some of this information may be contained in current news in the economy. For example, agents may get signals at different points in time about future changes in the θs. In general, if firms receive such signals about future θs, the expectation problem they need to solve is quite involved, as we will emphasize later. However, in the particular case where $\phi = 0$ (which corresponds to a one-sector model with N competitive firms), the problem becomes very tractable. In that case, the price in sector k can be written as

$$P_{kt+s} = \frac{1}{N}\frac{C^M_{t+s}}{X_{kt+s}}$$

$$= \frac{1}{N}\frac{\left(\Pi^N_{i=1}(X_{it+s})^{\frac{1}{N}}\right)}{X_{kt+s}}\left(\Pi^N_{i=1}(\theta_{it+s})^{\frac{1}{N}}\right).$$

From the point of view of a firm that is choosing current employment and investment levels, when $\phi = 0$, to predict the price in its sector, the firm will want to predict future market consumption and the future output level that will be offered in its sector.[11] The firm does not need to directly care about predicting technology levels. However, in a rational expectations equilibrium, this problem boils down to predicting a sequence of future aggregate technology indexes given by $\Theta_{t+s} \equiv \frac{1}{N}\Pi^N_{i=1}(\theta_{it+s})^{\frac{1}{N}}$. In particular, given that this price function is symmetric for all sectors, a symmetric equilibrium implies that the output prices take the following simple form for all sectors:

$$P_{kt+s} = \frac{1}{N}\left(\Pi^N_{i=1}(\theta_{it+s})^{\frac{1}{N}}\right) = \Theta_{t+s}.$$

Now to introduce news in this system, let us assume that the technology index Θ follows the autoregressive process given by

$$(10) \quad \Theta_t = (1-\rho)\overline{\Theta} + \rho\Theta_{t-1} + \epsilon_{t-q},$$
$$0 \le \rho < 1,$$

where ϵ_t is a Gaussian white noise process with variance σ^2_ϵ. We normalize $\overline{\Theta} = 100$ so that a unit shock to ϵ_{t-q} induces a 1 percent deviation of Θ from its steady state.[12] News in the system can then be introduced in the form of a signal S_t of ϵ_{t-q}. We assume that the signal is noisy, $S_t = \epsilon_{t-q} + \nu_t$ where ν_t is a Gaussian white noise error term.[13] This

[11] Such a mechanism echoes Pigou (1927), who introduces his discussion of the impulses behind changes in expectations of businessmen with the proposition that "the dominant causal factor is not on the side of the supply of mobile resources, but on the side of expectations of profit."

[12] Given our formulation for the process of Θ, it is formally possible that it becomes negative, which does not make sense in our setup. We disregard this possibility in the current presentation, assuming that σ_ϵ is small enough compared to $\overline{\Theta}$.

[13] An alternative information structure which would give very similar results is one where the the sector-level technology θ_{it} is an unpredictable iid process, say $\theta_{it} = \overline{\theta} + \epsilon_{it}$, with a variance for the ϵ, denoted $\sigma^2_\epsilon(t)$, that varies over time and is partially predictable by news. For example, the variance could be an autoregressive process $\sigma^2_\epsilon(t) = (1-\rho)\overline{\sigma}^2 + \rho\sigma^2_\epsilon(t-1) + \eta_{t-q}$, and the news could take the form of $S_t = \eta_t$. In this case, S_t would signal future variance of sector specific shocks, and this would

is an environment where agents receive q periods in advance information about future innovations to Θ. Our goal now is to illustrate how the economy reacts to the shocks ϵ_t and ν_t by use of impulse response functions. The easiest case for this is when $\gamma = 1$, that is, the case where employment is fully forward-looking, and current production results only from past investments. In this case, the impulse response function for percent deviations of aggregate employment from its steady state, denoted $\hat{L}_t^M$ is given by

$$\text{(11)}\quad \frac{(1-\rho(1-\delta)\beta)}{(1-(1-\delta)\beta)} \times \hat{L}_t^M = \sum_{s=0}^{q-1} ((1-\delta)\beta)^{q-s-1}\, \psi\epsilon_{t-s} + \sum_{s=q}^{\infty} \rho^{s-q+1}\, \epsilon_{t-s} + \sum_{s=0}^{q-1} ((1-\delta)\beta)^{q-s-1}\, \psi\nu_{t-s},$$

where $\psi = \frac{\sigma_\epsilon^2}{\sigma_\nu^2 + \sigma_\epsilon^2}$ captures the information content of the signal S_t with respect to ϵ_t.[14]

In comparison, the impulse response functions for percent deviations of Θ from its steady state is given by $\hat{\Theta}_t = \sum_{s=0}^{\infty} \rho^s \epsilon_{t-q-s}$. Figure 1 plots an example of the of impulse response for $\hat{L}_t^M$ and $\tilde{\Theta}_t$ to the shocks ϵ and ν when $\rho > (1-\delta)\beta$ and $\rho > \psi$.[15]

There are four panels in the figure. In panels (a) and (b) we plot the response of $\hat{L}_t$ and $\hat{\Theta}_t$ to a ϵ shock; that is, to a shock that first comes to the agents in the form of news (in the signal S_t), and then subsequently leads to increased productivity. As can be seen on panels (a) and (b), on receiving the news, employment starts to increase immediately, while $\hat{\Theta}$ does not change. Employment keeps increasing for q periods as firms hire labor to build capacity in anticipation of the increase in economic activity. The peak of employment arises at the same time productivity eventually starts to grow.[16] Following the peak, both employment and $\hat{\Theta}$ gradually decline to their previous steady states, as the shock is only temporary. In panels (c) and (d) we plot the response to a noise shock ν. This is a shock that first comes to agents as news about future productivity, but it is actually false information. In response to this shock, employment increases immediately as the response is identical to the response to an ϵ shock for the first $q-1$ periods. However, in period q, it is realized that the information was just noise and employment collapses. Through this process, since agents are reacting to noise, the technology index Θ does not move. A key feature of this model is that it creates potentially large reversals in employment as the result of agents reevaluating their information in period q.

lead to a lower expectation of aggregate demand. The model can therefore be extended to account for uncertainty shocks. Such news on the variance of forcing processes are introduced in Christiano, Motto, and Rostagno (2013) and in an example of Beaudry and Portier (2014).

14 To derive (11), we start from the equations for L_{it}^M which with $\gamma = 1$ is given by

$$L_{it}^M = \frac{\beta}{\alpha} E_t \sum_{s=0}^{\infty} (\beta(1-\delta))^s P_{it+s+1}.$$

Then we use the signal to predict prices according to $E_t P_{it+s} = (1-\rho)^s + \rho^s \Theta_t + \psi \sum_{r=1}^{s} \rho^{s-r} S_{t-q+r}$ for $s \le q$ and $E_t P_{it+s} = (1-\rho)^s + \rho^s \Theta_t + \psi \sum_{r=1}^{q} \rho^{s-r} S_{t-q+r}$ for $s > q$. Using $S_t = \epsilon_{t+q} + \nu_t$, and summing over the sectors we get

$$L_t^M = \frac{N\beta}{\alpha(1-\rho(1-\delta)\beta)} \Bigg[\overline{\Theta} + \sum_{s=0}^{q-1} ((1-\delta)\beta)^{q-s-1} \psi\epsilon_{t-s} + \sum_{s=q}^{\infty} \rho^{s-q+1}\epsilon_{t-s} + \sum_{s=0}^{q-1} ((1-\delta)\beta)^{q-s-1} \psi\nu_{t-s} \Bigg] + \frac{N\beta}{\alpha(1-(1-\delta)\beta)},$$

with the steady state being given by $\overline{L}^M = \frac{N\beta}{\alpha(1-\rho(1-\delta)\beta)}$. Finally, we define $\hat{L}_t^M = \frac{L_t^M - \overline{L}^M}{\overline{L}^M}$.

15 The impulse responses are calculated using the following parameters: $\beta = 0.99$, $\delta = 0.025$, $\rho = 0.999$, $q = 8$, $\psi = 0.8$, and $\alpha = 10$.

16 The peak in employment can arise either $q-1$ or q periods after receiving the shock depending on whether ρ is greater or smaller than ψ.

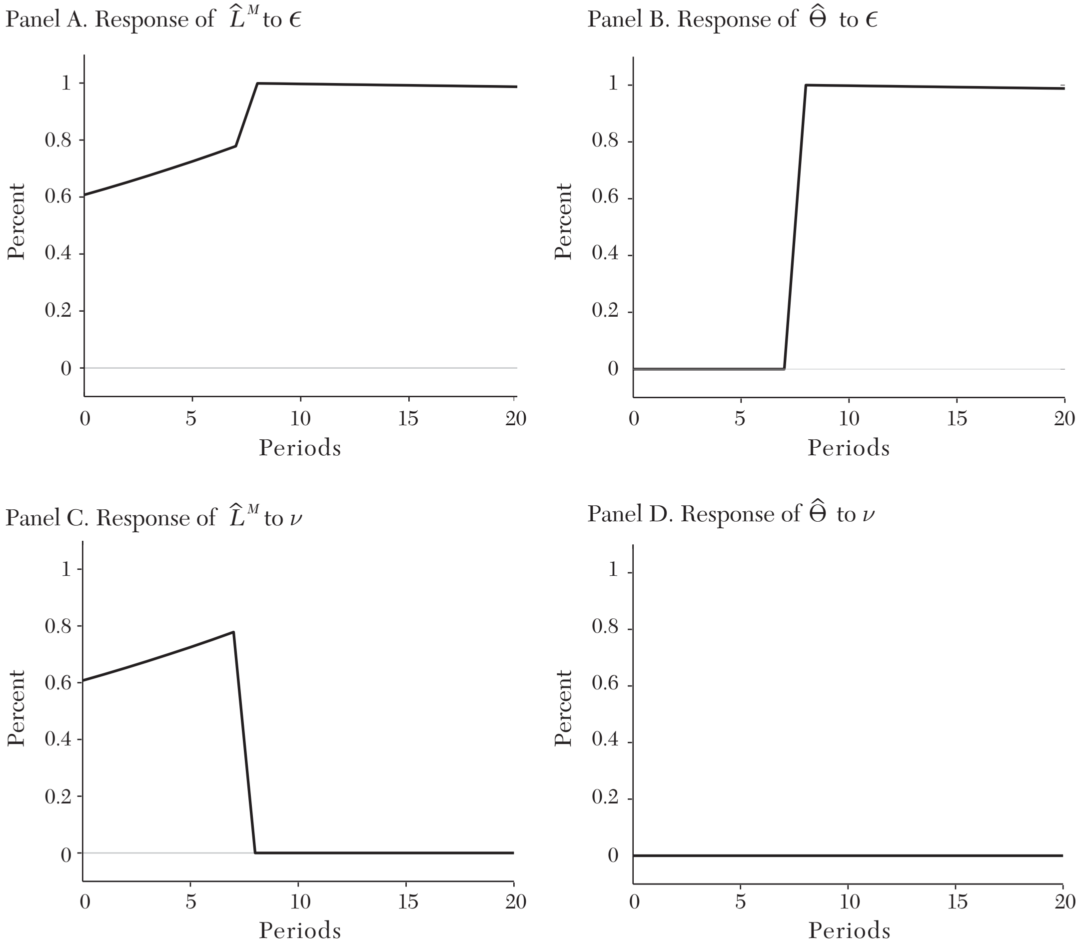

Figure 1. Response of Hours Worked $\hat{L}^M$ and *TFP* $\tilde{\Theta}$ to News (ϵ) and Noise (ν) Shocks in Period 0

Notes: This figure displays responses of hours worked $\hat{L}^M$ and *TFP* $\hat{\Theta}$ to news (ϵ) and noise (ν) shocks, as obtained from equation (11) with parameters $\beta = 0.99$, $\delta = 0.025$, $\rho = 0.999$, $q = 8$, $\psi = 0.8$ and $\alpha = 10$. Units are percentage deviations from the steady-state level.

In order to complete the picture of how this economy reacts to news, we also want to discuss the behavior of stock prices and consumption. Stock prices are given by the discounted sum of dividends, as follows

$$\mathcal{P}_{it} = E_t \sum_{s=0}^{\infty} \beta^s \, d_{it+s} = E_t \sum_{s=0}^{\infty} \beta^s (P_{it+s} \, K_{it+s} - w_t \, L^M_{it+s}) \,. \tag{12}$$

In contrast to the impulse response for employment, the impulse response for stock prices is not a simple linear function. For this reason, we will focus on a first order linear approximation of the deviation of stock prices from its steady state, which we will denote by $\hat{\mathcal{P}}_t$. Using the firm's optimality conditions for the choice of employment, the impulse response for $\hat{\mathcal{P}}_t$ can be written as

$$(13)\quad \hat{\mathcal{P}}_t = \sum_{s=0}^{q-1} \left\{ \bar{K} \frac{\beta^{q-s}}{1-\rho\beta} \psi + \left[1 + \alpha(1-\delta)\bar{L}^M\right] B_{s-1}\, \psi \right\} \epsilon_{t-s} + \sum_{s=q}^{\infty} \left\{ \bar{K} \frac{\rho^{s-q}}{1-\rho\beta} + \left[1 + \alpha(1-\delta)\bar{L}^M\right] \times \left[A_{s-1} + B_{s-1}(1-\delta)^{s-q}\, \psi\right] \right\} \epsilon_{t-s} + \sum_{s=0}^{q-1} \left\{ \bar{K} \frac{\beta^{q-s}}{1-\rho\beta} \psi + \left[1 + \alpha(1-\delta)\bar{L}^M\right] B_{s-1}\, \psi \right\} \nu_{t-s} + \sum_{s=q}^{\infty} \left\{ \left[1 + \alpha(1-\delta)\bar{L}^M\right] \times B_{q-1}(1-\delta)^{s-q}\, \psi \right\} \nu_{t-s}$$

where $A_s \equiv \rho^{1-q+s}\left(\frac{1 - \left[\rho^{-1}(1-\delta)\right]^{1-q+s}}{1-\rho^{-1}(1-\delta)}\right)$,

$$B_s \equiv \left[(1-\delta)\,\beta\right]^{q-s-1}\left(\frac{1 - \left[(1-\delta)^2\beta\right]^{s+1}}{1-(1-\delta)^2\beta}\right),$$

$\bar{K} = \frac{1}{\delta}\log\left(\frac{\beta}{\alpha[1-(1-\delta)\,\beta]}\right)$, and

$$\bar{L}^M = \frac{\beta}{\alpha[1-(1-\delta)\,\beta]}.$$

Stock prices will respond to both ϵ and ν shocks as both affect the agents' information set. Note that the impulse response for stock prices is very similar to that of employment, as illustrated in figure 2. In particular, in response to a shock to ϵ_t, which only has an effect on productivity q periods later, stock prices increase immediately. It continues increasing as we approach the eventual increase in Θ. When Θ increases in period q, stock prices jump and further increase due to the induced accumulation of capital. However, in response to the noise shock, stock prices experience an initial boom phase and then collapse once the agents learn that they were acting on noise, as opposed to good information. [17] In this simple model, we are allowing both stock prices and employment to immediately react to any signal S_t and for this reason, the two impulse responses are qualitatively similar. However, it may be more reasonable to assume that stock prices react quicker than employment to news. For example, this would arise if we modified the model so that employment needs to be determined one period in advance. Then, in such a case, upon receiving news, stock prices would jump immediately, employment would increase with a delay of one period, and finally Θ would increase with a delay of q periods if the news is realized to be true. Alternatively, if the news was really noise, then both stock prices and employment would eventually collapse, respectively, q and $q+1$ periods after the initial arrival of news. In this modified environment, stock prices would be the best indicator of the agents' information and would be the first variable to move in response to news. In general, we would expect stock prices to be at least as good or better in reflecting agents' information than any other economic variable as it is the least likely variable to be restricted by frictions and delays. This is a

[17] Note that the initial response of stock prices relative to its peak will generally be greater than that for employment.

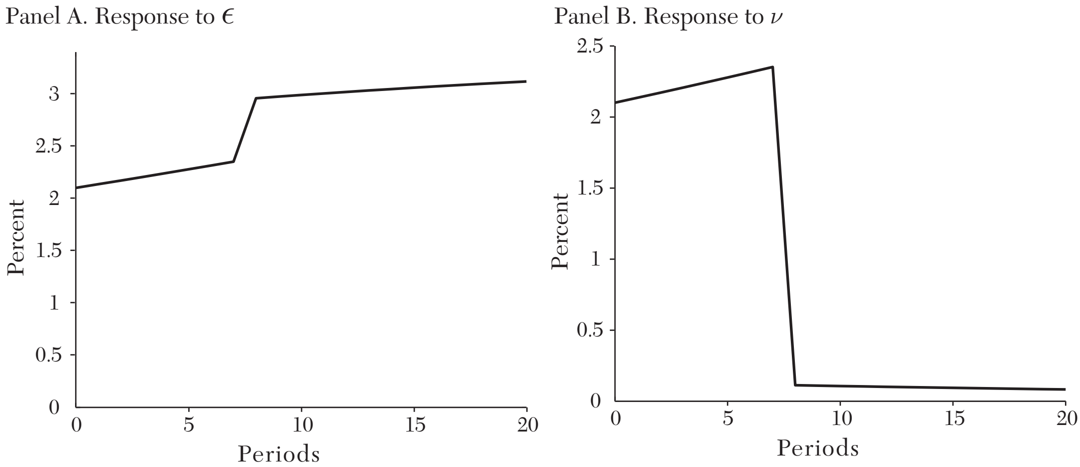

Figure 2. Response of Stock Prices $\hat{\mathcal{P}}$ to News (ϵ) and Noise (ν) Shocks in Period 0

Notes: This figure displays responses of stock prices $\hat{\mathcal{P}}$ to news (ϵ) and noise (ν) shocks, as obtained from equation (13) with parameters $\beta = 0.99$, $\delta = 0.025$, $\rho = 0.999$, $q = 8$, $\psi = 0.8$ and $\alpha = 10$. Units are percentage deviations from the steady state level.

key insight that will be exploited when discussing the identification of news shocks.

Market consumption in the version of the model with $\gamma = 1$ and $\phi = 0$ can be expressed as

$$\begin{aligned} C_t^M &= \Theta_t\big(\Pi_{i=1}^N X_{it}\big)^{1/N} \\ &= \Theta_t\big(\Pi_{i=1}^N K_{it}\big)^{1/N} \\ &= \Theta_t \sum_{s=0}^{\infty}(1-\delta)^s N \ln\left(\frac{L_{t-s-1}^M}{N}\right). \end{aligned}$$

This implies that market consumption does not respond immediately to news about θ, it only responds with a lag.[18] Since news affects employment and therefore capital accumulation, when agents get positive news about future technology, market consumption will start growing after the news through its effects on firms' capital stocks. It will keep on growing at least until q periods after the news, at which time it will start to reduce substantially if the news was misleading, or may increase further if the news was right. The fact that market consumption does not respond immediately to news can be seen as a weakness of the current model, as we will discuss when looking at empirical results. This will motivate our later exploration into mechanisms that change this property. Note that allowing γ to be smaller than 1, so that labor input enters the production of intermediate goods, will not change the fact that market consumption does not jump in response to news in this model, all it does is amplify the effects of actual change in technology and of the effects of capital accumulation. More generally, although we have derived the above impulse responses for the extreme case where $\gamma = 1$, the main qualitative feature about the effects of news remain unchanged if we extend to the case

[18] Market consumption in this model moves proportionately to the capital stock.

where $\gamma < 1$, it only makes presentation less straightforward.

2.2 *Extensions of the Basic Model*

Here we discuss various extensions or alternative interpretations of our basic model.

2.2.1 *Alternative News Formulation*

In our illustration of the effects of news, we have focused on the case where news can be subject to noise. As noted in the introduction of section 2, an alternative formulation would be to assume that the innovation in Θ_t is composed of two elements, say ϵ_{1t-q} and ϵ_{2t}, with the news taking the form $S_t = \epsilon_{1t}$. In this case, the impulse response for employment would be given by

$$\hat{L}_t^M = \frac{(1-(1-\delta)\beta)}{(1-\rho(1-\delta)\beta)} \times \left(\sum_{s=0}^{q-1}((1-\delta)\beta)^{q-s-1}\,\epsilon_{1t-s} + \sum_{s=q}^{\infty}\rho^{s-q+1}\,\epsilon_{1t-s} + \sum_{s=0}^{\infty}\rho^{s+1}\,\epsilon_{2t-s}\right).$$

The impulse response to ϵ_{1t} in this case closely resembles the response that we have derived in the previous case for ϵ_t with the exception that now the response will be stronger in the boom period as agents are not downplaying their signal by the factor ψ. In contrast, in this case we do not have a response that parallels the effect of a noise shock. Instead we have the effect of a pure unexpected shock, which has a simple autoregressive structure. It is this type of information structure that is the main focus of the VAR literature discussed in the next section, while the formulation with noise shocks requires a more structural approach as discussed in section 4.

2.2.2 *The Nontrivial Information Processing Problem and the Interpretation of Errors*

In our baseline model, news is affecting the economy through its effect on the firm's expectation of future demand for their product. Under the assumption that $\phi = 0$, meaning that there is a unit elasticity of substitution between intermediate goods, the expectation problem faced by firms is reduced to the rather simple problem of predicting the aggregate technology index Θ_t. However, if we slightly generalize the price function, for example by allowing $\phi \neq 0$, then the prediction problem faced by firms becomes much more involved. To see this, let us consider the case where $\phi \neq 0$, but where we simplify other aspects by assuming that $\delta = 1$ and that sector productivity is an i.i.d. process where innovations can be predicted using news only one period in advance, that is, $\theta_{jt} = \bar{\theta} + \epsilon_{jt-1}$ and $S_{jt} = \epsilon_{jt} + \nu_{jt}$.

In full generality, let's denote by E_{jt} the expectation operator conditional on the information set of firm j at time t. With full depreciation and one period news, employment in sector j is given by $L_{jt} = E_{jt}\left[\frac{\beta}{\alpha}P_{jt+1}\right]$ with the expected price in sector j being given by

$$E_{jt}P_{jt+1} = E_{jt}\left[\left(\frac{\sum_{i=1}^{N}(\epsilon_{it+1}X_{it+1})^{\phi}}{X_{jt}}\right)^{1-\sigma}\epsilon_{jt+1}^{\phi}\right], \tag{14}$$

with $X_{j+1} = \ln(L_{jt})$. In this case, to predict the price that is relevant for them, firms need to solve a nontrivial problem that involves predicting a nonlinear function of all the future sectoral outputs as well as all the future sector-specific technology shocks. Moreover, this expectation problem exhibits a type of complementarity structure whereby firms in one sector will want to increase their production if they expect others to increase their production, regardless of the actual news received.

Equation (14) can be rewritten as

$$E_{jt}\,P_{jt+1}$$
$$= E_{jt}\left(\frac{\sum_{i=1}^{N}\left(\epsilon_{it+1}\ln\left(E_{it}\left[\frac{\beta}{\alpha}P_{it+1}\right]\right)\right)^{\phi}}{X_{jt}}\right)^{1-\sigma}\epsilon_{jt+1}^{\phi}$$

If information is dispersed, the equilibrium involves higher-order expectations. We do not investigate here the possibilities opened by dispersed information, and assume that all agents observe the full collection of signals $\{S_{jt}\}_{j=1}^{N}$. While this type of problem has a rational expectations solution, it is quite possible that firms in a real economy would find computing the solution difficult and could, therefore, possibly make errors in predicting prices even if the variance of ν_{jt} is zero. Moreover, the complementarity structure may lead errors by some firms to lead to errors by other firms. This possibility opens the door to an alternative interpretation of the noise shocks in the model: these could reflect information-processing difficulty instead of reflecting simply noise in the signals received by agents. While we will not pursue this interpretation here, we believe that it may be a realistic way of interpreting why the economy may sometimes make big prediction errors; that is, it is not necessarily the case that the news on which people acted was noisy, but instead that agents' mapping between the news and the subsequent realization of prices may have been faulty.

2.2.3 *Recessions as Liquidation Periods*

The model we presented emphasizes how the economy can go through a news-driven boom period based on firms expecting higher demand for their products in the future, followed by a crash if the actual information content of the news was faulty. Since the boom involved investment, we can interpret the post-crash period as a period of liquidation,[19] where investment by firms falls and the capital stock is depleted as one returns to the initial steady-state level. However, in the baseline formulation, the liquidation period is quite mild in the sense that investment and employment simply return to their steady-state values after the crash and do not fall below their steady-state levels. This property arises only because of the simplifying assumptions of the setup. In particular, if we introduce into the model elements that cause output prices to respond negatively to past excesses in capital accumulation, then the dynamics of employment and investment become much richer, and a more explicit liquidation cycle emerges. To illustrate this, let us modify the baseline model and introduce decreasing returns to capital, so that an excess of capital is now associated with a low marginal return. First, let the production of market consumption goods be given by $C_t^M = \Theta_t X_t - \kappa\frac{X_t^2}{2}$, where X_t remains the aggregator function and where we replace here the sectoral shocks with an aggregate shock Θ_t. In this environment, agents continue to receive noisy signals q periods in advance regarding innovations to Θ_{t+q} (we also continue to assume that $\Theta_t = (1-\rho)\overline{\Theta} + \rho\Theta_{t-1} + \epsilon_{t+q}, \gamma = 1$ and $S_t = \epsilon_t + \nu_t$). Finally, to get a linear representation for the capital accumulation equations, we assume that $I_{it} = (2L_{it}^{I})^{\frac{1}{2}}$, where L_{it}^{I} remains the employment directed to the accumulation of capital by the representative firm in sector i. In this case, it can be shown

[19] De Long (1990) discusses the liquidationist view of the Great Depression, incarnated by the U.S. Secretary of the Treasury Mellon with his formula "Liquidate labor, liquidate stocks, liquidate the farmers, liquidate real estate." Interestingly, De Long (1990) develops a simple theoretical model of a "liquidationist" business cycle, in which large fluctuations in investment are driven by small fluctuations of expectations about future productivity.

that aggregate capital accumulation will be given by

$$K_{t+1} = \lambda K_t + \frac{\beta\lambda}{\alpha(1-\delta)} \sum_{s=0}^{\infty} (\beta\lambda)^s E_t \Theta_{t+1+s}$$

where λ is the root smaller than 1 of the polynomial $X^2 - \frac{(1+(1-\delta)^2\beta + \beta\alpha^{-1}\kappa}{(1-\delta)\beta} X + \frac{1}{\beta}$, with the property that $0 < \lambda < (1-\delta)$ when $\kappa > 0$. In this case, the response of investment and employment to a shock ϵ_t remains qualitatively very similar to one we derived previously. However the response to noise shock ν_t is quite different. In particular, the response of investment $\hat{I}_t$—defined in percentage deviations from the steady state—to a noise shock can be expressed as

$$(15) \qquad \hat{I}_t = \Phi \sum_{s=0}^{\infty} \phi_s \, \nu_{t-s}$$

where

$$\Phi = \frac{\beta(\beta\lambda)^{q+1}}{\alpha(1-\delta)(1-\rho\beta\lambda)\left(1-\beta\lambda^2\right)}$$

$$\phi_s \equiv$$

$$\begin{cases} \lambda^s \{\lambda\left[(\beta\lambda^2)^{-1-s} - 1\right] \\ \quad - (1-\delta)\left[\left(\beta\lambda^2\right)^{-s} - 1\right]\}\psi & \text{if } s < q \\ \\ -(1-\delta-\lambda)\left[\left(\beta\lambda^2\right)^{-q} - 1\right]\lambda^s\,\psi & \text{if } s \geq q \end{cases}$$

For $s \geq q$, it is straightforward to see that ϕ_s is negative, increasing and concave in s, approaching zero as $s \to \infty$. For $s < q$, it can be verified that ϕ_s is positive, increasing and convex in s.

A typical impulse response of investment to a noise shock in this case is illustrated in figure 3, assuming $\kappa = 0.1$. Note that this impulse response also captures, to a first-order linear approximation, the qualitative response of aggregate employment. In this figure, during the initial $q-1$ periods, investment (and hence employment) are increasing in response to firms' optimistic perception about future demand for their products. However, at time q it is realized that the information on which these expectations were formed was invalid and, accordingly, expectations are revised downward and investment drops suddenly. In contrast to the previous impulse response to a noise shock, we now see that investment drops below its steady state after the realization of overly-optimistic past behavior. The reason that investment drops is that the economy is in a situation of excess capital and firms realize that this depresses the current and future returns to capital accumulation. Over time, the excess capital is reabsorbed through depreciation and low investment, causing investment to gradually returning to its steady state. This figure illustrates clearly how the reaction to faulty news can cause both a boom and a bust, with the bust not only representing a fall in economic activity relative to the peak, but generating a sustained period where investment and employment are below their steady state levels. The behavior of consumption during this process is slightly different, as it increases in the first q periods and then gradually declines to its steady state without ever falling below its steady state.

2.2.4 *The Efficiency of News-Driven Booms and Busts*

In our baseline model, we have assumed that all markets function in a Walrasian fashion. Moreover, we have assumed that all information arises from exogenous sources. These two assumptions together imply that the fluctuations that arise as result of news are constrained efficient; i.e., they are efficient conditional on the agents' information set. In particular, it implies that a government with the same information set cannot

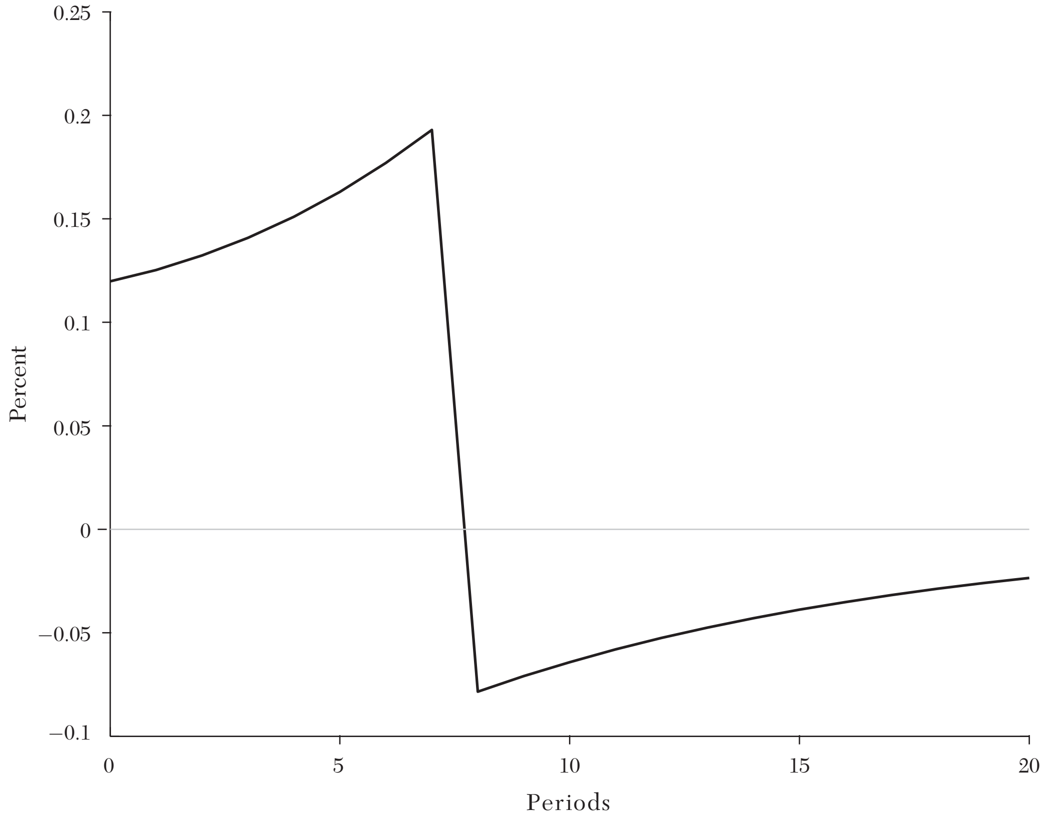

Figure 3. Response of Investment to a Noise Shock in Period 0

Note: This figure displays responses of investment $\hat{I}$ to a noise shock ν, as obtained from equation (15) with parameters $\beta = 0.99$, $\delta = 0.025$, $\rho = 0.999$, $q = 8$, $\psi = 0.8$, $\alpha = 25$, and $\kappa = 0.01$. Units are percentage deviations from the steady state level.

find a policy that would increase welfare by reducing fluctuations. However, as hinted to in the introduction, we do not see the news view of fluctuations as intimately linked to this property. Instead we interpret the news view of fluctuations as offering a positive theory of fluctuations, which can be embedded into different market structures with different normative implications.[20] For example, suppose we slightly change the labor market in our baseline model as to include a distortion whereby wages, instead of being at the Walrasian equilibrium level given by α, are set to equal $(1 + \tau)\alpha$, where $\tau > 0$ represents a distortion. For example, τ could reflect institutional features of wage determination in the form of worker bargaining power, or efficiency wage considerations, which could cause wages to be above the worker's marginal value of time. In this case, workers will feel constrained in

[20] Beaudry, Collard, and Portier (2011) is an example of an environment where news creates excessive fluctuations.

their labor supply as they would take market employment choices as determined primarily by firms. However, it is easy to verify that the positive properties of our baseline model would be essentially unchanged. News would cause fluctuations to arise, and the size of the fluctuations in percent deviations from the steady state would be almost identical to that derived in the Walrasian case. In this sense, the positive properties of the baseline model are robust to the issue of whether or not labor market fluctuations represent voluntary or involuntary outcomes. In contrast, the normative implications can be quite different in the two setups. To see this, consider a case where a boom is driven by noise. Ex post, in the Walrasian setup, the boom period would be viewed with clear regret as individuals worked too hard compared to the eventual payoffs of the work. With a distortion in the labor market, the interpretation of the boom could be quite different. Because market employment and market consumption are too low in the presence of the distortion, the positive noise shock in this case plays the role of a coordinating device whereby employment gets closer to its optimal level during the boom period and therefore, the boom can appear like a good period even if the expectations that generated the boom are not fulfilled.

2.2.5 *The Information Structure*

The information structure in the baseline model specifies news as information about technological innovations that will be realized at a precise date in the future. This information structure, while very useful and tractable for discussing impulse responses and VAR implications (as we will see in the subsequent section) is extremely particular. In reality, news outcomes that affect agents' expectations of future events likely arise in a much less structured way. For example, if one gets news today about a potential future technological breakthrough, it is unlikely to take the form of information that is relevant only for predicting changes at one particular date. The information may well increase the perceived expected return to certain investment activities, but it is generally not very precise about exactly when a commercial implementation will take place and, therefore, imprecise about which timing one should adopt for investment. Introducing more realistic specifications of the information structure associated with news appears to us as an important challenge to this literature.[21]

2.3 *Excluding Technological Regress*

To make presentation simple, we have been specifying a symmetric process for the technological driving force with Gaussian innovations. Such a formulation implies that technological regress is possible. However, one of the attractive features of the news view of business cycles is that technological regress is not required to explain recessions. Instead recession can arise due to a liquidation process following overly optimistic expectations. Since technological regress is not a very appealing feature of a business cycle model, it appears more reasonable to specify a process for technology that does not allow regress. This is conceptually straightforward, but generally complicates resolution. The papers by Beaudry and Portier (2004) and Jaimovich and Rebelo (2009) are examples where the potential effects of news in creating recessions is studied in environments where technological regress does not arise. An alternative is to model news about an exogenously evolving technology frontier. Comin, Gertler, and Santacreu (2009) develop such a model. The new technologies have to be adopted prior to being used in production. The firms' investments in adopting new technologies leads to a shift in

[21] The information structure presented in Blanchard, L'Huillier, and Lorenzoni (2009) is a good example of how news and noise can be introduced in a more realistic fashion.

labor demand when the news shock hits the economy. Firms have the right to the profit flow of current and future adopted technologies, in addition to the value of installed capital. Therefore, revisions in beliefs about this added component of expected earnings allow us to capture both the high volatility of the stock market and its lead over output.

2.4 *Expectations of New Markets as a Form Technological News*

The nature of technological news presented in this section, and modeled in much of the literature, relates to news on future productivity. An alternative form of news, which may be more intuitive, is one that relates to the creation of new goods or new markets, as this is the more common type of news that would be reported in the media. To see the very close link between technological news and news regarding new markets, consider the case where aggregate consumption depends on inputs from different sectors according to

$$C_t^M = N_t^{\xi+1-\frac{1}{\sigma}} \left(\sum_{i=1}^{N_t} X_{it}^{\sigma} \right)^{\frac{1}{\sigma}}, \quad \sigma < 1, \tag{16}$$

where X_{it} is the input from sector i, N_t is the number of goods, ξ a parameter that governs the returns to variety and where we allow N_t to expand over time. In a symmetric equilibrium where $X_{it} = \overline{X}_t / N_t$, consumption will take the form $C_t^M = N_t^{\xi} \overline{X}_t$. When ξ is positive, (increasing returns to variety), changes in N_t will play the exact same role as changes in productivity Θ. Hence, much of the literature on technological news can be re-interpreted as models with news of expanding markets. Beaudry, Collard, and Portier (2011) develop such a model in which firms need to invest in order to secure monopoly position on the newly created goods. In the case where $\xi = 0$, changes in N_t create cycles driven by competition of monopoly rents, which are socially inefficient as investment only redistributes rents without having any productive impact.

3. *Reduced Form and Structural Vector Autoregressive Evidence*

There are two main ideas in the news view of business cycles. First, there is the notion that booms are driven mainly by expectations. In particular, increased demand for investment arises as the result of agents becoming optimistic about the future prospects of the economy. According to this view, investment demand should, on average, lead technological change as it is trying to anticipate it. Second, this view contends that recessions are mainly periods of liquidation arising from agents' revision of expectations. Therefore, recessions should arise after a period of optimism where erroneous interpretation of news has led to excess capital accumulation. In this section we will overview some evidence that has been presented as supportive of the news view of business cycles, as well as discuss work that has challenged its importance. In subsection 3.1, we will be looking at evidence that tries to capture the spirit of the theory without taking a clear stand on the precise model that could be generating the data. As news are typically in the information set of the economic agents, but not necessarily in the one of the econometrician, the identification of news shocks can be subject to a problem known as nonfundamentalness. We will discuss this problem and its implications in subsection 3.2. In subsections 3.3 and 3.4, we will review evidence obtained using SVAR approaches to identify the effects of news shocks.

3.1 *Reduced Form Evidence*

It is well known that investment fluctuates greatly over the business cycle. The questions relevant for the news view are (i) whether such fluctuations appear to reflect mainly changes in the demand or the supply of investment goods, and (ii) if they reflect demand, what is the type of force driving the demand. In a standard real business cycle (RBC) model,[22] investment is procyclical because surprise improvements in technology create a situation where the capital stock is low relative to the new state of technology. This relatively low state of the capital stock creates incentives to invest and work more so that the capital stock can catch up to the level of technology. In particular, in the case of an RBC model in which *TFP* follows a random walk, the state of the economy can be summarized by a simple ratio: the ratio of capital stock to TFP, which we will denote as $\frac{K}{TFP}$. If this ratio is low compared to its long run level, the RBC model predicts that employment should be high, as it is a desirable time to work to produce capital goods. If the ratio is high, then employment should be low, as there are low returns to capital accumulation. So according to an RBC view, employment and $\frac{K}{TFP}$ should be strongly negatively correlated. In a view where pure demand shocks are the main driver of the cycle, there should be a strong positive correlation between hours and $\frac{K}{TFP}$, as TFP is not expected to move. In contrast with those two extreme views, the news view of business cycles suggest that these variables should most likely have a modest positive correlation because of countervailing forces. On the one hand, if employment booms arise because capital accumulation anticipates growth in *TFP*, then employment and $\frac{K}{TFP}$ should be positively correlated in booms. On the other hand, major recessions in the news view of business cycles arise when $\frac{K}{TFP}$ is high and expectations no longer support such a high capital stock, leading to a recession. The second force should contribute to a negative correlation between employment and $\frac{K}{TFP}$. Since, on average, agents should be right more often than wrong, it suggests that employment and $\frac{K}{TFP}$ should be positively correlated if the news view is central to fluctuations. In figure 4 we plot per capita hours worked and the ratio $\frac{K}{TFP}$.[23] Both variables are calculated as percent deviations from a Hoddrick–Prescott (HP)-filter trend, where the HP-filter has been used to remove low-frequency fluctuations not related to business cycles.[24]

As can be seen from the figure, these two variables do not exhibit the strong negative correlation predicted by RBC theory. In fact, the correlation between the two is actually positive and equal to 0.30. This indicates that, on average, periods when employment is high are periods where the capital stock is high, at least relative to a current fundamental measured by *TFP.* This observation runs counter to an RBC view of fluctuations, but is potentially consistent with the news view.

To pursue further the information content of the $\frac{K}{TFP}$ ratio, in figure 5 we plot the average value of $\frac{K}{TFP}$ prior to recessions, that is, we take the average value of this ratio at the peak of the business cycle and in the three preceding quarters. According to the news view of business cycles, recessions should arise after periods where there has been substantial speculative investment, that is, when $\frac{K}{TFP}$ is high. As can be seen in the figure, almost all the postwar recessions in the U.S. have been preceded by a period where capital accumulation outstripped growth in *TFP.* The only exceptions are the recessions of 1973 and 1980. Since both of these recessions are commonly thought of as having been driven by energy prices and monetary factors, not by revised expectations after a period of speculative accumulation, it is interesting to note that they were not preceded by a period of high

22 See Cooley and Prescott (1995) and King and Rebelo (1999) for an exposition of the standard RBC model.

23 Data are taken from Fernald (2014).

24 These low-frequency movements could arise due for example to movements in labor market participation.

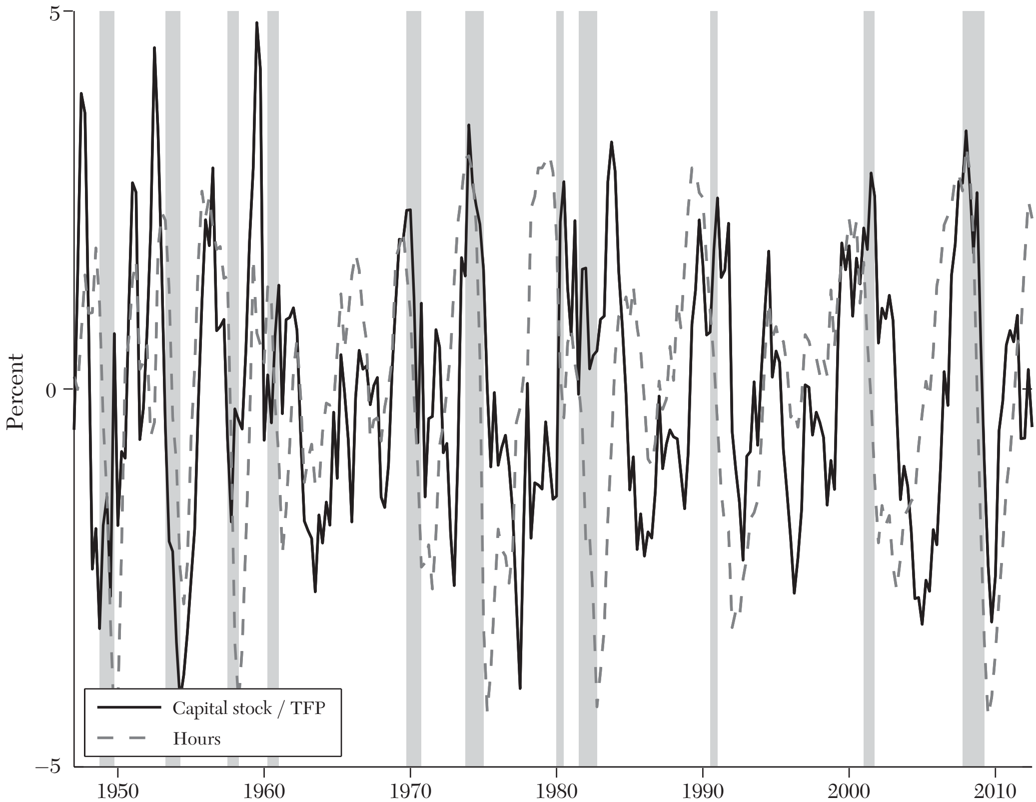

Figure 4. Cyclical Fluctuations of Hours Worked and Capital/*TFP* Ratio

Notes: This figure displays the Hoddrick–Prescott (HP) cycle (with smoothing parameter 1,600) of the ratio capital/Total Factor Productivity and of total hours. Capital, corrected *TFP*, and hours series are the ones of Fernald (2012) for the period 1947:I–2012:III. Units are percentage deviations from the HP trend. Grey areas correspond to NBER recessions. See the online appendix for a description of the data.

capital accumulation. While most recessions in the sample are preceded by a period of high capital accumulation relative to the state of technology, the news view of business cycles suggest that high values of $\frac{K}{TFP}$ should not be systematically predicting imminent recessions. Instead a high value $\frac{K}{TFP}$ should often be predicting further expansion. Interestingly, when we examine the correlation between $\frac{K}{TFP}$ at time t and the growth in hours of employment in the following quarter (growth between t and $t+1$), we find a positive correlation of 0.24 implying that, on average, a high $\frac{K}{TFP}$ ratio predicts further expansion, even though most recessions are preceded by high values of $\frac{K}{TFP}$.[25]

[25] As a robustness check, we also examined how hours worked covary with the ratio of capital to *TFP* when capital is measured in units of consumption goods (as opposed to units of output); that is, when we replace our previous ratio $\frac{K}{TFP}$ with $\frac{pK}{TFP}$ where p is the relative price of investment in terms of consumption good. For this case, we found very similar cyclical properties and we found again

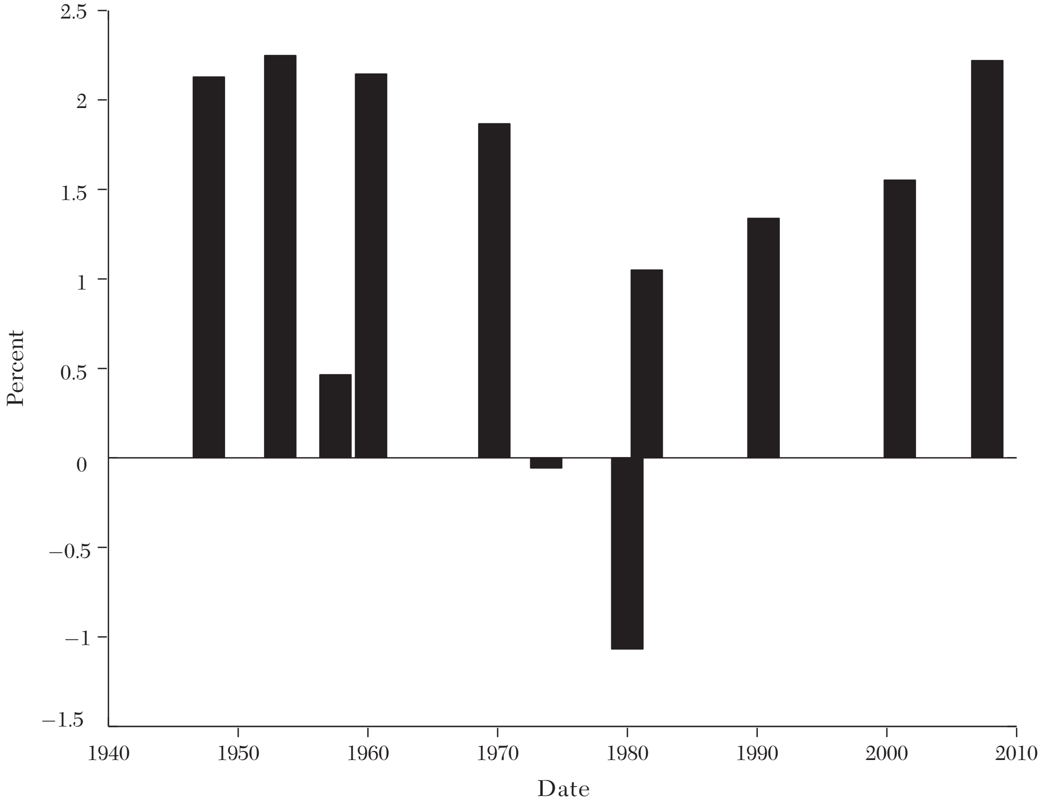

Figure 5. Average Deviation from HP Trend of the Capital/*TFP* Ratio over the Four Quarters Preceding a Recession

Notes: This figure displays the mean value of the Hoddrick–Prescott cycle (with smoothing parameter 1,600) of the ratio capital/Total Factor Productivity over the four quarters preceding a NBR recession (i.e., the quarter of the peak and the three quarters before). Capital and corrected *TFP* series are the ones of Fernald (2012) for the period 1947:I–2012:III. Units are percentage deviations from the HP trend. See the online appendix for a description of the data.

While the patterns we have reported between the ratio $\frac{K}{TFP}$ and hours worked appear more consistent with a news view of cycles than an RBC view, it does not yet tell us whether the observed positive correlation between $\frac{K}{TFP}$ and hours worked results from periods where capital accumulation is driven mainly by demand—as would be implied by a news view—or alternatively by supply. In particular, there is an important class of business cycle theories that suggests that it may be changes in the supply of investment goods that drive the cycle instead of demand. The mechanism is again technology-related and comes under the heading of investment-specific technological

that most recessions (with the exception of those of the 70s and earlier 80s) were preceded by periods where $\frac{pK}{TFP}$ was high.

TABLE 1
VARIOUS MEASURES OF THE RELATIVE PRICE OF INVESTMENT, DEFLATING WITH CORE CPI, CORRELATIONS WITH HOURS

Variable	1960:I–2012:III	Post-Volcker
Fixed investment	0.42	0.76
Structure investment	0.44	0.75
Equipment investment	–0.25	0.17
Residential investment	0.70	0.80
SP500	0.31	0.56

Note: All variables are quarterly HP filtered with smoothing parameter 1,600 and deflated by core CPI. See the online appendix for a description of the data.

change.[26] This view of business cycles argues that surprise improvements in the technology for producing capital goods cause periods where investment and employment will be high because the price of investment goods is low. Such a mechanism is consistent with a positive correlation between $\frac{K}{TFP}$ and hours worked. To differentiate between a story based on the supply of investment goods versus the demand for investment goods, the first piece of evidence to examine is the behavior of relative prices. In table 1 we report the correlation between per capita hours worked and different price indexes for capital goods.[27] We report the correlations for two samples, one starting in 1960:I and the other starting in 1987:IV and corresponding to the post-Volcker period, where nominal prices have been more stable. The investment prices we consider are: the BEA measures for fixed investment, structures, equipment, and residential investment.[28] We also report results using the S&P500 as a measure of the price of investment. This is closest to the model we have presented where it is the value of having capital goods installed in firms that is driving fluctuations. All these prices are deflated by the core CPI[29] and HP-filtered. We see in table 1 a mixed set of results for the cyclical pattern of the relative price of investment. If we focus on the most recent period where inflation has been stable, we observe that the relative price of investment is positively correlated with hours worked for all of our five indexes, with the relation being weak only for the relative price of equipment. So over this latter period, if investment was driving the cycle, then it appears most likely due to changes in the demand for investment goods as opposed to changes in their supply. However, if we

[26] See for example Greenwood, Hercowitz, and Huffman (1988); Greenwood, Hercowitz, and Krusell (2000); and Fisher (2006)

[27] Throughout this paper, our preferred measure of the cycle is hours worked. We like this measure since it is measured directly and not mechanically related to prices used to construct real output or measured *TFP*.

[28] Over the post-1960 period, structures represent 23 percent of fixed investment, equipment 48 percent, and residential investment 29 percent.

[29] We choose to deflate these series by the core CPI to eliminate changes in prices that are due to changes in the price of oil and commodities.

look at the longer sample, we get a more nuanced picture. The relative price of fixed investment, structures, residential investment and the stock prices index continue to show a strong positive relation with employment movements over the longer sample. In contrast, the relative price of equipment shows a negative comovement. Hence, over the longer sample there is room for debate regarding whether investment demand or the supply of investment goods have more likely played the greater role in fluctuations. From our point of view, the stock market index is our preferred index, since it represents the value to firms of investing to expand their production capacity and the behavior of this index is consistent with the pattern implied by the news view of fluctuations. Nonetheless we recognize that different researchers may or may not find the behavior of the relative price of investment goods, especially the relative price of equipment, to be consistent with the news view.

3.2 *The Nonfundamentalness Problem and Its Implications*

Structural vector autoregressive methods have been extensively used to explore the effects of news shocks on economic aggregates, and we will review this literature in the following subsection. However, before doing so, it is important to note that structural VAR methods require that the underlying data-generating process satisfy certain properties related to the invertibility of the model's solution when written in moving average form. In the presence of news, this property may not hold, which can render results from SVAR methods meaningless. Accordingly, in this subsection, our aim is to clarify the extent to which this noninvertibility problem, or alternatively known as a nonfundamentalness problem, limits the usefulness of SVAR methods in identifying the effects of news shocks.

3.2.1 *Introducing the Nonfundamentalness Problem Using Univariate Processes*

To begin, let us consider a simple economic environment where the solution to the model generating the data is the one-dimensional stationary[30] stochastic process x_t with moving average (MA) representation given by:

$$(17)\quad x_t = \theta_0 \varepsilon_t + \theta_1 \varepsilon_{t-1} + \cdots + \theta_k \varepsilon_{t-k} + \cdots$$
$$= \theta(L)\varepsilon_t .$$

where ε_t is a univariate zero mean white noise process with time-invariant variance and uncorrelated components. $\theta(L)$ is a polynomial of possibly infinite order, whose coefficients are absolutely summable. For simplicity, the process x_t is assumed to be purely nondeterministic, with MA roots exactly on the unit circle being excluded. We will refer to this process as the structural representation of x_t, that is, the representation that is derived from a model where the ε_t are economically meaningful shocks. The question we want to address is whether or not an econometrician is able to recover this structural model, i.e., the coefficients θ_k and the shock ε, from observations of current and past values of x_t. The advantage of first considering a univariate case is that we can focus on the issue of fundamentalness, without needing to discuss additional issues associated with identification that emerge in the multivariate multishock case.

A shock ε_t is said to be a fundamental shock (more precisely x_t-fundamental[31]) if it can be

[30] In most of the economic application we will review, variables will be nonstationary. The process x will then have to be thought of as (typically) the first difference of the macroeconomic series under consideration, or as a linear combination of them in the case of a multivariate model with cointegration.

[31] See Lütkepohl (2012) for a formal presentation. See also Alessi, Barigozzi, and Capasso (2008) for a review of

recovered from observing the current and past observations of x. From the inspection of (17), it is clear that ε can be expressed as a function of current and past values of x if and only if the polynomial $\theta(L)$ can be inverted, so that $\varepsilon_t = [\theta(L)]^{-1}x_t$. The condition for fundamentalness is therefore that all the roots of $\theta(L)$, i.e., the solution to the equation $\theta(z) = 0$, are strictly outside the unit disc. When the shock in (17) is nonfundamental, the econometrician will typically not be able to recover the ε shocks from estimating the Wold representation[32] and therefore will not be able to recover the structural impulse response of x_t to a shock ε_t.[33]

We now define a *news-rich* process as process for which there exists at least one q such that $|\theta_q| > |\theta_0|$. Such processes are of the "news" type in the sense that a larger share of the variance of x_t is attributable to the shock ε_{t-q} than to the shock ε_t, that is, more variance is due to a shock known q period in advance than due to the current period shock. Structural models with news shocks, for example the ones presented in the previous section, generally have a solution that corresponds to a *news-rich* process.

Our goal in this section is to clarify two points. The first point is qualitative: a model with news shocks may give rise to a nonfundamental representation, but does not necessarily give rise to a nonfundamental representation. The second point is quantitative: when a model with news shocks gives rise to a nonfundamental representation, its fundamental representation can be "close" to its nonfundamental representation, implying that SVAR methods may nonetheless deliver a good approximation of structural impulse responses even when the nonfundamentalness problem arises.[34] To set the stage, we will begin by highlighting a negative result, that is, we will show that a model with news shocks may exhibit a nonfundamentalness problem, and this problem can be severe in the sense that its fundamental representation will be far from its (structural) nonfundamental representation. The easiest case to show this problem is in the case where the model's solution is an MA(1) process. However, as we will show, several results from the MA(1) example do not generalize, and it is for these reasons that the nonfundamentalness issue may not be as serious as it may first appear from the MA(1) example we present below.

Before we proceed, let us notice that if $\theta_0 = 0$, then $\theta(L) = (\theta_1 + \theta_2 L + \cdots) \times L$. In this singular case, $z = 0$ is a root of $\theta(z)$ and the process is nonfundamental. The univariate processes we are examining in the next section are assumed to be nonsingular news-rich processes, with $\theta_0 \neq 0$, with the normalization $\theta_0 = 1$. As the literature has often focussed on singular news-rich processes, we therefore also examine this case and show that such singular processes are not qualitatively different if some extra information is given to the econometrician.

3.2.1.1 *The MA(1) case*

Consider the following simple rational expectations model:[35]

$$x_t = aE_t x_{t+1} + y_t,$$

$$y_t = \varepsilon_t + (1+\alpha)\varepsilon_{t-1},$$

nonfundamentalness and identification in structural VAR models.

[32] The Wold representation is the unique linear representation of a stationary process where the shocks are linear forecast errors.

[33] Recall that the impulse response function (IRF) of x_t to a unit shock $\varepsilon_t = 1$ is given by the sequence of MA coefficients $\{\theta_k\}$ for $k = 0, 1, \ldots$.

[34] To overcome invertibility problems, Lanne and Saikkonen (2011 and 2013) have proposed to directly estimate nonfundamental representations as noncausal autoregressive models.

[35] See Fève, Matheron, and Sahuc (2009) for a similar model but with a singular news-rich process of the type $y_t = \varepsilon_{t-q}$ with $q > 0$.

with $0 < a < 1$, $E(\varepsilon_t) = 0$ and $E(\varepsilon_t^2) = \sigma^2$. x_t is an endogenous variable and y_t is the news-rich exogenous process. The assumption that $\alpha > 0$ is meant to capture the idea that ε_t is a news shock as information obtained today implies expected growth in y_t. Solving this model forward, we obtain

$$x_t = \sum_{\tau=0}^{\infty} a^{\tau} E_t y_{t+\tau}.$$

Using the process of y, the model's solution reduces to

$$x_t = (1 + a(1+\alpha))\varepsilon_t + (1+\alpha)\varepsilon_{t-1}.$$

The solution to the model is therefore a news-rich process if $a < \frac{\alpha}{1+\alpha}$. Moreover, this is the same condition that implies nonfundamentalness, as the root of $\theta(z)$ will be inside the unit circle if and only if $a < \frac{\alpha}{1+\alpha}$. This simple example shows that (i) news shocks ($\alpha > 0$) do not necessarily mean nonfundamentalness and (ii) if the model solution is a news-rich MA(1), the ε_ts are not fundamental shocks and therefore cannot be recovered from current and past observations on x_t. In other words, one cannot use the Wold representation of the data to obtain structurally meaningful impulse responses.

3.2.1.2 *Is the Fundamental Representation Close to the Nonfundamental Representation in the MA(1) Case?*

The question we now want to address is, suppose we are in a situation where the solution to a model is nonfundamental, and the researcher is not aware of the issue and derives an impulse response for x_t from its Wold representation. Will the resulting impulse response be very different from the impulse response for ε_t implied by the model?

To explore this, consider the situation where the solution to the model is a news-rich MA(1) process, which in the MA(1) case is equivalent to noting that it is a nonfundamental process:

$$x_t = \varepsilon_t + (1+\alpha)\varepsilon_{t-1}, \tag{18}$$

with $\alpha > 0$.

How far from this nonfundamental representation—or structural representation—is the fundamental representation—or Wold representation? Let the Wold representation be denoted by:

$$x_t = \tilde{\varepsilon}_t + \theta_1 \tilde{\varepsilon}_{t-1},$$

where θ_1 and $\tilde{\sigma}^2$ need to be found. We can obtain those two parameters by matching the autocorrelation functions. Computing variance and autocorrelation from (18) and (19), we obtain the two equations:

$$\begin{cases} E(x_t^2) = (1 + (1+\alpha)^2)\sigma_\varepsilon^2 = (1+\theta_1^2)\sigma_\varepsilon^2, \\ E(x_t x_{t-1}) = (1+\alpha)\sigma_\varepsilon^2 = \theta_1 \sigma_{\tilde{\varepsilon}}^2. \end{cases}$$

Solving those two equations, we obtain the following fundamental representation

$$x_t = \tilde{\varepsilon}_t + \frac{1}{1+\alpha}\hat{\varepsilon}_{t-1}.$$

with $E(\tilde{\varepsilon}_t) = 0$ and $E(\hat{\varepsilon}_t^2) = (1+\alpha)^2\sigma^2$.

As illustrated in figure 6, the fundamental (Wold) representation gives an impulse response function to a unit shock[36] that is very different from the structural one. In particular, the structural IRF shows a hump shape, while the fundamental one is monotonic and decreasing.

[36] All the IRFs are normalized to be the response to a unit shock. Note that if one computes the IRF to a one standard deviation shock, the fundamental and structural IRF would not start from the same point, as the fundamental and structural shocks have different standard deviations.

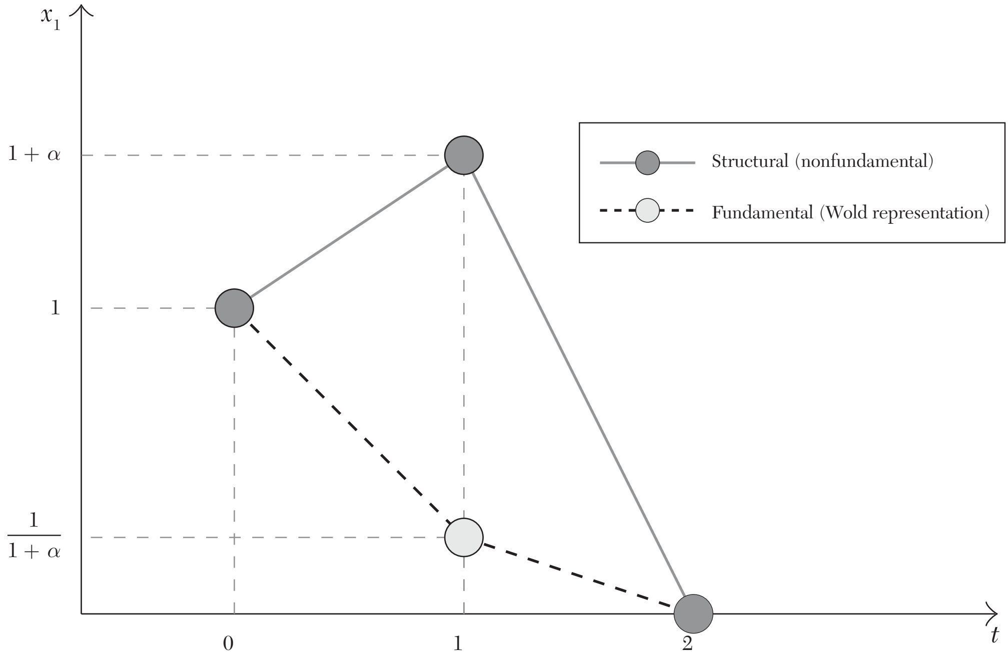

Figure 6. A Structural Nonfundamental News-Rich MA(1) Process and its Fundamental Representation

Note: This figure displays the impulse response functions to a unit shock for the structural nonfundamental process (18) and its Wold representation (19).

In summary, in the case where the solution of a model with news is a news-rich MA(1) process, then the solution is nonfundamental and this nonfundamental solution is qualitatively different from the fundamental representation. This suggests that the nonfundamentalness issue is likely very problematic in models with news shocks. However, as the following two subsections will clarify, the MA(1) case may be somewhat misleading because in more general settings news-rich processes are not necessarily nonfundamental, and even if they are nonfundamental, they are not necessarily very different from their fundamental representation.

3.2.1.3 *News-Rich Processes are Not Necessarily Nonfundamental*

We now consider the news-rich MA(2) process:

$$(20)\quad x_t = \varepsilon_t + (1+\alpha)\varepsilon_{t-1} + \beta\varepsilon_{t-2},$$

with $\alpha > 0$. Can this process be fundamental, or to put it differently can we find conditions on β under which the two roots of the polynomial $\theta(z) = \beta z^2 + (1+\alpha)z + 1$ are outside the unit disc? The answer is yes.

As can be verified,[37] a news-rich MA(2) process is fundamental if and only if $\alpha < \beta < 1$. Panel (a) of figure 7 displays the IRF of x to a unit structural shock ε in such a case. Note that, contrary to what the MA(1) case suggests, the process is news-rich *and* nevertheless fundamental. Panels (b), (c), and (d) illustrate the three reasons nonfundamentalness could occur: α large, β large given α, or β low given α. The invertibility condition $\alpha < \beta < 1$ states that the process need not increase too much between period 0 and period 1 ($\alpha < 1$) and that it not decline too abruptly between period 1 and period 2 ($\beta > \alpha$). This example nicely illustrates that news-rich processes may or may not be fundamental.

3.2.1.4 *Nonfundamental Structural News-Rich Processes Can Be Close To Their Fundamental Representation*

The MA(1) case was very stark in the sense that the fundamental IRF was qualitatively different from the structural nonfundamental one: the structural IRF was hump-shaped while the fundamental one was not. We show here that this is also not a general result. To do so, we again restrict to a MA(2) news-rich process.

$$x_t = \varepsilon_t + (1+\alpha)\varepsilon_{t-1} + \beta\varepsilon_{t-2},$$

with $\alpha > 1$ or $\beta \notin [\alpha, 1]$, so that ε is nonfundamental. Let us consider the Wold representation of this MA(2):

$$x_t = \tilde{\varepsilon}_t + \theta_1\tilde{\varepsilon}_{t-1} + \theta_2\tilde{\varepsilon}_{t-2},$$

with $E(\tilde{\varepsilon}_t) = 0$ and $E(\tilde{\varepsilon}_t^2) = \tilde{\sigma}^2$. Equating variance, first and second order covariances of the two representations gives:

$$\begin{cases} E(x_t^2) = (1+(1+\alpha)^2+\beta^2)\sigma_\varepsilon^2 = (1+\theta_1^2+\theta_2^2)\sigma_{\tilde{\varepsilon}}^2, \\ E(x_t x_{t-1}) = (1+\alpha)(1+\beta)\sigma_\varepsilon^2 = \theta_1(\theta_2+1)\sigma_{\tilde{\varepsilon}}^2, \\ E(x_t x_{t-2}) = \beta\sigma_\varepsilon^2 = \theta_2\sigma_{\tilde{\varepsilon}}^2. \end{cases}$$

We obtain the three following equations whose unknowns are θ_1, θ_2, and $\sigma_{\tilde{\varepsilon}}^2$:

$$(21)\quad \sigma_{\tilde{\varepsilon}}^2 = \frac{\beta}{\theta_2}\,\sigma_\varepsilon^2,$$

$$(22)\quad \theta_1 = \frac{(1+\alpha)(1+\beta)}{\beta}\,\frac{\theta_2}{1+\theta_2},$$

$$(23)\quad 0 = 1 - \frac{1+(1+\alpha)^2+\beta^2}{\beta}\,\theta_2 + \theta_2^2 + \left(\frac{(1+\alpha)(1+\beta)}{\beta}\right)^2 \frac{\theta_2^2}{(1+\theta_2)^2}.$$

(23) is an order four equation in θ_2 and we know that β is a root of this equation. Knowing θ_2, (21) and (22) trivially gives the values of $\sigma_{\tilde{\varepsilon}}^2$ and θ_1. Factorizing with $(\theta_2 - \beta)$, (23) can be written as

(24)

$$(\theta_2 - \beta)\big(\beta^2\theta_2^3 + \beta\big(2\beta - (1+(1+\alpha)^2)\big)\theta_2^2 + (\beta^2 - 2\beta + (1+\alpha)^2)\theta_2 - \beta\big) = 0.$$

It is hard to find easily interpretable formulas for θ_2 and we therefore simply give here a set

[37] The discriminant of the polynomial is $\Delta = (1+\alpha)^2 - 4\beta$. If $\beta > \frac{(1+\alpha)^2}{4}$, $\Delta < 0$. Therefore, the two roots are complex and conjugate. As the product of the root is equal to β^{-1}, the two roots are complex and outside the unit disc if and only if $\frac{(1+\alpha)^2}{4} < \beta < 1$, which defines a nonempty set for values of β is $\alpha < 1$. If $\Delta \geq 0$, the two roots of θ are real. Note that $\theta(0) = 1 > 0$, $\theta(-1) = \beta - \alpha$ and $\theta(1) = 2 + \alpha + \beta$. If $0 < \beta < \alpha$, then $\theta(-1) < 0$. Given that $\theta(0) = 1 > 0$, one root has to be between -1 and 0, and the structural representation cannot be fundamental. If $\frac{(1+\alpha)^2}{4} > \beta > \alpha$, then $\theta(-1) > 0$ and $\theta(1) > 0$ and the two real roots of $\theta(L)$ have modulus greater than one.

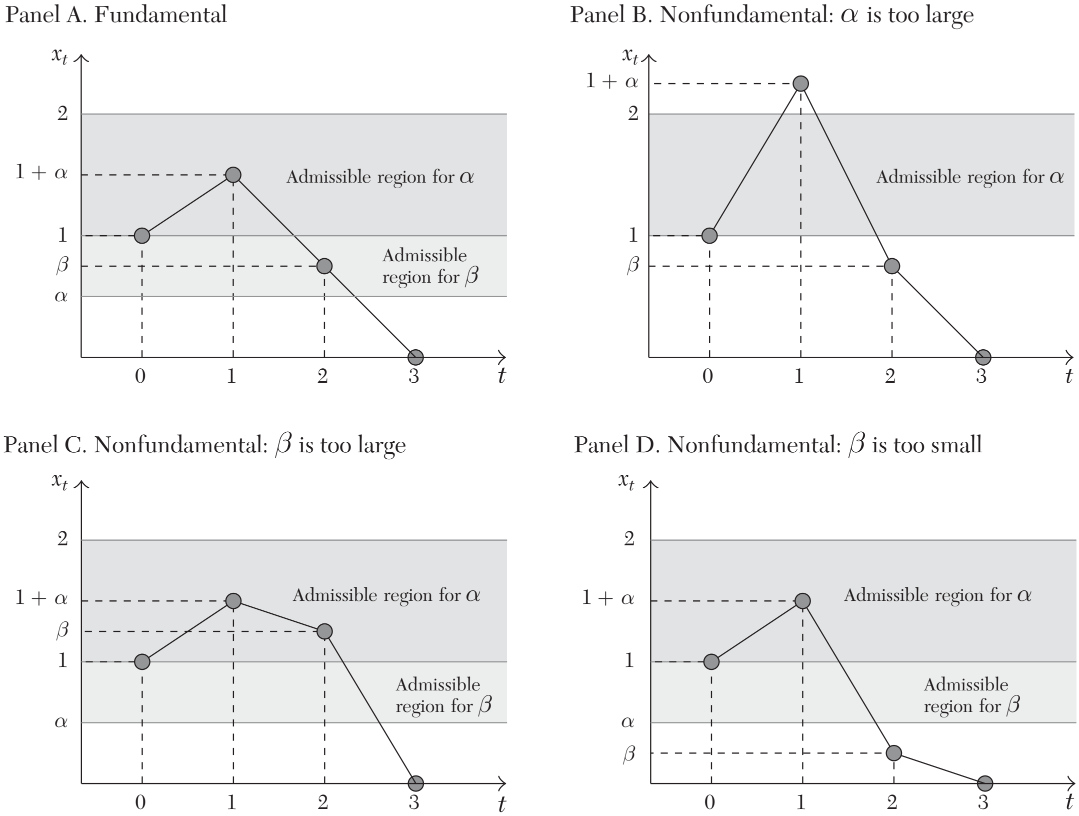

Figure 7. News-Rich MA(2) Processes

Note: This figure displays four possible configurations of the MA(2) process (20), by plotting IRF to a unit shock. The MA(2) process is described by the couple (α, β). Condition for fundamentalness is $\alpha < \beta < 1$.

of examples.[38] We start with the MA(2) news-rich fundamental process with $\alpha = 0.7$ and $0.7 < \beta < 1$. We then construct three non-fundamental processes by violating one after the other of the conditions $\alpha < 1$, $\beta < 1$, and $\beta > \alpha$. In each case, we move the parameter 20 percent above the upper bound of the admissible region for fundamentalness. And for each case, we compute the Wold representation, which amounts to solving numerically the order three polynomial (24) and picking up the only real solution for which the $\theta(L)$ is invertible.

Results are displayed in figure 8. As we can see from the figure, in the three cases, the fundamental IRF to a unit shock is quite close to the structural one. We do not aim

[38] Mertens and Ravn (2010) and Offick and Wohltmann (2013) discuss of a case in which analytical results can be obtained. If $x_t = aE_t x_{t+1} + \varepsilon_{t-q}$ with $|a| < 1$, then the model solution is $x_t = \Theta^q(L)\varepsilon_t$, with $\Theta^q(L) = \sum_{i=0}^{q} q^{q-i} L^i$. Such a lag polynomial is closely related to a cyclotomic polynomial, so that its roots can be computed analytically.

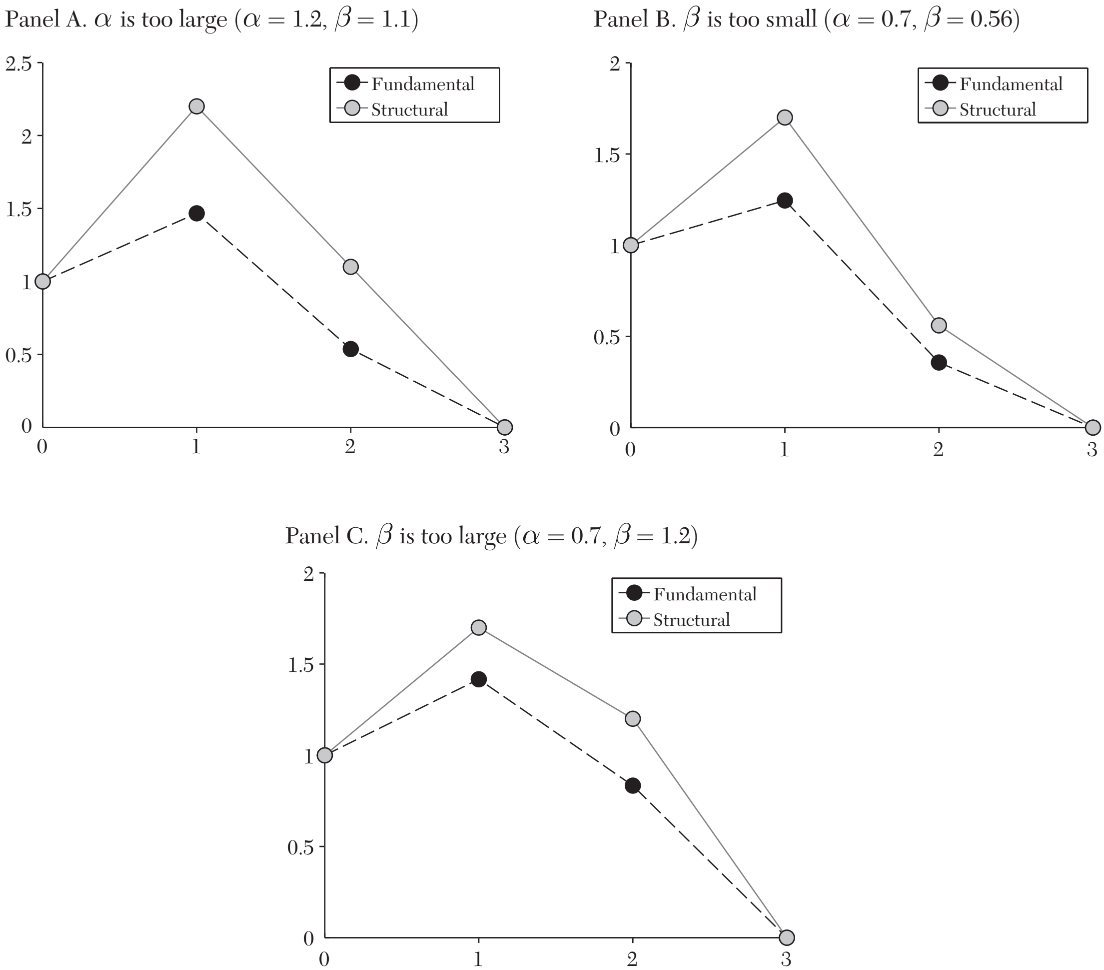

Figure 8. Structural Nonfundamental News-Rich Processes and their Fundamental Representation

Note: This figure displays three configurations of the MA(2) process (20), by plotting IRF to a unit shock. The MA(2) process is described by the couple (α, β). Condition for fundamentalness is $\alpha < \beta < 1$. In each of this configuration, the process is nonfundamental, and its fundamental representation is also displayed, as obtained from solving equations (21), (22), and (23).

at showing here that, in general, nonfundamentalness is not quantitatively relevant, but that it is not true that it is always so.[39]

[39] Lippi and Reichlin (1993) show that the structural shocks estimated by Blanchard and Quah (1989) can be nonfundamental in a model in which productivity follows an exogenous news-rich process. Such a diffusion process is also analyzed in Lippi and Reichlin (1994b). Lippi and Reichlin (1994a) show that nonfundamental representations can be obtained by the use of Blaschke matrices. Blanchard and Quah (1993) underline the fact that structural representations can be nonfundamental but close to the fundamental one.

3.2.1.5 *The Role of Information*

The previous MA(2) examples have illustrated that nonfundamentalness does not necessarily render Wold representations useless for understanding the effects of structural shocks. Instead, it suggests that the problem is quantitative in nature, and depends on the quantity of information in the current and past realizations of the observable variables. In the next section, we will analyze multivariate processes and show that the quantity of information available to the econometrician matters for invertibility and for the distance between the structural representation and the fundamental one. As a prelude to the more general result, intuition about the relation between the information set and nonfundamentalness can be obtained in the following simple case where we again consider the MA(1) news-rich process, but now also allow for singularity, as θ_0 is not restricted to be nonzero:

$$x_t = \theta_0 \varepsilon_t + (\theta_0 + \alpha)\varepsilon_{t-1},$$

with (for simplicity) $\theta_0 \geq 0$ and $\alpha > 0$. We know from the previous analysis that ε in this case is nonfundamental, more precisely x_t-nonfundamental, if we only have information on x_t. Let us now enlarge the observation set of the econometrician by allowing for the observation of a second variable, y_t, that contains information about ε_t (typically, one would think of an asset price variable in the case of technological news shocks). In order to avoid nongeneric singularities, we assume that there is a second shock ν_t (with $E\nu_t = 0$) that we interpret as pure noise. To save notations, let's normalize the covariance matrix of (ε, ν) to the identity matrix. The structural model is therefore given by

$$x_t = \theta_0 \varepsilon_t + (\theta_0 + \alpha)\varepsilon_{t-1} + \nu_t, \tag{25}$$

$$y_t = \gamma \varepsilon_t + \nu_t, \tag{26}$$

with $\gamma > 0$ for simplicity. Its matrix representation is

$$\begin{pmatrix} x_t \\ y_t \end{pmatrix} = \begin{pmatrix} \theta_0 + (\theta_0 + \alpha)L & 1 \\ \gamma & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_t \\ \nu_t \end{pmatrix}$$
$$= \Theta(L)\begin{pmatrix} \varepsilon_t \\ \nu_t \end{pmatrix}.$$

The process will be invertible, and therefore ε will be fundamental, when the roots of the determinant of the matrix $\Theta(z)$ are outside the unit disc. In this case, the determinant of $\Theta(z)$ has only one root which is $z = \frac{\gamma - \theta_0}{\theta_0 + \alpha}$.

If $\gamma = 0$, meaning that y is uninformative about ε, then $|z| < 1$ and ε is nonfundamental, which is the result we had in the previous section. But if y is informative enough about ε, meaning that γ is large enough (precisely $\gamma > 2\theta_0 + \alpha$), then ε is fundamental. In the case where $\gamma < 2 + \alpha$, then ε is not fundamental, but it will be "close" to the fundamental shock if γ is high enough, or in other words if y is informative enough about ε. Note that there is now nothing specific with singular news-rich processes. When $\theta_0 = 0$, the condition for invertibility is written $\gamma > \alpha$: that is, the signal needs to be informative enough to allow invertibility. We now formally discuss the role of information in a general multivariate case.

3.2.2 *The Multivariate Case*

Consider an economic model who has a representation for $\{y_t\}$ in the state-space form

$$x_{t+1} = Ax_t + B\varepsilon_t, \tag{27}$$

$$y_t = Cx_{t-1} + D\varepsilon_t. \tag{28}$$

x_t is $n \times 1$ vector of possibly unobserved state variables, y_t is a $k \times 1$ vector of variables observed by the econometrician, and

ε_t is $m \times 1$ vector of structural shocks. The shocks ε are Gaussian vector white noise with $E\varepsilon_t = 0, E\varepsilon_t\varepsilon_t' = I$ and $E\varepsilon_t\varepsilon_{t-j} = 0$ for $j \neq 0$. We restrict to the "square case" in which there are as many shocks as observables in y $(k = m)$ and in which D has full rank. Our discussion in this section closely follows the presentation of Fernàndez-Villaverde et al. (2007) and Sims (2012).

The question we ask is whether or not one can recover the structural shocks from the following VAR that involves only the observable variables y:

$$(29) \qquad y_t = F(L)y_{t-1} + G\hat{\varepsilon}_t,$$

where $F(L)$ is a infinite-order lag polynomial. In other words, does there exist an $F(L)$ and a matrix G such that $\hat{\varepsilon}_t = \varepsilon_t$?

Note that the answer to the question relies on two different sets of properties. First, assuming perfect observability of the state variables $(y = x)$, the question is whether the VAR process (27) is invertible, which is a constraint on A. Second, given that information is imperfect, is the informational content of y enough to recover the structural shocks, which is a constraint on C and D, given A and B? Fernàndez-Villaverde et al. (2007) derive what they call a poor man's invertibility condition. If the matrix $A - BD^{-1}C$ is stable (meaning that all its eigenvalues are inside the unit disc), then the structural shocks ε_t are the innovations of VAR (29), meaning that there are the fundamental ones. Let us follow Sims (2012) to show this. Solve for ε_t in (28):

$$\varepsilon_t = D^{-1}(y_t - Cx_{t-1}),$$

then plug into (27):

$$x_t = (A - BD^{-1}C)x_{t-1} + BD^{-1}y_t.$$

Solving backward yields

$$(30) \quad x_t = (A - BD^{-1}C)^{t-1}x_0 + \sum_{\tau=0}^{t-1}(A - BD^{-1}C)^{\tau-1}BD^{-1}y_{t-\tau}.$$

If $\lim_{t\to\infty}(A - BD^{-1}C)^{t-1} = 0$ (which is the case if $(A - BD^{-1}C)$ is a stable matrix), then the history of observables perfectly reveals the current state. One can then plug (30) in (28) to obtain a VAR in obervables whose innovations are ε:

$$y_t = C\sum_{\tau=0}^{t-1}(A - BD^{-1}C)^{\tau-1}BD^{-1}y_{t-1-\tau} + D\varepsilon_t.$$

The structural shocks ε are therefore fundamental. Note that one will still need to make identifying assumptions related to D to recover the ε from the VAR innovations, which is a key issue in Structural VAR methods discussed in the next section.

If $A - BD^{-1}C$ is not stable, then the structural shocks cannot be obtained from the estimation of a VAR like (29). In such a case, how close will be the fundamental shocks to the structural one depends on how much information is contained in y. As shown in Sims (2012), one can use the Kalman filter to form a forecast of the current state, $\hat{x}$, given observables and a lagged forecast:

$$(31) \qquad \hat{x}_t = (A - KC)\hat{x}_{t-1} + Ky_t,$$

where K is the time invariant Kalman gain and $A - KC$ a stable matrix under some stabilizability and detectability conditions (see Hansen and Sargent 2012, chapter 8). Let us denote by $\tilde{x}_t = x_t - \hat{x}_t$ the forecast error of the filter and $\tilde{\Sigma}$ its variance matrix. Adding and substracting $C\hat{x}_t$ from (28), one obtains

$$(32) \qquad y_t = C\hat{x}_{t-1} + u_t,$$

with

$$(33) \qquad u_t = C(x_{t-1} - \hat{x}_{t-1}) + D\varepsilon_t.$$

Using lagged (31), substituting in (32) and solving backward gives, when $t \to \infty$ and using the fact that $(A - KC)$ is a stable matrix:

$$(34) \quad y_t = C\sum_{\tau=0}^{t-1}(A - KC)^{\tau} K y_{t-1-\tau} + u_t.$$

This VAR representation in observables has innovations u, which are a linear combination of the structural shocks ε and errors in forecasting the states $\tilde{x}$. The innovations variance is given by

$$\Sigma_u = C\tilde{\Sigma}C' + DD',$$

where we use the assumption that ε has an identity variance matrix.

When the poor man's invertibility condition holds, Fernàndez-Villaverde et al. (2005) [40] show that $\tilde{\Sigma} = 0$, so that the structural shock is fundamental. When that condition does not hold, $\tilde{\Sigma} \neq 0$ and the innovation variance from the VAR is strictly larger than the innovation variance in the structural model. Invertibility fails because the observables do not allow for full revelation of the state vector. Put that way, it becomes clear that noninvertibility is fundamentally an issue of missing information.[41] As Sims (2012) puts it clearly, noninvertibility is not an "either/or" problem, as we have already illustrated in the univariate MA(2) case. If $\tilde{\Sigma}$ is nonzero but small (meaning that its spectral radius is close to zero), then u_t is almost equal to $D\varepsilon_t$. This implies that SVAR methods may provide good approximations to the effects of structural shocks even in the presence of nonfundamentalness. Sims (2012) and Seymen (2013) provide Monte Carlo evidence showing this to be the case in a reasonably calibrated macroeconomic model with news shocks.[42] Fève and Jidoud (2012a) also consider a stylized dynamic model with news shocks in which the model solution is an infinite order nonfundamental VAR. They show that even in such a case, finite order nonfundamental VARs approximated quite well the model solution.[43]

3.3 *Structural VAR Evidence*

In this section, we will discuss how SVAR methods have been used to evaluate the relevance and effects of news shocks. As emphasized in the previous section, the appropriateness of using VARs to discuss structural shocks relies on the structural shocks either being fundamental, or that the nonfundamentalness problem—if present—is not quantitatively severe. We will assume this to be the case in this section, recognizing that the caveats discussed in the previous section may raise doubts about this assumption.

[40] Fernàndez-Villaverde, Rubio-Ramírez, and Sargent (2005) NBER working paper is an extended version of Fernàndez-Villaverde et al. (2007)

[41] This interpretation of the econometrician being "short of observations on a sufficient number of series" is the one of Hansen and Sargent (1994). It suggests a way to test for nonfundamentalness, as formalized by Forni and Gambetti (2011). They characterize necessary and sufficient conditions under which a set of variables is *informationally sufficient* in a VAR, i.e., that it contains enough information to estimate the structural shocks. Then, they propose a testing procedure based on such conditions, which relies on the fact that the estimated "structural" shocks of the VAR should not be Granger-caused by the principal components of a large Factor Augmented VAR.

[42] Fernàndez-Villaverde and Rubio-Ramírez (2006) evaluate nonfundamentalness in a DSGE linearized solution. They consider the monetary model of Christiano, Motto, and Rostagno (2003) and study two eight-variable VARs with two different sets of observables from the model. They show that one of the two is fundamental, while the other one is not. This nicely illustrates that fundamentalness is essentially a question of information sets. Forni et al. (2009) have developed Factor Augmented VARs that use a large number of variables (hundreds) in order to avoid nonfundamentalness.

[43] See Fève and Jidoud (2012b) for a discussion of short run and long run identification in such an analytical case.

The earliest work using VARs and discussing results in terms of news is Cochrane (1994) using a bivariate consumption and income VAR. It followed a couple of papers by Blanchard and Hall. Looking for the sources of the 1990–91 U.S. recession, Blanchard (1993) and Hall (1993) concluded that the recession was likely to have been caused by a shock to consumption. As Cochrane (1994) put it, "since consumption is an endogenous variable, the ultimate source of variability must be news about future values of any the above," the "above" variables being "factor prices, especially oil, monetary policy, government purchases, tax increases, technology shocks, bank regulation, international factors, and sectoral shifts."

Beaudry and Portier (2006) focused this idea by examining the potential effects of news regarding technological opportunities. Since much of the SVAR literature on news pursued this narrower interpretation, we will begin by presenting the approach used in Beaudry and Portier (2006) and we will implement it on a more up-to-date sample. We then extend the analysis to higher dimension VARs and present different routes the literature has taken to identify technological news shocks.

The central idea in Beaudry and Portier (2006) is that financial variables, and especially stock prices, are the type of variables most likely to reflect news, as they are clearly forward looking and free to jump in response to revised expectations. Hence, to look at the relevance of technological news, one can look at the extent to which innovations in stock prices contain information about future technological growth, or alternatively whether periods of high technological growth are preceeded by increase in stock prices. Beaudry and Portier (2006) implemented this idea using alternatively a short run and a long run identification scheme in a bivariate setting.

3.3.1 *A Bivariate SVAR*

Let us start from a situation where we already have an estimated Wold representation for the bivariate system composed of Total Factor Productivity (TFP_t) and a stock prices index (SP_t). This moving average representation is given by (for ease of presentation we neglect any drift terms):

$$\begin{pmatrix} \Delta TFP_t \\ \Delta SP_t \end{pmatrix} = C(L)\begin{pmatrix} \mu_{1,t} \\ \mu_{2,t} \end{pmatrix},$$

where L is the lag operator, $C(L) = I + \sum_{i=1}^{\infty} C_i L^i$, and where the variance covariance matrix of μ is given by Ω. Furthermore, we will assume that the system has at least one stochastic trend and therefore $C(1)$ is not equal to zero.

From this Wold representation, we can derive infinitely many alternative representations with orthogonalized errors. Beaudry and Portier (2006) focused on two representations, one that imposes an impact restriction and one that imposes a long run restriction, where the resulting representations can be expressed as:

$$\begin{pmatrix} \Delta TFP_t \\ \Delta SP_t \end{pmatrix} = \Gamma(L)\begin{pmatrix} \epsilon_{1,t} \\ \epsilon_{2,t} \end{pmatrix}, \tag{35}$$

$$\begin{pmatrix} \Delta TFP_t \\ \Delta SP_t \end{pmatrix} = \tilde{\Gamma}(L)\begin{pmatrix} \tilde{\epsilon}_{1,t} \\ \tilde{\epsilon}_{2,t} \end{pmatrix}, \tag{36}$$

where $\Gamma(L) = \sum_{i=0}^{\infty} \Gamma_i L^i$, $\tilde{\Gamma}(L) = \sum_{i=o}^{\infty} \tilde{\Gamma}_i L^i$ and the variance covariance matrices of ϵ and $\tilde{\epsilon}$ are identity matrices. In order to get such a representation, we need to find the Γ matrices that solve the following system of equations:

$$\begin{cases} \Gamma_0 \Gamma_0' & = & \Omega, \\ \Gamma_i & = & C_i \Gamma_0 \quad \text{for } i > 0 \end{cases}$$

Since the above system has one more variable than equations, it is necessary to add a restriction to pin down a particular solution.

Now suppose we believed the data was driven by only two type of shocks: a surprise technology shock and some sort of demand shock. If we are ready to assume that the technology process is I(1) and that the demand shock has no permanent effects, then there are two ways of isolating a technology shock and the demand shock using a bivariate VAR composed of *TFP* and stock prices. In the first case, say as represented by (35), we can use a short run identification strategy that does not exploit the long run properties of the data. In this case, we can recover the structural shocks by imposing that the $(1, 2)$ element of Γ_0 be equal to zero. This strategy chooses an orthogonalization where the second disturbance ϵ_2 has no contemporaneous impact on *TFP.* If the only two shocks to the system are the technology shock and the demand shock, this should allow us to recover ϵ_1 as the technology shock and ϵ_2 as the demand shock since the demand shock should not affect *TFP* on impact. In a second case, as represented by (36), we could alternatively use a long run identification strategy by imposing that the $(1, 2)$ element of the long run matrix $\tilde{\Gamma}(1) = \sum_{i=0}^{\infty} \tilde{\Gamma}_i$ is zero. This orthogonalization forces the disturbance $\tilde{\epsilon}_2$ to have no long run impact on *TFP.* In this case, $\tilde{\epsilon}_1$ should represent the technology shock and $\tilde{\epsilon}_2$ should represent the demand shock, as only the technology should have a long run effect on measured *TFP.* If we perform both of these exercises, we can then look at the correlation between the shocks derived from the two different identification strategies. For example, suppose we look at the correlation between ϵ_2 and $\tilde{\epsilon}_1$. If the data is driven by only a surprise technology shock and a demand shock, then the correlation between these two shocks should be zero, as one represents the demand disturbance and the other the supply disturbance. This is the exercise performed in Beaudry and Portier (2006).[44]

We replicate the estimation of Beaudry and Portier (2006) here, where we extend the sample to cover the period from 1947:I to 2012:III, as opposed to the period 1947:I–2000:I in the original paper. All the VARs will be estimated with three lags in the VECM form, and four lags when estimation is done in levels. Panels (a) and (b) of figure 9 present impulse responses to a ϵ_2 shock identified using the short run identification strategy discussed above. The results obtained closely replicate the patterns reported in Beaudry and Portier (2006), even if the sample is extended.[45] The first observation is that the innovation to the stock market, ϵ_2, that is orthogonal to current *TFP* by construction, does not affect *TFP* for about ten quarters, but does permanently affect *TFP* in the long run (panel (a)). This shock is by design reflected instantaneously in the stock market (panel (b)), but interestingly, stock prices respond once and for all to this disturbance with little short run dynamics. In panels (c) and (d) of figure 9 we report impulse responses associated with the $\tilde{\epsilon}_1$ shock identified using the

[44] Haertel and Lucke (2008) apply the same procedure on German data with similar results. Beaudry and Portier (2005) and Vukotić (2011) perform the same type of identification of news shocks using sectoral data. Lanne and Lutkepohl (2008) use the same bivariate system but estimate a two-state Markov regime switching model. Imposing orthogonality of the two shocks in each of the two regimes allows for identification of two shocks, so that short and long run identification restrictions can be tested.

[45] Because of space limitations, we do not present robustness results for alternative specification of this VAR. The punchline is that the properties of these two identification schemes imposed on a bivariate VAR with U.S. *TFP* and stock prices is a very robust result with respect to lag length and to estimating the VAR in level or as a VECM. However, if one starts from estimating a VAR in differences with noncointegration imposed, the results change quite substantially, as we will show later. Also, the properties depend on using a measure of *TFP* that corrects for capacity utilization. If one uses a measure of *TFP* that does not correct for capacity utilization, then the response of *TFP* to a news shock (as associated with either ϵ_2 or $\tilde{\epsilon}_1$) is much quicker.

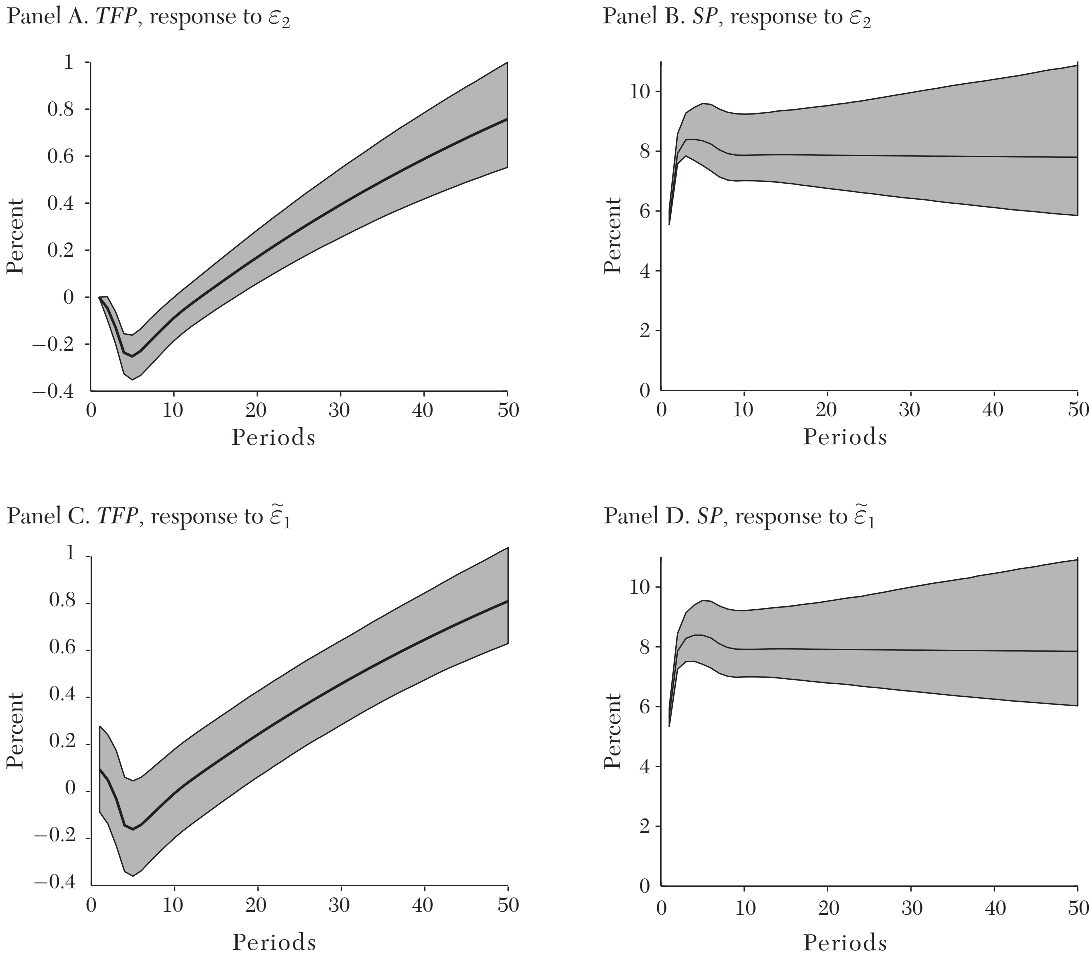

Figure 9. Impulse Response in the (*TFP*, *SP*) VAR

Note: This figure displays impulse responses in the log (*TFP*, *SP*) VAR to a one percent shock. The first line corresponds the the short run identification, where ε_2 is the shock that does not affect *TFP* on impact. The second line corresponds to the long-run identification, where $\tilde{\varepsilon}_1$ is the only shock that affects *TFP* in the long run. The VAR is estimated as a VECM with one cointegrating relation and three lags. The unit of the vertical axis is percentage deviation from the situation without shock. Grey areas correspond to the 66 percent confidence band. The distribution of IRF is the Bayesian simulated distribution obtained by Monte Carlo integration with 10,000 replications, using the approach for just-identified systems discussed in Doan (1992). The sample is 1947:I–2012:III. See the online appendix for a description of the data.

long-run identifying restriction. Under the assumption that the data are driven by a surprise technology shock and a demand shock, the responses reported in panels (c) and (d) should be quite different from those obtained in panels (a) and (b), since one should represent the effects of a demand shock while the other should represent the effects of a

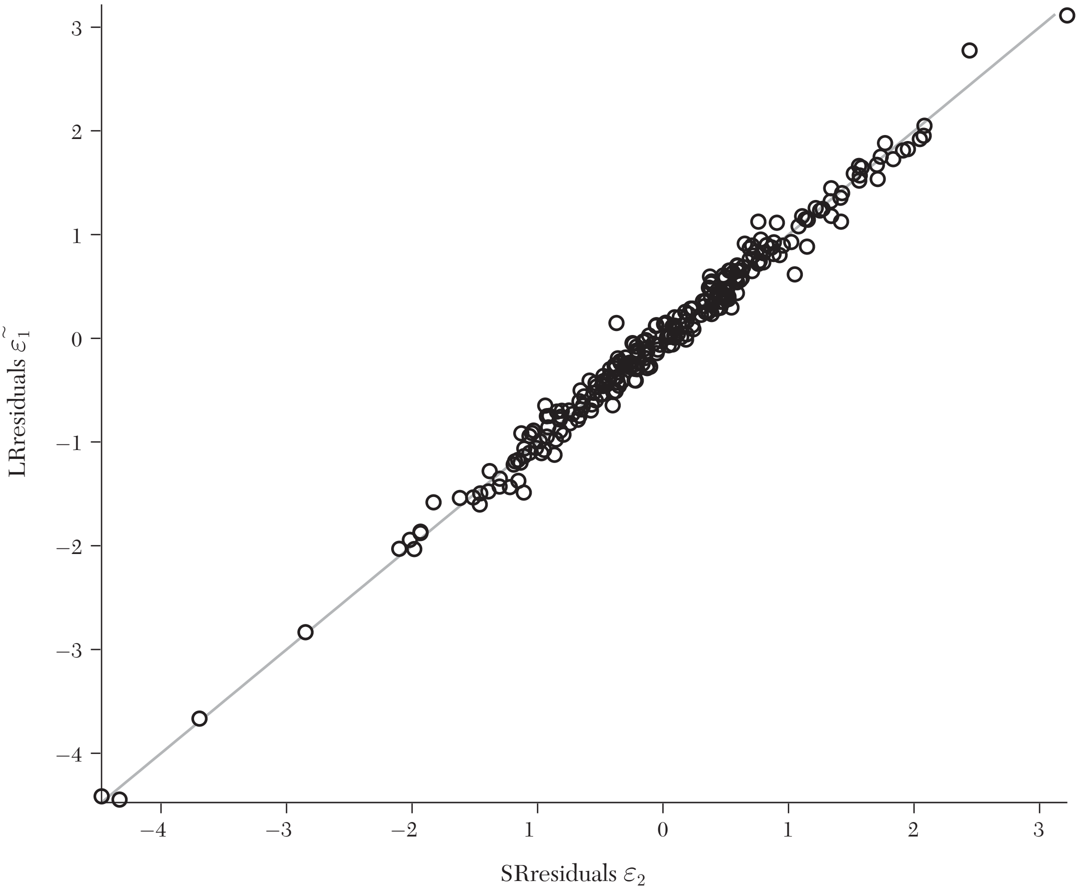

Figure 10. Short-Run Residuals ε_2 Against Long-Run Ones $\tilde{\varepsilon}_1$ in the (*TFP*, *SP*) VAR

Note: This figure displays short-run residuals ε_2 against long-run ones $\tilde{\varepsilon}_1$ in the log (*TFP*, *SP*) VAR. ε_2 is the shock that does not affect *TFP* on impact in the short-run identification. $\tilde{\varepsilon}_1$ is the only shock that affects *TFP* in the long run in the long-run identification. The VAR is estimated as a VECM with one cointegrating relation and three lags. The sample is 1947:I–2012:III. See the online appendix for a description of the data.

supply shock. Instead, we see by comparing the panels that the responses of each variable are strikingly similar. This similarity is further illustrated in figure 10, where we plot $\tilde{\varepsilon}_1$ against ε_2. While one could have expected these shocks to be almost orthogonal, the two shocks are instead closely aligned on the forty-five degree line, meaning that they are almost indistinguishable one from another.

While the patterns in figure 9 do put into question a two-shock model of the economy driven by a surprise technology shock and a demand shock, the relevant question is whether the patterns reported in the panels tell us anything regarding news or other models of the economy. In Beaudry and Portier (2006) it is argued that one simple interpretation of these observations is that they are driven by a two-shock model where one shock is a technological news shock and the other a surprise trend-stationary technology shock. Under this interpretation, the shock ε_2 should capture the news shock as it should be reflected in stock prices before it is reflected in *TFP*. If, in addition, we assume that news relates to permanent changes to *TFP*, then $\tilde{\varepsilon}_1$ identified using the long run restrictions should also isolate the news shock, thereby explaining the similarity in responses. In that sense, ε_2 and equivalently $\tilde{\varepsilon}_1$ correspond to two ways of isolating *news* about further productivity that are instantaneously priced in the stock market, although the news does not lead to actual increases in productivity for a rather long time. As noted, the results from this SVAR exercise place doubt on the common interpretation of the economy driven primarily by a demand shock and a surprise technology shock since, if this were the case, innovations in stock prices that are orthogonal to *TFP* should reflect the demand shock and should not resemble supply shocks identified by long-run restrictions.[46]

3.3.2 *Extending to Higher-Dimension VARs*

3.3.2.1 *Three-Variable VARs*

There are at least three reasons for exploring the robustness of the Beaudry and Portier (2006) findings to higher-dimension VARs.[47] First, as we have discussed before, increasing the information set reduces the likelihood of nonfundamentalness problems. Second, if this identification scheme is identifying the effects of news, it is interesting to know how other variables respond to news, and this can be explored by considering a larger VAR. Third, there are likely more than two types of shocks that drive macrofluctuations and therefore, considering a system with more shocks appears desirable. However, the drawback or difficulty with a larger system is that it requires more identification assumptions. We will review several different identifying assumptions that have been made in the literature. To begin, we will focus on the following simple approach to identifying news shocks. To see how the approach can be applied to systems with many variables, consider a vector of macroeconomic times series of dimension n, whose Wold representation is estimated to be (again neglecting drift terms):

$$\begin{pmatrix} \Delta X_{1t} \\ \Delta X_{2t} \\ \vdots \\ \Delta X_{nt} \end{pmatrix} = C(L) \begin{pmatrix} \mu_{1,t} \\ \mu_{2,t} \\ \vdots \\ \mu_{nt} \end{pmatrix}. \tag{37}$$

Where the two first variables in the system are always *TFP* and stock prices, $X_{1t} = TFP_t$ and $X_{2t} = SP_t$, while the $n-2$ other variables can be different from one system to another. We aim at identifying some of the structural shocks from the following alternative representation with orthogonal innovations:

$$\begin{pmatrix} \Delta X_{1t} \\ \Delta X_{2t} \\ \vdots \\ \Delta X_{nt} \end{pmatrix} = \Gamma(L) \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \vdots \\ \varepsilon_{nt} \end{pmatrix}. \tag{38}$$

[46] It is important to recognize that this "news" interpretation is not the only possible interpretation of these observations. For example, an alternative view is that *TFP* is endogenous, and that short run nontechnological intrinsic shocks (preference, government spending, taxes, etc...) eventually affect *TFP*. Such a view would be, for example, supported by an endogenous growth model with learning by doing.

[47] Beaudry and Portier (2006) do not only focus on a bivariate VAR. They also report results for larger systems. However, as noted by Kurmann and Mertens (2013) and formally shown in Lucke (2010), some of the identification schemes used for larger systems in Beaudry and Portier (2006) may be problematic (in the case of long-run restrictions and when the system is not estimated in levels). For this reason, we do not report results from such schemes here, and instead provide new results.

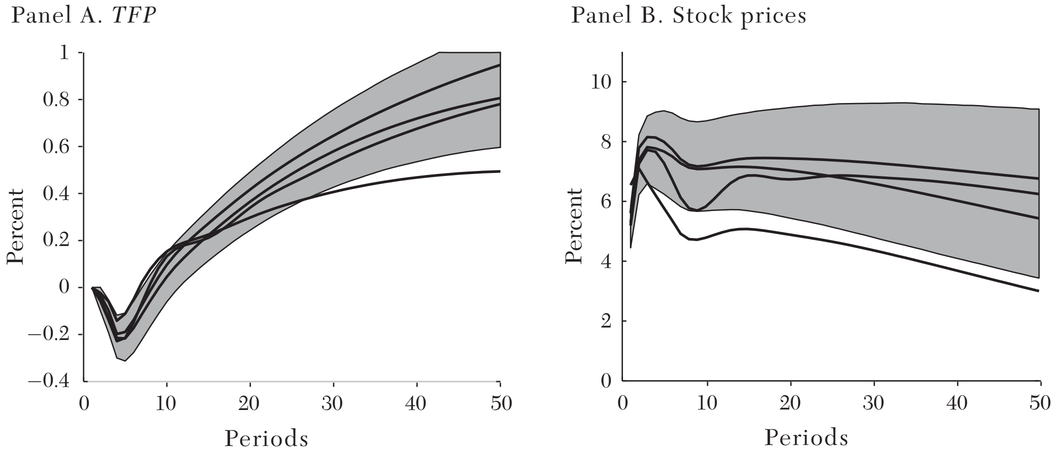

Figure 11. Impulse Response of *TFP* and Stock Prices to the News Shock ε_1 in the 3-Variable VARs

Note: This figure displays impulse responses to the news shock ε_1 in the log (*TFP*, *SP*, *X*) VAR, where *X* is alternatively *C*, *I*, *Y*, and *H*. The news shock is identified as the only shock that does not affect *TFP* on impact, but that is allowed to do so in the long run. The VAR is estimated as a VECM with two cointegrating relations and three lags when *I*, *C*, or *Y* are the third variable. It is estimated in levels with four lags when *H* enters the system. Each of the four bold lines corresponds to a different VAR. The unit of the vertical axis is percentage deviation from the situation without shock. Grey areas correspond to the 66 percent confidence band. The distribution of IRF is the Bayesian simulated distribution obtained by Monte Carlo integration with 10,000 replications, using the approach for just-identified systems discussed in Doan (1992). Its is the one obtained in the (*TFP*, *SP*, *C*) VAR. The sample is 1947:I–2012:III. See the online appendix for a description of the data.

To fully identify the n structural innovations, we need $n(n-1)/2$ restrictions. As we aim at identifying news shocks about future productivity, we can consider a subset of restrictions that will allow us to identify only the news shock and a surprise technology shock. To do this, we first assume that only two shocks can permanently affect *TFP* in the long run. This amounts to imposing $n-2$ zeros for the last $n-2$ columns of the first line of the long-run matrix $\Gamma(1)$. We then need to separate those two technology shocks: this is done by assuming that the surprise technology shock is the only shock that affects *TFP* on impact, which implies that the only nonzero term in the first row of the impact matrix Γ_0 is the $(1,1)$ term. These $2n-3$ restrictions allows for a unique identification of the news shock ε_2 and the surprise technology shock ε_1.

Figure 11 displays the responses of *TFP* and stock prices to the ε_2 shock (the expected news shock) estimated using a trivariate system where the third variable is varied. Confidence bands are the ones obtained for the (TFP, SP, C) system, and the four bold lines correspond to the response in the four three-variable VARs in which the third variable is alternatively C, I, Y and H (i.e., per capita values of consumption, investment, output, and hours worked). All estimations are in levels. Two main conclusions can be drawn from theses responses: firstly the responses stay the same when we change the third variable in the system; secondly, the responses are remarkably similar to the ones obtained in the two-variable case.

Figure 12 shows how four macroeconomic aggregates react to the news

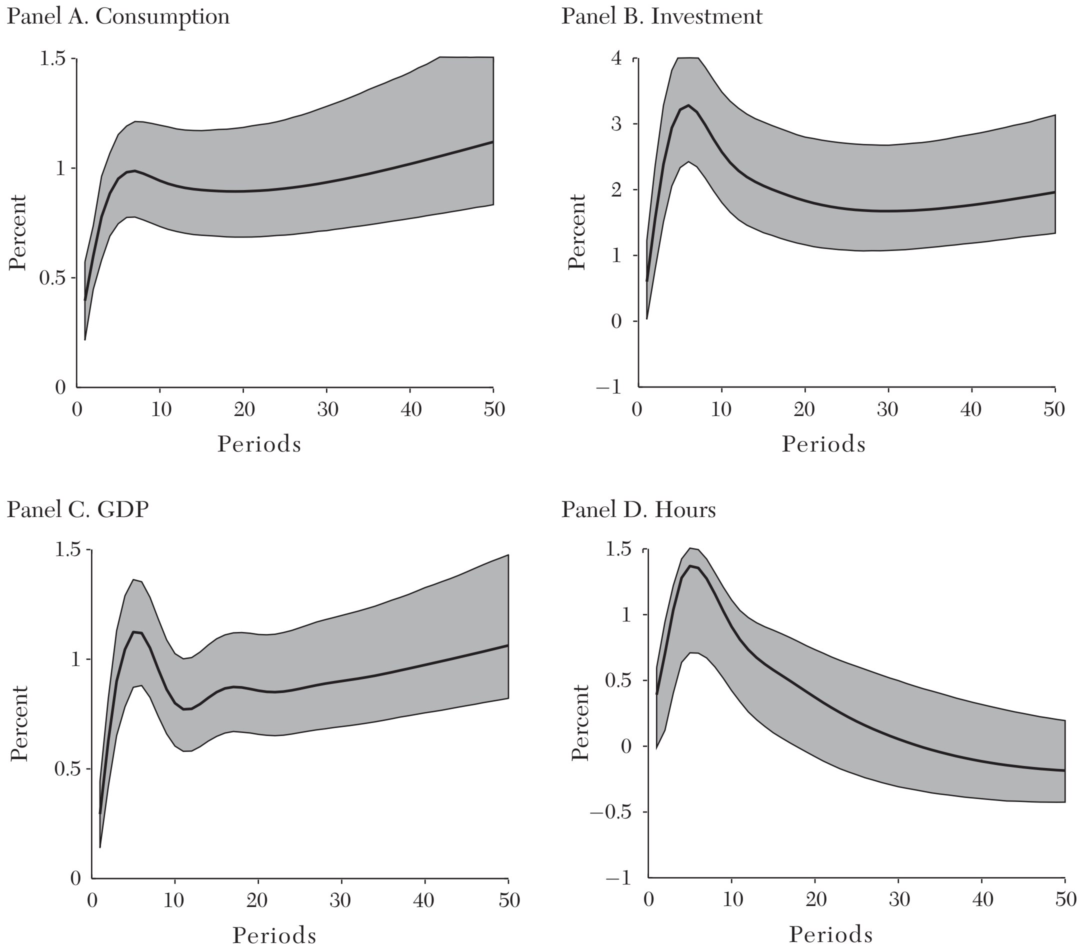

Figure 12. Impulse Response of C, I, Y, and H to the News Shock ε_1 in the Three-Variable VARs

Notes: This figure displays impulse responses to the news shock ε_1 in the log (TFP, SP, X) VAR, where X is alternatively C, I, Y, and H. The news shock is identified as the only shock that does not affect TFP on impact, but that is allowed to do so in the long run. The VAR is estimated as a VECM with two cointegrating relations and three lags when I, C, or Y are the third variable. It is estimated in levels with four lags when H enters the system. The unit of the vertical axis is percentage deviation from the situation without shock. Grey areas correspond to the 66 percent confidence band. The distribution of IRF is the Bayesian simulated distribution obtained by Monte Carlo integration with 10,000 replications, using the approach for just-identified systems discussed in Doan (1992). The sample is 1947:I–2012:III. See the online appendix for a description of the data.

shock: consumption, investment, GDP, and hours worked all increase on impact. Consumption's response is close to a once for all jump, while investment, hours, and GDP display a hump-shaped response in the short run. As shown in table 2, the news shock explains between 60 and 80 percent of the variance of C, I, Y,

TABLE 2
SHARE OF THE VARIANCE EXPLAINED BY THE NEWS SHOCK IN THREE-VARIABLE VARS (IN PERCENT)

Horizon	1	4	8	12	16	120
			Level specification			
TFP	0	2	2	2	3	56
C	39	71	77	77	75	67
I	16	53	65	66	65	57
Y	30	72	82	80	78	64
H	39	70	81	82	79	56
			2 cointegrating relations specification			
TFP	0	2	2	2	4	84
C	22	55	63	65	66	87
I	5	36	50	52	53	78
Y	4	49	64	64	65	87

Note: This table is obtained from the estimation of a (*TFP*, *SP*, *X*) VAR, where *X* is alternatively *C*, *I*, *Y*, and *H*. The news shock is identified as the only shock that does not affect *TFP* on impact, but that is allowed to do so in the long run. The VAR is estimated as a VECM with two cointegrating relations and three lags when *I*, *C*, or *Y* are the third variable. It is estimated in levels with four lags when *H* enters the system. Results for *TFP* are given for the (*TFP*, *SP*, *C*) VAR. The sample is 1947:I–2012:III. See the online appendix for a description of the data.

and *H* for horizons between four and sixteen quarters, although it explains less than 3 percent of the variance of *TFP* at the same horizon, and about one half of its variance in the long run. Note from the table that the short run variance decomposition is robust to level or VECM specification. We also see in table 2 that long run properties are not invariant to the cointegration rank specification: the news shock explains more than 80 percent of the variance of *TFP* in the VECM specification,[48] but only one half in the level one.[49] The possible sensitivity of results to cointegration assumptions will be a recurring theme. Let us nevertheless stress that although cointegration assumptions do matter for the long run, they do not affect much the short run dynamics in response to a news shock as long as the model is not estimated in first-difference i.e., with zero cointegrating relation. To illustrate this point, we have estimated a four-variable VAR with (TFP, SP, C, I) with zero to four cointegrating relations and used our identification to

[48] The results from the VECM system are likely more credible as results from estimating the system in levels may not lead to consistent estimates of forecast variances. See Phillips (1998) on that point.

[49] The proper cointegration rank is questionable when hours enter the system, as there is an open debate on the proper specification of hours (level or difference) (see Christiano, Eichenbaum, and Vigfusson 2004; Chari, Kehoe, and McGrattan 2008; and Fève and Guay 2010). We have verified that this issue is not very important in this system, as the response of hours is very similar when the VAR is estimated with one cointegrating relation involving only *TFP* and *SP* and hours in levels or in difference.

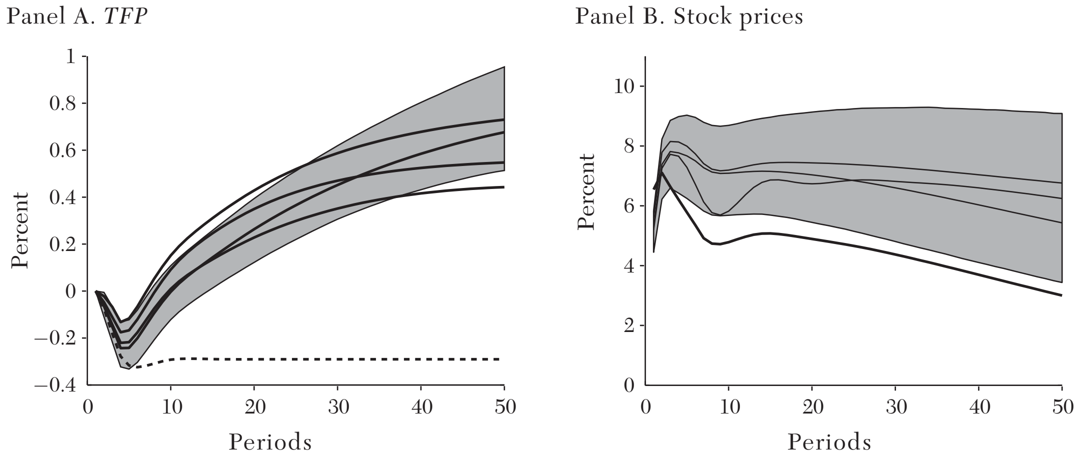

Figure 13. Impulse Response to a News Shock, (*TFP*, *SP*, *C*, *I*) VAR, Levels or Three to Zero Cointegrating Relations

Notes: This figure displays impulse responses to the news shock ε_1 in the log (*TFP*, *SP*, *C*, *I*) VAR. The news shock is identfiied as the only shock that does not affect *TFP* on impact but that is allowed to do so in the long run. The VAR is estimated in levels with four lags or as a VECM with 3 to 0 cointegrating relations and three lags. The unit of the vertical axis is percentage deviation from the situation without shock. Grey areas correspond to the 66 percent confidence band for the benchmark VECM with three cointegrating relations. The dashed lines correspond to the estimation in difference (zero cointegrating relations), while the plain lines correspond to the level estimation or to the ones with one to three cointegrating relations. The distribution of IRF is the Bayesian simulated distribution obtained by Monte-Carlo integration with 10,000 replications, using the approach for just-identified systems discussed in Doan (1992). The sample is 1947:I–2012:III, as the consumer confidence index is not available before. See the online appendix for a description of the data.

separate news and technological surprises. Impulse responses of *TFP* and *SP* to a news shock are displayed on figure 13. The dashed line corresponds to the zero cointegration case. Note that as long as some long-run information about the relation between *TFP* and *SP* is kept, results are very similar. But when the VAR is estimated in first-difference, this long-run relation is lost, and the VAR estimates a quite counter-intuitive negative long run relation between *TFP* and *SP* levels.

3.3.2.2 *Consumer Confidence*

In the above VAR exercises, we have been using information from stock prices to help identify news shocks. It is reasonable to believe that stock prices are good indicators of agents' perceptions about future economic outcomes. However, it is interesting to ask whether the news shocks identified using the combination of short and long run restrictions suggested in this subsection are also reflected in measures of consumer confidence. If it were not the case, this would put into question the interpretations of these shocks.[50] To this end, we examined how

[50] Sill (2009), Leduc and Sill (2010), and Barsky and Sims (2012) explore the relationship between economic activity measures of consumer confidence. Lamla, Lein, and Sturm (2007) identify news shocks making use of the

measured consumer confidence—as captured by the Michigan survey—reacts to a news shock in a three-variable VAR where the first two variables remain *TFP* and stock prices, while the third variable is the index of consumer sentiment drawn from the Michigan survey. In figure 14, we report the response of the consumer sentiment index when the news shock is identified as the shock that has no impact effect on *TFP*, but is allowed to have a long run effect on *TFP*. As can be seen, in response to the identified news shock, consumer sentiment jumps up and continues to rise for two quarters. In terms of variance decomposition, the identified news shocks explain about 80 percent of the variance of this consumer sentiment index. Hence, in this system, positive news shocks appear to be associated with optimism on the part of consumers, which is reassuring for the proposed interpretation. In order to explore the robustness of this result, we also examined how results changed if we replaced stock prices in this three-variable VAR with sequentially consumption expenditure (nondurable and services) and hours worked. When stock prices are replaced by consumption expenditures, we find very similar effects of the news shock. In particular, the identified news shock accounts for the majority of the movement in consumer sentiments. However, when we replace stock prices with hours worked, we get quite different results. In such a case, the news shock accounts for much less of the movements in consumer sentiments and it has much less effect on long run *TFP* movements. How to interpret this result? First, this result indicates that the identification of news shocks may be quite sensitive to the variables used in the VAR. This observation should not be too surprising, given our discussion of nonfundamentalness where we emphasized that a VAR would need to include variables with sufficient information content if one hopes to properly learn about news shocks. Second, these results suggest to us that it may be more appropriate to identify news shocks using a combination of stock prices and survey evidence as to increase the information set of the econometrician, as opposed to using only one of the variables.

3.3.2.3 *Alternative Identification Schemes in Larger Systems*

Several different avenues have been pursed in the literature to identify the effects of technological news using VARs with many variables. For example, Beaudry and Lucke (2010) consider a framework that allows for several of the main forces emphasized in the macroeconomic literature to compete with news shocks. They consider an environment with five types of shocks: surprise *TFP* shocks, surprise investment-specific technology (IST) shocks, news shocks regarding *TFP*, monetary policy shocks, and preference shocks. Their baseline model is composed of five variables: measured total factor productivity, the relative price of investment goods, an index of stock prices, hours worked, and the Fed funds rate.[51] They choose hours of work as their primary measure of aggregate economic activity, but also document the robustness of their results by considering alternative measures of economic activity such as consumption,

business tendency surveys of the German Ifo Institute. Milani and Rajbhandari (2012b) exploit information from the term structure of survey expectations to identify news shocks in a DSGE model with rational expectations. Recently, Angeletos, Collard, and Dellas (2013) and Fève and Guay (2013) have made use of consumer confidence data in order to disentangle technological news from "sentiment" shocks.

[51] Bunk (2011) has shown that Beaudry and Lucke's (2010) identification of news shock is robust to the use of alternative "forward looking variable" (S&P500, Wilshire 5000, number of patent applications, three-month to ten-year treasuries rates). Xu and Fan (2010) have shown that new business formation is also procyclical when included in a VAR similar to Beaudry and Lucke (2010).

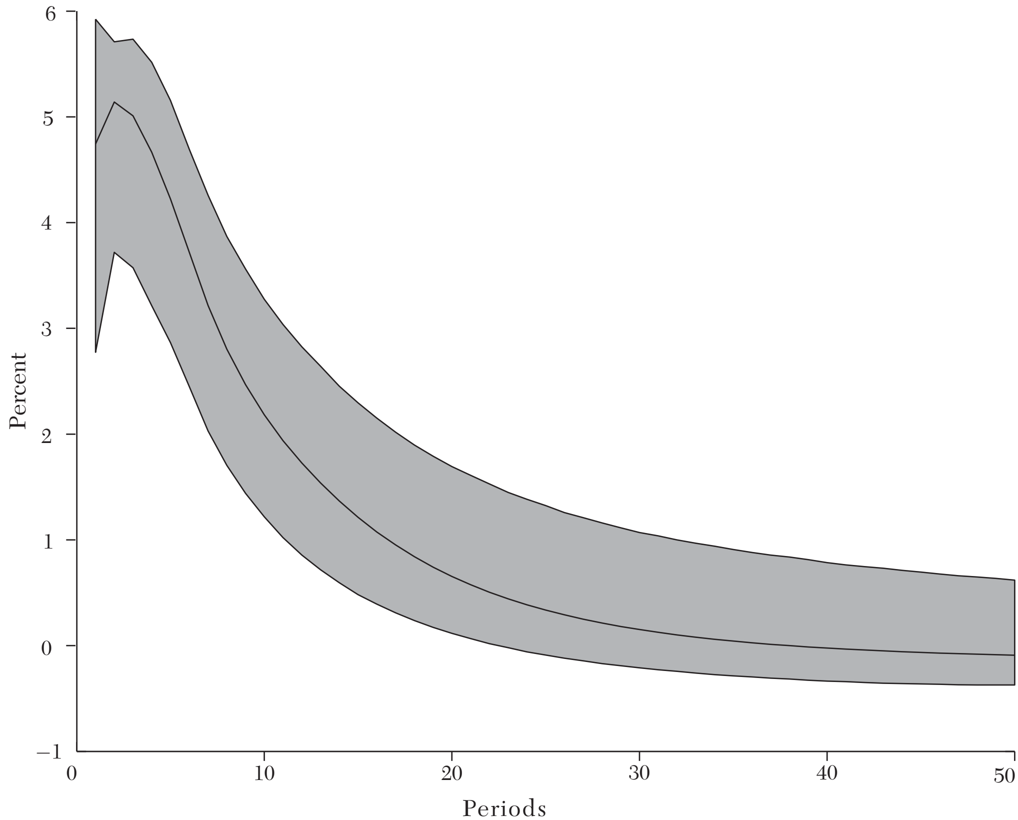

Figure 14. Impulse Response of the Index of Consumer Sentiment to a News Shock in the Three-variable VAR (*TFP*, *SP*, *ICS*)

Notes: This figure displays impulse responses of the index of consumer sentiments ICS to the news shock ε_1 in the log (*TFP*, *SP*, *ICS*) VAR. The news shock is identified as the only shock that does not affect *TFP* on impact but that is allowed to do so in the long run. The VAR is estimated in levels with four lags. The unit of the vertical axis is percentage deviation from the situation without shock. Grey areas correspond to the 66 percent confidence band. The distribution of IRF is the Bayesian simulated distribution obtained by Monte Carlo integration with 10,000 replications, using the approach for just-identified systems discussed in Doan (1992). The sample is 1960:I–2012:III, as the index of consumer sentiments is not available before. See the online appendix for a description of the data.

investment, and output. Their data run from 1955:I to 2007:II. The baseline VAR is estimated with three cointegrating relations. Beaudry and Lucke adopt two main identification schemes. In both, (i) only *TFP* shocks may have contemporaneous effects on *TFP,* (ii) preference shocks and monetary shocks have no long run effects on *TFP* and (iii) monetary shocks do not have a contemporaneous effect on economic activity. The first identification, which is mainly a short run one, also imposes that news, preference, and monetary shocks have no contemporaneous effects on the relative price of investment. The second one, which relies more on the long run, also imposes that preference and monetary shocks have no long-run effects on the relative price of investment and that investment specific technology (hereafter IST) shocks do not have a long run effect on *TFP*.

Both identification strategies give very similar results, as far as news shocks are concerned. Identified surprise *TFP* and IST shocks contribute little to the variance of hours at all horizons and the single most important contributor to hours variance is the news shock. News shocks have effects very similar to those found in the original bivariate estimation of Beaudry and Portier (2006) and presented in the previous section. The news shock seems to convey information about *TFP* growth that starts eight to ten quarters in the future. This shock nevertheless causes an immediate expansion in hours lasting for about ten quarters. These identified news shocks also appear to be associated with an increase in nominal interest rates, although this estimate is mostly insignificant. News shocks seem to have a marginally significant negative effect on the relative price of investment goods within the first four years or so. For investment, output and consumption, the same results are obtained: they display a gradual increase over a year or so in response to a news shock. However, Fisher (2010) points outs that the results in Beaudry and Lucke (2010) are dependent on cointegration assumptions. For example, if one restricts the VECM to only one or two cointegrating relationships, then results can change quite drastically with IST shocks becoming in some cases the dominant force driving the variance of hours.

Beaudry, Nam, and Wang (2011) is another example of using VARs in large systems, but it differs by using sign restrictions[52] to identify what they call "optimism" shocks. Their benchmark model contains five variables: *TFP*, stock price, consumption, the real interest rate, and hours worked. Investment and output are included in the extended seven-variable VAR. All estimations are done in levels, and the sample runs from 1955:I to 2010:IV. Optimism shocks are identified by imposing that they lead to increases in stock prices and consumption, as these are generally viewed as the best indicators of how individuals perceive the future. Moreover, these optimism shocks are constrained to be orthogonal to changes in *TFP* on impact. They also consider the further sign restrictions that the real interest rates increases on impact. Results show that the identified optimism shocks resemble the news shock with it initially leading hours to increase gradually over time and exhibit a hump-shaped response before *TFP* starts to increase about eight quarters later. Splitting their sample in two, they find that macroeconomic variables generally respond more strongly to optimism shocks in the post-1983 subsample than in the pre-1978 subsample. Also, optimism shocks seem to have larger permanent effects on variables such as *TFP*, consumption, investment, and output in the more recent subsample. In the second part of the paper, Beaudry, Nam, and Wang (2011) relate this optimism shock to a news shock, i.e., a shock that anticipates by construction future growth in *TFP*. This shock is identified as the one that is orthogonal to current *TFP* and that maximizes the share of the forecast error variance of *TFP* attributable to this shock at a finite horizon h, following an approach originally proposed by Francis et al. (2005). Results show that responses to this identified news shock are very similar to the responses associated with the optimism shock identified using sign restrictions.

3.3.2.4 *The Barsky–Sims Approach*

The approach of identifying news shocks by imposing that it maximizes a measure of

[52] The sign restrictions method has been proposed by Uhlig (2005) and Mountford and Uhlig (2009). See also Ko, Miyazawa, and Vu (2012) for the identification of *TFP* news with sign restrictions using Japanese data, Berg (2012) for the euro area, and Crouzet and Oh (2012) using U.S. data. and focusing on the response on inventories.

the forecast error variance of *TFP* at some horizon can be particularly useful to identify news shocks in large VAR systems. As it has been shown by Barsky and Sims (2011), it can allow for identification with a rather minimal set of assumptions. Consider again the Wold representation (37) and the structural representation (38). Barsky and Sims (2011) propose to identify a surprise technology shock as the only one that affects *TFP* on impact.[53] This shock would correspond to the first shock in a Choleski identification in which $X_1 = TFP$. Out of the $n-1$ other shocks, the news shock ε_2 is then identified as the one that maximizes $\sum_{j=1}^{h} \Omega_2(j)$, where $\Omega_2(j)$ is the forecast error variance at horizon j that is attributed to ε_2. Note that this criterion is related but different from the one proposed in Francis et al. (2005), where it is simply $\Omega_2(h)$ that is maximized. By summing over all the horizons between one and h, the criterion used in Barsky and Sims (2011) is putting more weight on the short run variance of *TFP* in the maximization. As made explicit in Barsky and Sims (2011), if one is ready to assume that no other shocks affect *TFP* at any horizon, then no other restrictions are needed to identify a news shock. In their analysis, Barsky and Sims (2011) choose a horizon of forty quarters when maximizing $\sum_{j=1}^{h} \Omega_2(j)$. We follow this identification strategy with a first four-variable VARs (TFP, Y, C, H) estimated in levels over the period 1960:I–2007:IV, as in Barsky and Sims (2011). Impulse response functions are displayed on figure 15 with plain lines. The identified news shock is very different from the ones obtained using the combination of impact and long run restrictions suggested in subsection 3.3.2.1. In this figure, we see that hours fall in response to the identified news shock and stay for at least twenty quarters below their preshock level. Output does not increase much while *TFP* increases very quickly following the news. This pattern is the one emphasized in Barsky and Sims (2011)[54] and suggests that the effects of news shocks may actually be to create a recession—as would be consistent with a RBC model, as opposed to creating a boom.

Since this view is drastically different from the one obtained in Beaudry and Portier (2006), we estimate a second VAR over the full sample 1947:I–2012:III (to be comparable with the estimates of subsection 3.3.1) that is composed of (TFP, SP, Y, H) of (TFP, SP, Y, C). The main difference with the previous VAR we have estimated is that those ones include the stock prices index *SP*. In figure 15, we report with dashed lines the impulse obtained using the method proposed by Barsky and Sims (2011), but with the stock prices index. As can be seen from the figure, the impulse responses to the identified news shock now look very similar to those presented in subsection 3.3.2.1, with both hours and consumption increasing after the arrival of news, and *TFP* taking several quarters before starting to increase. These results highlight once again that the identification of news shocks may be sensitive to the choice of variables included in the VAR. In particular, this pair of contrasting results suggest that the inclusion or not of stock prices in a small VAR may drastically change one's perception of the effects of news shocks. Further systematic exploration on the role of the identification methodology proposed by Barsky and Sims (2011) versus the information content of the VAR appears warranted

[53] As an alternative example of the use of the Barsky–Sims methodology to identify news shocks, see Kurmann and Otrok (2013) and Ben Zeev and Khan (2013).

[54] Although we estimated the VAR over the same sample 1960–2007, the impulse responses reported here are slightly different from those presented in Barsky and Sims (2011) because the definition of variables is not exactly the same. Barsky and Sims measure consumption excluding durable goods and output is nonfarm private GDP, while we consider total consumption and total GDP.

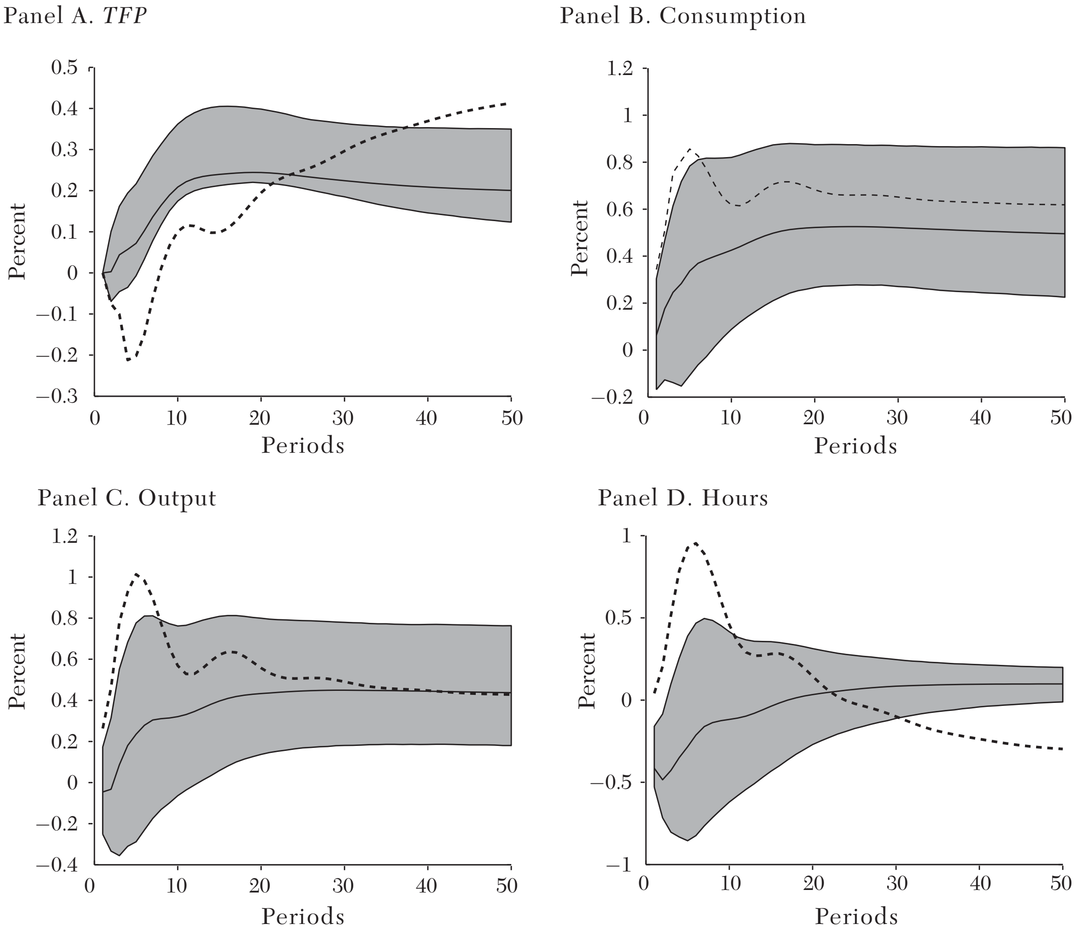

Figure 15. IRF to a News, Barsky and Sims's (2011) identification in the (*TFP*, *C*, *Y*, *H*) VAR and in the (*TFP*, *SP*, *Y*, *H*, or *C*) One

Notes: This figure displays impulse responses to the news shock ε_1 in the log (*TFP*, *C*, *Y*, *H*) VAR (plain lines) and in the (*TFP*, *SP*, *Y*, *H*, or *C*) ones (dashed lines). The news shock is identified following Barsky and Sims (2011) as the shock that does not affect *TFP* on impact and that maximizes $\sum_{j=1}^{40} \Omega_2(j)$, where $\Omega_2(j)$ is the forecast error variance at horizon j that is attributed to that shock. The VAR is estimated in levels with four lags. The unit of the vertical axis is percentage deviation from the situation without shock. Grey areas correspond to the 66 percent confidence band for the (*TFP*, *C*, *Y*, *H*) VAR. The distribution of IRF is the Bayesian simulated distribution obtained by Monte Carlo integration with 10,000 replications, using the approach for just-identified systems discussed in Doan (1992). The sample is 1960:I–2007:IV for the (*TFP*, *C*, *Y*, *H*) VAR and 1947:I–2012:III for the (*TFP*, *SP*, *Y*, *H*, or *C*) ones. See the online appendix for a description of the data.

to get a more complete understanding of the likely effects of news shocks.[55]

3.3.2.5 *Using Large Time Series Models to Identify News*

Forni, Gambetti, and Sala (2011) substantially increase the amount of data used to estimate the effects of news shocks by using a large dimensional dynamic factor model. Their dynamic factor model comprises 116 U.S. quarterly series, covering the period 1959:I–2007:IV. The series include both national accounting data (GDP, investment, consumption, and the GDP deflator), *TFP*, consumer sentiment, financial indicators, industrial production indices, CPI, PPI, and employment. They then consider the two or six first factors. In the case of the two first factors, they identify the news shock in the factor model assuming that it has no contemporaneous effect on *TFP*. In the case of the six-factor model, they use Barsky and Sims' identification: the news shock is the shock that does not have a contemporaneous impact on *TFP* and that has a maximal effect using the Barsky–Sims variance criterion for *TFP* at $h = 40$. Their findings for news shocks are as follows. *TFP* grows quite rapidly, doing more than half of the adjustment in the first six quarters; investment and output drop on impact and then gradually grow to a new long-run level; consumption does not move on impact and only after the first quarter does it start to increase; hours fall in the short run. These results are quite different from many of the results reported to date, with the exception of our results aimed at reproducing Barsky and Sims (2011). One of the attractive features of Dynamic Factor Models is that they reduce the probability of a nonfundamentalness problem by enlarging the set of observables.[56]

In order to compare our results from the previous sections with the ones using a dynamic factor model, we estimated a seven-variable VAR with variables $(TFP, SP, C, H, I, F_1, F_2)$, where F_1 and F_2 are the two first factors used in Forni, Gambetti, and Sala (2011).[57] To identify a news shock, we used our baseline identification scheme where only two shocks are allowed to have a long-run impact on *TFP* with only the surprise technology shock is allowed to affect *TFP* on impact. The impulse responses associated with news shock derived from this exercise are presented on figure 16. The important aspect to notice on this figure is that for the first twenty quarters, point estimates show what we regard as our typical response to a news, as all variables increase. This contrasts with the results presented in Forni, Gambetti, and Sala (2011), and the source of the difference appears to be use of the Barsky–Sims identification method versus our baseline identification method. When the horizon used in the Barsky–Sims method is increased, then we find that two sets of results converge. One dimension on which the impulse response in figure 16 differs from our previous results is with respect to the stock price. Here we can see that the stock price does not immediately respond to the news. This pattern is also observed in the results reported in Forni, Gambetti, and Sala (2011). This observation is worrisome to us, as we are suspicious of any identification

[55] As shown in Beaudry, Nam, and Wang (2011), Barsky and Sims' method may be sensitive to the choice of the truncation horizon h. The criterion proposed by Francis et al. (2005) appears to give more stable results.

[56] Ng and Stevanovic (2012) propose the identification of news shocks in a large factor augmented autoregressive distributed lag (FADL) model. FADL models estimate the impulse responses directly rather than inverting a VAR.

[57] We thanks the authors for kindly providing us with their estimated factors. As shown in their paper, results are not affected when more than the two first factors are included. Note that we have had to use the shorter sample 1960:I–2010:IV to conduct this exercise as this is the sample on which Forni, Gambetti, and Sala (2011) estimated the factors.

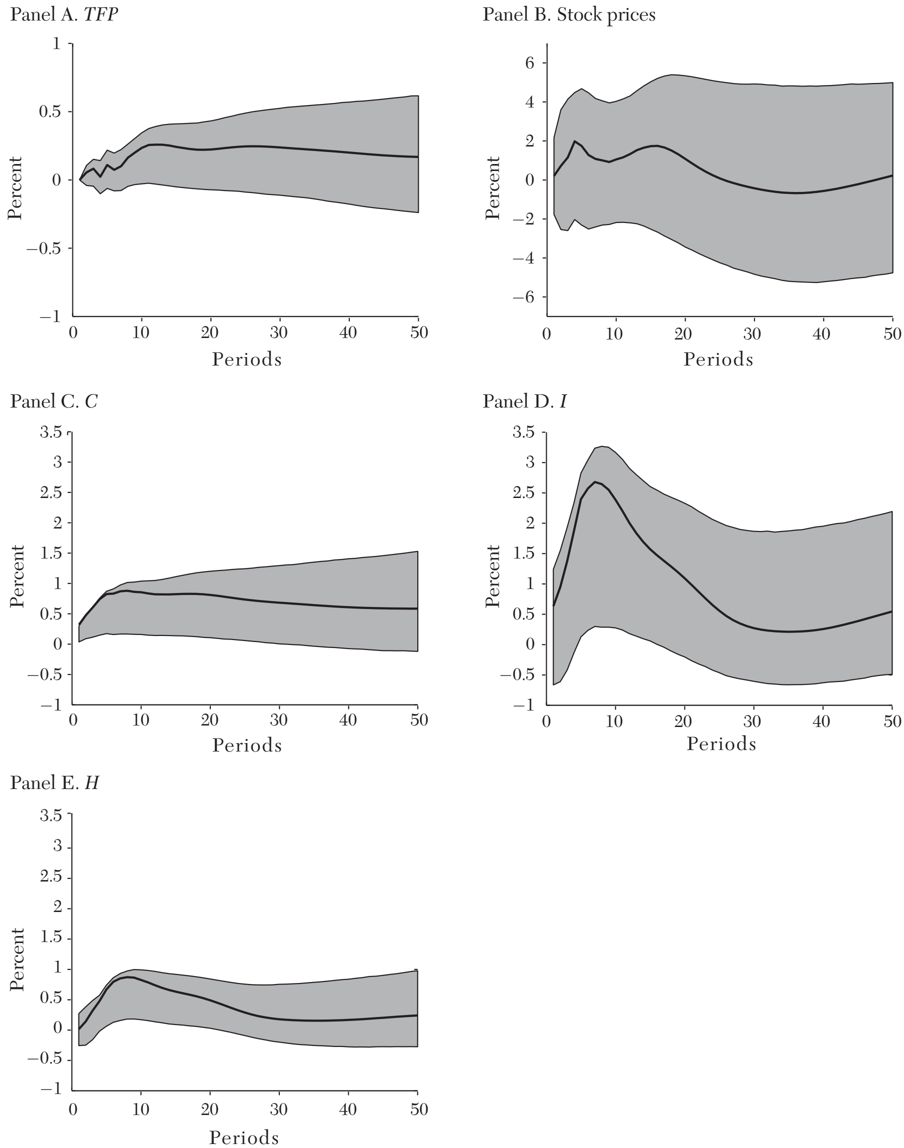

Figure 16. Impulse Response to a News Shock, (*TFP*, *SP*, *C*, *I*, *H*) VAR Augmented with the First Two Factors of Forni, Gambetti, and Sala (2011)

Notes: This figure displays impulse responses to the news shock ε_1 in the (log for the first five variables) (*TFP*, *SP*, *C*, *I*, *H*, F_1, F_2) VAR, where F_1 and F_2 are the two first factors estimated by Forni, Gambetti, and Sala (2011). The news shock is identified as the only shock that does not affect *TFP* on impact, but that is allowed to do so in the long run. The VAR is estimated in levels with four lags. The unit of the vertical axis is percentage deviation from the situation without shock. Grey areas correspond to the 66 percent confidence band. The distribution of IRF is the Bayesian simulated distribution obtained by Monte Carlo integration with 10,000 replications, using the approach for just-identified systems discussed in Doan (1992). The sample is 1960:I–2010:IV, as the factors are estimated before. See the online appendix for a description of the data.

scheme aimed at isolating news that is not affecting the stock market on impact. At this stage, we believe that more work is needed to fully understand the Forni, Gambetti, and Sala (2011) results.

3.3.2.6 *Summary of VAR Results*

Although in our explorations we have found that the estimation of impulse responses to news shocks using a combination of different identifying restrictions give quite similar results, recall that there exist configurations of the data and identification methods that give very different results. In particular it should be recognized that, even disregarding the issue of nonfundamentalness, there remains considerable debate regarding the effects and importance of identified news shocks since results can be sensitive to cointegration assumptions and to the choice of variables in the system. As a rule of thumb, when a VAR is estimated allowing for a high degree of cointegration between the variables, and when stock prices are included in the system, results tend to confirm the type of findings first suggested in Beaudry and Portier (2006). In contrast, when cointegration relations are restricted or when information contained in stock prices is omitted, then very different results often emerge.

3.4 *Other VAR-based Empirical Work on News*

Up to now, we have examined approaches to the identification of news shocks that address the issue indirectly, treating news as an unobserved disturbance. In contrast, there are a set of papers that try to look at the issue of news in a much more direct fashion by systematically deciphering information that may contain explicit news events.

One example is given by the research on tax news and government spending news. Mertens and Ravn (2012) study the impact of tax liability changes using the U.S. tax narrative provided by Romer and Romer (2009). For each piece of tax legislation, they define an announcement date and an implementation date. When the difference between these two dates exceeds 90 days, they assume that the tax liability change is preannounced. They find that the economy reacts in a different way to preannounced and surprise tax cuts: a preannounced tax cut with an anticipation horizon of six quarters gives rise to preimplementation declines in aggregate output, investment and hours worked. In contrast, aggregate consumption is hardly affected by the announcement. Mertens and Ravn (2011) then propose a DSGE model that can account for the impact of such tax policy shocks.

Once it is recognized that some tax and fiscal changes are anticipated, one should revisit some of the previous VAR literature on fiscal shocks, as representations are likely to be nonfundamental, as illustrated by Leeper, Walker, and Yang (2008). Ramey (2011) shows that both professional forecasts and the narrative approach shocks Granger-cause fiscal VAR shocks, implying that these shocks are missing the timing of the news, and therefore that VARs do not properly estimate dynamic fiscal multipliers. Mertens and Ravn (2010) nicely show that rational expectations models introduce restrictions on the nonfundamental roots of the MA representations that allows to examine the sensitivity of SVAR based estimates of the impact of fiscal shocks to news shocks. They use the fact that rational expectations models imply that fiscal news are discounted at a constant rate, denoted the anticipation rate by Ljungqvist and Sargent (2004). This parameter can be used to recover the structural shock of a fiscal VAR from its nonfundamental representation. Leeper, Richter, and Walker (2012) also identify two types of fiscal news—government spending and changes in tax policy. They identify news concerning taxes through the municipal bond market, and news concerning government spending through the Survey of Professional Forecasters. They then map the reduced-form estimates of news into a DSGE framework. Gambetti (2012) measures fiscal news as as the difference between the forecast of government spending growth over the next three quarters made by the agents at time t (measured with the Survey of Professional Forecasters) and the forecast of the same variable made at time t. This variable is then introduced in an otherwise standard VAR, and multipliers are found to be close to one. Ben Zeev and Pappa (2013) identify U.S. defense news shocks as shocks that best explain future movements in defense spending over a five-year horizon and are orthogonal to current defense spending. Those identified shocks induce significant and persistent increases in output, consumption, investment, hours and the interest rate.

On a different perspective, Bruckner and Pappa (2013) examine the macroeconomic effects of bidding for the Olympic Games using panel data for 188 countries during the period 1950–2009. News about the Olympics makes output and investment surge already at the time of the bidding. In unsuccessful bidding countries, the agents' optimism turns out to be unjustified and, as a result, the economy returns to its original trend, while hosting economies enjoy quantitatively large and significant positive effects from hosting.

Approaches where news events are directly observed and measured have an important advantage over SVAR approaches, as they tend not to be subject to the problem of nonfundamentalness and are therefore more likely to produce credible and less controversial results. However, since these papers are not focused on business cycle issues and do not examine the effects of technological news, their findings cannot be compared with the SVAR reviewed in the previous subsection. One paper that is more closely related is Alexopoulos (2011). Alexopoulos (2011) identifies dates where there are publications of books related to new technological developments. She then uses these identified episodes to look at how the economy reacts after a flurry of such technological dissemination. The main finding is that *TFP* tends to increase with a substantial lag after such episodes, especially in the sectors most likely to take advantage of such technological developments. Moreover, Alexopoulos finds that economic activity tends to pick up after these news events, which supports the idea that such positive news creates an expansion. Baron and Schmidt (2013) propose the use of technological standardization as a novel indicator of technological change. They find that standardization is an essential mechanism for revealing news about future movements of macroeconomic aggregates, as evidenced by the positive and immediate reaction of stock market data to a technology shock.[58]

4. *Building and Estimating Structural Models with News*

As we discussed in the previous section, the are several limitations of using VAR approaches to evaluating the plausibility and importance of news-driven business cycles. The main alternative to VARs is to use fully specified dynamic general equilibrium models (either estimated, calibrated, or a mixture of both) to do model-based structural decompositions of the sources of fluctuations. However, this alternative approach also has its limitations. As is well known, when doing

[58] The results in Lucke (2013) can be viewed as an intermediate step between these two approaches. He uses information on patent filings in the United States and Germany to see if the news shocks identified using a methodology similar to that used in Beaudry and Portier (2006) predicts patent filings. He finds they do and interprets that as supporting the idea that the identified shocks contain news about subsequent technological developments.

model-based structural decompositions, the resulting inferences depend critically on the assumed structure being right. If, for example, one adopts a dynamic general equilibrium model where the underlying structure is such that the economy's response to news can never cause a generalized boom or bust—that is, the assumed structure is such that news can never cause outcomes where consumption, investment, and employment all comove positively together—then by construction, such an approach will almost surely attribute little importance to news in driving fluctuations, even if in fact they are relevant. Therefore, before discussing the insights regarding news-driven business cycles obtained by doing model-based structural decompositions, it is important to first ask the following two questions: (i) in what types of dynamic general equilibrium models does news have the potential to create business cycle-type fluctuations, and (ii) is the resulting class of models reasonable? Once we clarify the answer to these two questions, we will be in a better position to discuss results from the model-based structural decompositions found in the literature.

4.1 *In What DSGE Environment Can News Creates Business Cycle Fluctuations?*

It appears intuitive to many that if agents in an economy wake up to news about new market opportunities developing on the horizon, this will likely cause increased activity immediately, as agents start to both invest early to be ready when the new demand patterns materialize and consume early as they feel richer. We have shown in the previous section that such an intuitive pattern emerges from the VAR literature that aim at identifying the effect of *TFP* news shocks. However, it turns out that such patterns are difficult to generate within the confines of many of the simple dynamic general equilibrium models used in macroeconomic literature. In particular, the difficulties arise on two fronts, which we will refer to as the dynamic front and the static front. On the dynamic front, as we shall show, in many simple dynamic models it is difficult for positive technological news to cause an increased desire to invest today. On the static front, we will show that even if positive technological news causes increased desire to invest, in many models this will not be translated into increased consumption and investment today. Instead, it is most generally be associated with either consumption or investment decreasing today.

To set the stage, let us begin by considering a very simple DSGE model in the RBC tradition where (i) there is a representative agent who discounts the future at rate β with per-period utility $\hat{U}(C_t, \bar{L} - L_t)$ that depends on consumption C_t and leisure $\bar{L} - L_t$, where both consumption and leisure are normal goods (L_t represent hours worked, and $\bar{L}$ is the labor endowment), (ii) there is one final good that is produced with capital and labor using a Cobb–Douglas technology $\theta_t K_t^{\alpha} L_t^{1-\alpha}$, where θ_t is a stochastic technology index and (iii) the final good can be consumed or invested, with capital accumulation obeying $K_{t+1} = (1-\delta)K_t + I_t$, where δ is the rate of depreciation and I_t is investment. In this environment, what happens if today the representative household receives news that indicates that θ will increase in q periods? As first hinted to in Barro and King (1984) and discussed in more detail below, in such an environment it will never be the case that the news will lead to an immediate increase in consumption, investment, and employment. Moreover, under standard calibrations, the news will not even lead to an increased desire to invest in anticipation of the future technological change, but will instead lead to a decrease in current investment and employment. Hence, if someone chose to use such a framework to evaluate the importance of news using model-based structural decomposition, then almost certainly the results will be that news does not play a very important role. While that may be the right conclusion, before drawing such a conclusion it is important to understand which assumptions cause which difficulties for the news view of business cycles. To this end, we will present here a framework that helps separate static difficulties and dynamic difficulties. An underlying message of the section will be to show that standard DSGE models do not easily embody the narrative of news-driven business cycles without significant modifications. This can be interpreted in two ways: either the news view should be discounted, as it does not fit into mainstream models, or our standard business models are very restrictive and may need to be generalized. Moreover, while the literature has recognized and offered solutions to the static problem, this section will also emphasize a dynamic challenge that is somewhat less recognized.

4.1.1 *Addressing the Static Problem between News and Business Cycles*

As mentioned previously, the mechanisms behind the news view can be divided into two distinct elements. First, there is the effect of news on agents' and firms' desire to invest in order to be well placed to take advantage of future developments. We refer to this as the dynamic element, since it depends primarily on how agents' perceptions about the future translate into investment demand. Second, there is the notion that increased investment demand leads to increased economic activity without creating negative comovements between investment and consumption. We refer to this second element as the static element, since it looks at current adjustment conditional on how agents perceive the future. In this subsection, we want to restrict attention to situations where (by assumption) news generates increased incentive to invest and focus on clarifying the conditions under which the increased investment demand creates a boom. In order to make this distinction between the static and dynamic elements operational, it is helpful to explicitly model the continuation value of capital in preferences. In particular, let us start by assuming that we have a representative agent with a current utility function given by $\hat{U}(C_t, 1 - L_t) = U(C_t, L_t)$, where both consumption and leisure are normal goods. Furthermore, let us summarize the agent's perceived future utility by the value function $\tilde{V}(K_{t+1}, \Gamma_{t+1})$. Here, K_{t+1} is the stock of capital the agent will have next period and Γ_{t+1} is the state of the world next period. Let us be clear that we assume here that $V_{KS} > 0$ so that desired investment increases at the reception of the news. The features of the model that can solve the static problem might not be sufficient to also solve the dynamic problem: once the continuation value V is derived from the model fundamentals, it might not satisfy $V_{KS} > 0$. Some extra features will then be needed, that we discuss when looking at the dynamic problem.

4.1.1.1 *A One-Sector Economy:*

Consider a one-sector economy in which there is a representative firm that hires labor and rents capital to produce output using the concave production function $F(K_t, L_t, \theta_t)$. There is also a representative household whose objective can then be stated as follows:

$$\max_{C_t, K_{t+1}, L_t} U(C_t, L_t) + \beta E\left[\tilde{V}(K_{t+1}, \Gamma_{t+1}) |\, \Omega_t\right],$$

$$\text{s.t.} \quad C_t + K_{t+1} = w_t L_t + K_t(1 - \delta + r_t) + \pi_t,$$

where w_t and r_t are the wage rate and the rental rate of capital, and π_t are firm profits. Ω_t is the agent's information set in period t, which can for example include the current state of technology θ_t and any signal S_t that the agent may have received as exogenous news. We will refer to this simple macro model as the RBC structure. For ease of exposition it will be helpful to define a continuation value function $V(\,\cdot\,)$ as follows

$$V(K_{t+1}, \theta_t, S_t)$$
$$= \beta E\big[\tilde{V}(K_{t+1}, \Gamma_{t+1}) |\ \Omega_t = \{\theta_t, S_t\}\big].$$

So the continuation value function of an agent is just the expectation of his value function and therefore depends on the stock variables one brings into next period—which, in the RBC structure is only K_{t+1}—and on his information set Ω, which he used to form his expectations. The information set in this case is comprised of both the current state of technology θ_t, as well as extra information arrived in the form of news denoted by S_t. Although in general the news could be multidimensional, we will assume for now that it corresponds simply to a scalar where a higher value of S_t corresponds to more productive technology in the future. While the agent's continuation value function depends on future utilities $U(C_{t+i}, 1 - L_{t+i})$ and future production possibilities, for now we will bypass thinking about these links explicitly and instead assume that an increase in the signal S_t increases the desire to invest by assuming that

$$\frac{\partial^2 V(K_{t+1}, \theta_t, S_t)}{\partial K_{t+1} \partial S_t} > 0.$$

That is, we assume that an increase in the signal increases the perceived marginal value of entering next period with greater capital. We are not being specific about the type of technological change that the news S_t could be forecasting or why it would cause an increase in the marginal value of acquiring capital. The conditions under which an expected technology improvement causes the perceived value of holding capital to go up will be discussed in the subsection under the heading of dynamic challenge. By taking this property of the value function as given and assuming that $V_{KK}(\,\cdot\,) \leq 0$, we can focus solely on how the economy adjusts immediately to an increased desire to hold capital, which is a static problem, without needing to get entangled with dynamics. In other words, we study the temporary equilibrium of the economy for given expectations, those expectations being embedded into the V function. The Walrasian equilibrium quantities for this problem, K_{t+1}, C_t, and L_t, can then be represented as the solution to the three following equations:

$$(39) \quad \frac{\partial V(K_{t+1}, \theta_{t+1}, S_t)]}{\partial K_{t+1}} = U_C(C_t, L_t),$$

$$(40) \quad F_L(K_t, L_t, \theta_t) = \frac{-\,U_L(C_t, L_t)}{U_C(C_t, L_t)},$$

$$(41) \quad C_t + K_{t+1} = F(K_t, L_t, \theta_t) + (1 - \delta) K_t.$$

Equation (39) is the usual intertemporal Euler equation, (40) is the intratemporal consumption–leisure decision (the labor market equilibrium in a decentralized version) and (41) is the economy resource constraint. This setup allows us to examine how K_{t+1}, C_t, and L_t change in response to an increase in S_t by performing a simple comparative static exercise on this three-equation system. It is here that we can see what we refer to as the static challenge for news-driven business cycles. In this setup, if the news increases the desire to invest (which we are assuming it does by assumption), then it will lead to a decrease in consumption; that is, the news cannot cause a generalized boom with both consumption and investment increasing. This property of the RBC structure was first noted in Barro and King (1984) and made more explicitly related to news (or expectations) in Beaudry and Portier (2007). The property can be seen directly from equation (40): the intratemporal labor market equilibrium condition. From this equation, under the assumption that consumption and leisure are both normal goods, it can be directly verified by simply taking a total differential holding capital and technology constant, that consumption and employment cannot move in the same direction. Hence, consumption and investment cannot move in the same direction. This is the precise point made by Barro and King (1984).

Why is Barro and King (1984) observation a difficulty for a news view of business cycles? To the extent that we interpret the previous VAR result as suggesting that, in response to news, the economy expands with both consumption and investment increasing (at least weakly) throughout the substantial period where technology has not yet increased, then such features cannot be generated within the structure. Furthermore, even if one is unsure about the VAR results, but one believes that news may offer a reasonable theory of the business cycle, then it is useful to identify conditions under which news shocks do not create negative comovement between consumption and investment. Accordingly, we take this static difficulty as a challenge for news-driven business cycles and we proceed to discuss here the different solutions proposed in the literature. However, before looking at different possibilities we want to first clarify the limited role played by income effects in creating the difficulty, since there appears to be some confusion on this point. In fact, Barro and King's (1984) result is not at all driven by income effects on labor supply. If we exclude income effects on labor supply, for example by assuming that the utility function is of the form $U(C_t - \tau_1 L_t^{1+\tau_2})$, where τ_1 and τ_2 are positive parameters, then we get the exact same difficulty.[59] Actually, the problem becomes even simpler in the absence of income effects on labor supply, since with such preferences, technology and preferences pin down output, independently of the value function. Hence, in this case news can only cause purely off-setting changes in C_t and I_t, keeping the sum constant.

In response to this static challenge, the literature has proposed several departures from the simplest RBC-style structure to explain why news shocks do not necessarily imply an initial phase of negative comovement between investment and consumption. These departures range from modest to substantial. We will start by discussing changes that to do not require modifying the arguments of the value functions, and then discuss those that do require such changes.[60]

4.1.1.2 *Changing Preferences*

One simple departure that overcomes Barro and King's (1984) problem is to allow consumption or leisure to be inferior goods. In particular, if we assume that consumption is an inferior good then the difficulty does not necessarily emerge. Moving away from the normality assumption about goods may at first pass appear unreasonable, but Eusepi and Preston (2009) argue that the representative agent's preferences should be

[59] This should not be surprising, as these preferences were not ruled out by our assumptions.

[60] Wang (2012) has proposed a review of the models that generate positive comovements. Those properties are nicely presented in terms of labor market structure (upward or downward sloping labor supply, outwards shifting labor demand following a technological news). Eusepi (2009) shows that in a one-sector model with economywide externalities, there is a tight connection between positive comovements and indeterminacy, as conditions for positive comovements are necessary to obtain indeterminate equilibria. That connection is broken in two-sector economies. Guo, Sirbu, and Suen (2012) show that good technological news actually creates an aggregate recession in Eusepi (2009) simple on-sector model. Guo, Sirbu, and Weder (2012) also discuss the link between positive comovements and indeterminacy. Sorge (2012) show that news-driven models and indeterminate equilibrium economies with i.i.d. fundamentals are observationally equivalent.

thought of as an aggregation of preferences for workers and nonworkers (under complete insurance), and that in the presence of nonconvexities,[61] the resulting aggregate preference may have consumption as an inferior good even if the preferences of the underlying agents have both consumption and leisure as normal goods. Using this idea they then show that in a reasonably calibrated model, the arrival of news can lead to an immediate increase in both consumption and investment. Eusepi and Preston (2011) use a similar framework to show how learning dynamics create shifts in expectations and generate business cycles.[62]

In a different take on this idea, Karnizova (2010b) suggests that news directly affects labor supply, which relaxes the resource constraint allowing both investment and consumption to increase. This is achieved by assuming that financial wealth enters the utility function. She calls this effect the Spirit of Capitalism and shows how news can cause consumption and investment to grow on impact. While these are interesting ideas, they both imply that the initial expansion following news is due to a labor supply effect instead of increased demand for labor. This implies that real wages should be counter-cyclical. Again, to the extent that the VAR results are informative about the effects of news, such an implication may be at odds with the data, as real wages appear to be weakly increasing in response to news. However, more exploration along this front will be needed to assess the validity of such mechanisms.

[61] Eusepi and Preston (2009) assume that participating to the labor market entails a fixed cost.

[62] Zhang (2012) study the stability under learning (E-stability) of Jaimovich and Rebelo (2009) model, and shows that when agents do not observe current state variables when forming expectations, the rational expectations equilibrium is not learnable for calibrated parameter values capable of generating news-driven recessions.

Finally, Malkhozov and Shamloo (2012) introduce nonseparable Epstein and Zin (1989) preferences in an RBC model with news shocks and show that it creates a persistent predictable component in consumption growth, that is often referred to as long-run risk in the finance literature (Bansal and Yaron 2004). Although the model does not allow for variable labor, so that consumption and investment move in opposite direction following a technological news, an extension with variable labor supply could potentially solve the static problem.

4.1.1.3 *Allowing for Sticky Prices and Accommodative Monetary Policy*

Another avenue discussed in the literature for overcoming the "static problem" associated with news is to allow for sticky nominal prices. When prices are fixed, the very mechanism of IS–LM imply that C, Y, and H all increase following an exogenous increase in I, that is driven by "animal spirits." When prices are not fixed but sticky, this avenue has been pursued in many papers including Christiano et al. (2010); Khan and Tsoukalas (2012); Lorenzoni (2009); Auray, Gomme, and Guo (2009); Fujiwara, Hirose, and Shintani (2011); Jinnai (2013); and Blanchard, L'Huillier, and Lorenzoni (2009). However, as we shall show, it is not sticky prices in and of themselves that is needed to overcome the static problem, but it is sticky prices combined with a particular type of monetary policy. In effect, what is required is that monetary policy be sufficiently accommodative to news. To understand how news and sticky prices interact on impact, consider a slight generalization of the one-sector framework where agents can now hold money and capital, and where we assume that the nominal price of goods is predetermined. Money is directly introduced in the agents' value functions as a short hand for its eventual liquidity services.

The representative household's problem can then be stated as

$$\max_{C_t, K_{t+1}, M_{t+1}, L_t} U(C_t, L_t)$$

$$+ \beta E[V(K_{t+1}, M_{t+1}, \theta_t, S_t),$$

$$\text{s.t. } C_t + K_{t+1} + \frac{M_{t+1}}{P_t}$$

$$= w_t L_t + (1 - \delta + r_t)K_t$$

$$+ \frac{M_t}{P_t} + \pi_t + \frac{\tau_t}{P_t},$$

where P_t is the price of goods in terms of money, and τ_t is an exogenous money transfer with next period's money supply given by $M_{t+1} = M_t + \tau_t$. Money balances are directly assumed to enter the function $V(\cdot)$ with $V_{22} < 0$. To give sticky prices their full force, we will assume that P_t does not react to news. Without loss of generality, we can therefore set $P_t = 1$. To complete the model we need to specify how the money transfer τ_t is determined. Since the nominal price of goods is assumed to be fixed, a simple monetary rule is to have τ react to deviations of output from a long run average. The rule would then take the form

$$\tau_t = \alpha(Y_t - \overline{Y}),$$

where $\overline{Y}$ is a reference rate of output, $Y_t = C_t + I_t$ and α governs the extent to which monetary policy either leans against demand shocks or amplifies them. If $\alpha < 0$ monetary policy leans against demand shocks; if $\alpha > 0$ then monetary policy is pro-cyclical in the sense of expanding when demand is high. The equilibrium levels of consumption C_t and investment I_t are then determined by the set of equations

$$V_K(K_{t+1}, M_{t+1}, \theta_t, S_t) = V_M(K_{t+1}, M_{t+1}, \theta_t, S_t),$$

$$U_C(C_t, L_t) = V_K(K_{t+1}, M_{t+1}, S_t),$$

$$F(K_t, L_t) = C_t + K_{t+1} - (1 - \delta)K_t,$$

$$M_{t+1} = M_t + \alpha(C_t + I_t - \overline{Y}),$$

$$I_t = K_{t+1} - (1 - \delta)K_t.$$

Now consider the arrival of a signal S_t that increases the marginal value of holding capital ($V_{KS} > 0$). How does this affect investment and consumption? To simplify the analysis, assume that $U(C_t, L_t)$ is separable between consumption and employment, and assume that $V(K_{t+1}, M_{t+1}, S_t)$ is separable between capital and money, with S_t only affecting the value of capital. In this case, investment increases, but the response of consumption is ambiguous as it hinges on the sign of α in the monetary rule. If $\alpha < 0$ then consumption decreases in response to news that increases the demand for investment. If $\alpha = 0$ then consumption is unchanged. Only if $\alpha > 0$ do we have both consumption and investment increasing in response to the news. The positive comovement arises because monetary policy becomes expansionary in response to the news. Hence, sticky prices offers an avenue to overcome the static problem with news-driven business cycles, but the mechanism is somewhat fragile, since it relies crucially on how monetary policy reacts to news.[63] For example, in

[63] Karnizova (2010a) study a simple New Keynesian monetary business cycle model with news shocks and sunspot ones when monetary policy is passive or active. Another model that also leads to countercyclical markups is proposed by Pavlov and Weder (2013). Using Galí's (1994) monopolistic competition framework in which investment and consumption have a different price elasticity of demand, they show that news shocks imply

a simple New Keynesian model[64] in which price stickiness is the only distortion and without cost push shocks, the optimal monetary policy replicates the flex price allocations. The model is then a standard *RBC* model (without capital), and consumption and hours worked always move in opposite directions following a news shock. It is only when monetary policy is suboptimal that C and H can comove positively.[65]

4.1.1.4 *Adopting a Two-Sector Structure*

One of the reasons that increased investment demand leads to decreased consumption in an RBC model structure is due to the one-sector assumption. With only one sector, investment goods and consumption goods are perfect substitutes[66] and therefore it is generally optimal to reduce one when there is increased demand for the other. In contrast, with a two-sector model, where factors are specific to the sector, investment and consumption are not direct substitutes and, accordingly, it turns out to be much easier to generate increased investment in response to news without having consumption decrease. To see this, let us slightly extend the previous setup to allow for two sectors, maintaining for now the assumption of a representative household. The first sector is the consumption sector with $C_t = F(K_t^C, L_t^C; \theta_t^C)$, where L_t^C is the level of employment in the sector, K_t^C is the capital used in the sector, θ_t^C is a technology index in the consumption sector and $F(\,\cdot\,; \theta^C)$ is a concave function. The second sector is the investment sector with $I_t^I + I_t^C = G(K_t^I, L_t^I; \theta_t^I)$, where I_t^I and I_t^C are the investments directed to the accumulation of capital in the investment and consumption sectors, respectively. K_t^I and L_t^I are sector-specific factors, and $G(\,\cdot\,; \theta^I)$ is a concave function. The accumulation of capital is given by $K_{t+1}^I = I_t^I + (1-\delta)K_t^I$ and $K_{t+1}^C = I_t^C + (1-\delta)K_t^C$. The household's utility is assumed to take the form $U(C_t, L_t^C, L_t^I)$, where we allow for the possibility that labor from the two sectors are imperfect substitutes in preferences. Finally, as before, we summarize the agent's perception about the future as given by the continuation value function $V(K_{t+1}^I, K_{t+1}^C, \theta_t^I, \theta_t^C, S_t)$, so that the agent's problem can be stated as

$$\max_{C_t, K_{t+1}^C, K_{t+1}^I, L_t^C, L_t^I} U(C_t, L_t^C, L_t^I) + V(K_{t+1}^C, K_{t+1}^I, \theta_{t+1}^C, \theta_{t+1}^I, S_t),$$

$$\text{s.t. } C_t + P_t^I(K_{t+1}^C + K_{t+1}^I) = w_t^C L_t^C + w_t^I L_t^I + K_t^C(P_t^I(1-\delta) + r_t^C) + K_t^C(P_t^I(1-\delta) + r_t^I) + \pi_t^C + \pi_t^I,$$

where P_t^I is the price of investment goods and the superscripts C and I indicate the consumption and investment sectors. In this setup, suppose the representative household receives news about future technological change that leads him to believe that the marginal value of holding capital—either in one or both sectors—increases. What happens to consumption and employment in each sector assuming a Walrasian equilibrium? In contrast to the one-sector model, consumption

countercyclical markups and can therefore generate positive comovements.

[64] See for example chapter 3 in Galí's (2008) book.

[65] Guo (2007) explores the optimal response of a central bank when a news shock hits the economy in a two-sector model with price rigidities in each of the nondurable and durable sectors. Blake (2012) also shows that monetary policy can be designed to mitigate the effects of news shocks on output and inflation. Romero Alom (2012) presents a simple New-Keynesian model in which it is optimal to include asset prices in the Taylor rule when there are news shocks. On monetary policy with news shocks, see also Jinnai (2013).

[66] If capital is fully mobile between the two sectors, then the Walrasian equilibrium in the two-sector model behaves similarly to that of the one-sector. In particular, in response to news that increases the marginal value of holding capital, the production of the consumption good will decrease. See Beaudry and Portier (2007) for details.

does not necessarily decrease in this case. The easiest case to see this is the one where $U(C_t, L_t^C, L_t^I)$ is separable in its three arguments.[67] In such a setup, consumption and employment in the consumption sector are determined by the two equations:

$$\frac{-U_{L^C}(L_t^C)}{U_C(C_t)} = F_{L^C}(K_t^C, L_t^C),$$

$$C_t = F(K_t^C, L_t^C).$$

Under the assumption of separability in the utility function, these two equations can be solved independently of the decisions in the investment sector, and therefore independently from any change in the information set Ω_t, which would be affected by news. In other words, employment and output in the consumption sector do not respond to news. In contrast, employment in the investment goods sector will generally be directly affected by news. Investment decisions and employment in that sector are determined by the set of three equations:

$$G_{L^I} = \frac{-U_{L^I}}{V_{K^I}},$$

$$G_{L^I} = \frac{-U_{L^I}}{V_{K^C}},$$

$$G(K_t^I, L_t^I) = K_{t+1}^I - (1-\delta)K_t^I + K_{t+1}^C - (1-\delta)K_t^C.$$

Therefore, if news increases either V_{K^I} or V_{K^C}, then it will lead to increased employment and output in the investment sector. Hence, in such a two-sector structure, news that increases demand for investment does not give rise to a negative comovement between consumption and investment or, stated differently, the static problem with news seen in the one-sector model does not arise. However, in the separable case, since consumption neither increases nor decreases in response to news, it may be considered a knife-edge result.

Recall from the VAR results that consumption seemed to increase immediately in response to news, so it would be interesting to know if both consumption and investment can respond positively to news in the Walrasian equilibrium of a two sector model. It is actually possible to have both consumption and investment strictly increase in response to news in this setup, but if we maintain a representative agent assumption, it requires quite uncommon nonseparability assumptions for the utility function $U(C_t, L_t^C, L_t^I)$.[68] A more promising avenue for having both consumption and investment increase in response to news in a two-sector framework is, according to Beaudry and Portier (2014), to depart from the representative agent setup and adopt a framework with static gains from trade between heterogenous agents. It is shown there that, in a two-sector model where households are specialized in the sense of being attached to one sector for their employment,[69] then increased

[67] Or when it can be written as $\tilde{U}(C_t - h^C(L_t^C) - h^I(L_t^I))$, where $\tilde{U}(\cdot)$ is a concave function and where the functions $h(\cdot)$ are convex

[68] For example if the $U(C_t, L_t^C, L_t^I) = \ln(C_t - \tau_1(L_t^I)^{1+\tau_2}) - \nu \cdot L_t^C$, then an increase in V_{K^I} or V_{K^C} will lead to a simultaneous increase in consumption and total investment. Alternatively, if we summarize the two sector production possibilities by $(C_t^\sigma + I_t^\sigma)^{\frac{1}{\sigma}} = F(K_t, L_t)$ with $\sigma < 1$, we can also get news to lead to an increase in both consumption and investment, as shown in Beaudry and Portier (2007) for details. Katayama and Kim (2010) have built a two-sector model whose key elements are frictions in intersectoral labor mobility and nonseparable preferences in consumption and leisure, along with adjustment costs to investment and variable capital utilization. That model is able to generate comovements in response to both contemporaneous shocks and news shocks about fundamentals.

[69] This result also relies on incomplete insurance markets so that the economy does not aggregate to a representative setup.

demand for investment goods will most often be associated with an immediate increase in aggregate consumption, as those employed in the investment goods sector will use part of their increased income to buy consumption goods. Luttmer (2013) also explores a model with expectation revisions in a multisectoral structure with consumption and investment sectors. The consumption sector is labor intensive, whereas the investment sector is manager intensive. When a good news hits, consumption increases, which increases the labor wage via a Stolper–Samuelson effect, which in turn increases hours worked. In the Luttmer (2013) model, such a consumption and hours boom is nevertheless accompanied by a drop in investment. To summarize, moving from a one-sector to a two-sector framework greatly reduces, and can even overcome, the static problem of having news cause negative comovement between consumption and employment.

4.1.1.5 *Current Employment in the Value Function*

A fourth avenue that has been suggested as a way to solve the negative comovement problem between consumption and investment is to have the level of past employment directly enter the value function, with the property that news increases the marginal value of past employment. Consider a model in which the household problem can be written as follows:

$$\max_{C_t, K_{t+1}, L_t} U(C_t, L_t) + V(K_{t+1}, L_t, \theta_t, S_t),$$

$$\text{s.t.} \quad C_t + K_{t+1} = w_t L_t + K_t(1 - \delta + r_t) + \pi_t,$$

where we assume that $V_{KL} \geq 0$, $V_{LS} > 0$ and $V_{LL} \leq 0$. The simplest rationale for why past employment may enter the value function this way is adjustment costs to labor. In the presence of convex adjustment costs for labor, current news that anticipates later employment growth will directly favor employment today as to reduce the adjustment costs. This increased labor demand then leads to increased production, which can be split between consumption and investment. In effect, the intratemporal consumption–leisure decision (40) is now given be the following

$$-U_C(C_t, L_t) F_L(K_t, L_t, \theta_t) = U_L(C_t, L_t) + V_L(K_{t+1}, L_t, \theta_t, S_t).$$

Fully differentiating the above equation and assuming separability of utility for the ease of exposition, one obtains

$$\underbrace{(U_C F_{LL} + U_{LL} + V_{LL})}_{-} dL_t = \underbrace{-U_{CC}}_{+} dC_t + \underbrace{-V_{LK}}_{-} dK_{t+1} + \underbrace{-V_{LS}}_{-} dS_t.$$

As it is clear from this equation, positive news dS_t that increases investment ($dK_{t+1} > 0$) can move upwards C_t and L_t.

Hence, the presence of convex adjustment to labor offers a very simple resolution of the static problem with news. However, there are a few potential drawbacks of this mechanism. First, much of the microeconomic evidence suggests that labor adjustment costs are either fixed or linear, not convex. Second, to the extent that the microeconomic literature does find evidence of convex adjustment costs to labor, they tend to be small, which means that in response to news, this mechanism may be quantitatively too weak to offset the negative comovement problem. Third, with convex labor adjustment costs, the response when agents discover that they have been accumulating too much capital will no longer cause an abrupt fall in employment—which is a feature we believe is desirable. Instead the adjustment will tend to be gradual.

The papers by Den Haan and Kaltenbrunner (2009) and Gunn and Johri (2011) implicitly exploit ideas that work somewhat similarly to convex adjustment costs to labor, but offer more plausible mechanisms. In particular, Den Haan and Kaltenbrunner (2009) explored the effects of news in a search and matching model. The search frictions give rise to a mechanism by which news leads firms to want to post vacancies immediately, as to have sufficient employed workers when the expected demand forecasted by the news is eventually realized. This is similar in spirit to convex adjustment costs to labor, but with better microeconomic support. Den Haan and Kaltenbrunner (2009) showed that the static problem associated with news can be overcome in such a setup.[70] In a quite different spirit, Gunn and Johri (2011) have suggested that learning by doing creates a reason why news may directly affect labor demand today. In response to news, it becomes profitable to hire more workers today as to have more human capital built up through learning-by-doing when new demand arises. They show that such a learning-by-doing mechanism can also overcome the negative comovement problem, and it works essentially by giving a dynamic value to current employment.[71]

In summary, we have defined the static challenges associated with news as the difficulty of getting both consumption and investment to increase when agents get information regarding a future technology improvement. While this problem is present in the Walrasian equilibrum of a one-sector representative agent model, we have shown that the problem can be overcome by departing from such a simple model. In particular, we have discussed, among others, how sticky prices, adjustments costs to labor, and adopting a two-sector formulation can mitigate the tendency of increased investment to cause a decrease in consumption. While the different mechanisms presented each have their strengths and weaknesses, further empirical exploration is needed to identify which path offers a more plausible solution.[72]

4.1.2 *The Dynamic Challenge of News and Business Cycles*

As mentioned previously, there are two central elements to the news view of business cycles that we have set out. Firstly, there is the idea that news about future developments in the economy create incentives for either firms or individuals to start investing immediately in preparation for the eventual changes. Second is the idea that the increased investment demand induced by news stimulates economic activity in a way that generates an aggregate boom in both consumption and investment. One challenge for a news theory of business cycles, especially one based on technological news, is to present plausible but simple DSGE models that capture these two features. In the previous section we have discussed what we have referred to as the static challenge; that is,

[70] In their survey on the news-shocks literature, Krusell and McKay (2010) also propose a simple search model that generate cycles driven by news shocks.

[71] See also Qureshi (2009) for a similar mechanism.

[72] All the mechanisms we have discussed in this section have assumed a production structure which is not subject to increasing returns-to-scale. However, increasing returns-to-scale offers an alternative mechanism that can explain how changes in expectations can lead to increases in both consumption and investment. In fact, as shown in Benhabib and Farmer (1994), in the presence of increasing returns to scale the economy can exhibit business cycles driven by self-fulfilling beliefs.

identifying environments where increased investment demand can lead to aggregate booms in both investment and consumption. In this section, we want to discuss a dynamic challenge, that is, clarifying how and when news of future technological improvements creates increased incentive to invest today. In terms of our notation, the dynamic challenge refers to presenting environments where the agents' continuation value functions have the property that positive technological news increases the marginal value of bringing capital into the future. While the literature has recognized the static challenge related to the comovement problem and suggested solutions, the dynamic challenge has been much less discussed or recognized.[73] To highlight the nature and extent of the dynamic challenge, we begin by discussing it within the context of a two-sector model, since such structure allows us to consider separately the effects of expected technological improvements in either the consumption or the investment sector. Note that the one-sector model is just a special case of our two-sector setup.

4.1.2.1 *Two-sector Case*

Let us return to the two-sector model we have previously introduced in this section, where $F(K_t^C, L_t^C, \theta_t^C)$ is the production function in the consumption sector and $G(K_t^I, L_t^I, \theta_t^I)$ is the production function in the investment sector. For simplicity, let us assume that $\theta_{t+1}^j = \rho\theta_t^j + \epsilon_t^j$ with $j \in \{C, I\}$ and where ϵ_t^j is an innovation that affects technology at time $t+1$, but is known by agents through news at time t. If the representative agent's period utility is given by $U(C_t, L_t^C, L_t^I)$, competitive allocations can be obtained from a social-planner problem, and the planner value function at time t can be defined as

$$
\begin{aligned}
&\tilde{V}(K_t^C, K_t^I, \Sigma_t) \\
&= \max_{\substack{\{C_{t+i}, K_{t+1+i}^C, \\ K_{t+1+i}^I, L_{t+i}^C, L_{t+1+i}^I\}_{i=0}^{\infty}}} E_t \sum_{i=0}^{\infty} U(C_{t+i}, L_{t+i}^C, L_{t+i}^I),
\end{aligned}
$$

$$
\begin{aligned}
\text{s.t. } C_{t+i} &= F(K_{t+i}^C, L_{t+i}^C, \theta_{t+i}^C), \\
&\quad (K_{t+1+i}^C - (1-\delta)K_{t+i}^C) \\
&\quad + (K_{t+1+i}^I - (1-\delta)K_{t+i}^I) \\
&= G(K_{t+i}^I, L_{t+i}^I, \theta_{t+i}^I),
\end{aligned}
$$

where $\Sigma_t = (\theta_t^C, \theta_t^I, \epsilon_t^C, \epsilon_t^I)$ is the vector of current exogenous states. The issue we want to examine is how changes in news represented by changes in ϵ^C and ϵ^I affect the marginal value of holding capital. Using the envelope condition, the marginal value of having capital in period $t+1$ can be expressed, for each type of capital, as

$$
\begin{aligned}
&\tilde{V}_{K^C}(K_{t+1}^C, K_{t+1}^I, \Sigma_{t+1}) \\
&= U_C(C_{t+1}, L_{t+1}, L_{t+1}^I) F_{K^C}(K_{t+1}^C, L_{t+1}^C, \theta_{t+1}^C) \\
&\quad + \frac{(1-\delta)}{G_{L^I}(K_{t+1}^I, L_{t+1}^I, \theta_{t+1}^I)} \\
&\quad - U_{L^I}(C_{t+1}, L_{t+1}^C, L_{t+1}^I)
\end{aligned}
$$

and

$$
\begin{aligned}
&\tilde{V}_{K^I}(K_{t+1}^C, K_{t+1}^I, \Sigma_{t+1}) \\
&= \frac{-U_{L^I}(C_{t+1}, L_{t+1}, L_{t+1}^I)}{G_{L^I}(K_{t+1}^I, L_{t+1}^I, \theta_{t+1}^I)} ((1-\delta) \\
&\qquad + G_{K^I}(K_{t+1}^I, L_{t+1}^I, \rho\theta_{t+1}^I)).
\end{aligned}
$$

[73] One paper that emphasizes and addresses this dynamic challenge is Dupor and Mehkari (2013).

Let us now follow some standard parameterizations in the literature by assuming that the utility function is of the form $\ln C_t - \nu \cdot (L_t^C + L_t^I)$, and that the production functions are Cobb–Douglas: $F(\cdot) = \theta_t^C (K_t^C)^{\alpha^C} (L_t^C)^{1-\alpha^C}$ and $G(\cdot) = \theta_t^I (K_t^I)^{\alpha^I} \times (L_t^I)^{1-\alpha^I}$. The linearity in the disutility of work is not important, but will make our argument more transparent. Under these two parametric assumptions, the expected marginal values of bringing capital into the next period (that is, the derivative of the continuation value function) can be expressed as

$$V_{K^C}(K_{t+1}^C, K_{t+1}^I, \Sigma_{t+1}) = \beta\left(\frac{\alpha^C}{K_{t+1}^C} + \frac{\nu(1-\delta)E_t(L_{t+1}^I)^{\alpha^I}}{(1-\alpha^C)(\theta_t^I + \epsilon_t^I)(K_{t+1}^I)^{\alpha^I}}\right),$$

$$V_{K^I}(K_{t+1}^C, K_{t+1}^I, \Sigma_{t+1}) = \beta\left(\frac{\nu(1-\delta)E_t(L_{t+1}^I)^{\alpha^I}}{(1-\alpha^C)(\theta_t^I + \epsilon_t^I)(K_{t+1}^I)^{\alpha^I}} + \frac{\nu E_t(L_{t+1}^I)}{K_{t+1}^I}\right).$$

There are several aspects we want to emphasize about how these particular parametric assumptions on utility and production functions restrict the incentive to hold capital. First, note that the only endogenous variable as of time $t+1$ to appear in either (42) or (43) is employment in the capital goods sector. Second, the information related to future technological progress in the consumption sector ϵ_t^C does not appear anywhere in these two expressions except potentially through the expectation of L_{t+1}^I. Finally, the information on technological progress in the investment sector appears directly only in the denominator of these expressions. Under these parametric assumptions, we can see why it will be very difficult for positive technological news to create an incentive to hold more capital. Actually, it can be shown that under these assumptions, news about technological improvements in the consumption goods sector never increases the marginal value of holding capital, since it does not affect L_t^I. Hence, this type of parameterization entirely rules out the possibility that expected technological improvements in the consumption good sector creates incentives for agents start to accumulating capital immediately to take advantage of the news.[74] For technological news regarding the investment sector, such a general statement is harder to obtain. Nonetheless, we have found the effect of positive news to almost always decrease the value of holding capital. This later property should not be surprising, as expected technological improvement in the capital goods sector creates a very intuitive incentive to postpone buying capital now, when one knows that improvements in the sector are imminent.[75]

What to take from these observations on the continuation value function? On the one hand, if one is wedded to standard parameterizations of business cycle models, these observations suggest that positive technological news is unlikely to be an important driving force in investment demand. On the other hand, if one believes the business press, which commonly suggests that investment demand is an important driver of business cycles, then it favors considering models which allow substantial departures from standard parameterization of DSGE models. In the latter case, there are two avenues that

[74] This effect is closely related to the fact that in a Lucas tree model, an increase in future productivity of trees does not increase the price of the tree in terms of the consumption good when utility is of the form $U(C_t) = \ln(C_t)$.

[75] Note that this structure implicitly nests a more standard one-sector model when one assumes that $\alpha^C = \alpha^I$, and accordingly implies that positive technological news in a one-sector model with Cobb–Douglas technology and log preferences for consumption will generally decrease the incentive to invest, not increase them.

appear to us to be most promising. The first relates to reducing the sensitivity of the stochastic discount factor. In the above setup, one of the main reasons that positive news about future technology is not associated with increased incentives to invest is that it simultaneously leads to an increased interest rate that fully offsets the expected increase in the marginal productivity of capital. There are potentially many avenues to reduce the effect of news on the interest rate including: changing the preference structure;[76] allowing for heterogeneous agents with some agents having intertemporal elasticity of substitution greater than one; or adopting a sticky price setting with lax monetary policy. A second avenue for obtaining $V_{K\epsilon^I} > 0$ is to consider production structures where technological news has a much greater effect on the marginal product of capital in comparison to the average product of capital. With a Cobb–Douglas structure, technological change causes the average product of capital to increase in the same proportion as the marginal product of capital, and the expectation of such a change is therefore associated with a substitution effect (induced by the increase in the marginal product of capital) that favors more investment to be offset by a large income effect (induced by the increase in the average product of capital) that favor postponing investment. Departing from a Cobb–Douglas structure can change the relative size of the effects. For example, if one adopts a CES structure where labor and capital are very complementary and the news relates to labor augmenting technological change, the news will then increase the marginal product of capital more than the average product.[77] This will create incentives to invest. Alternatively, if capital and labor are very substitutable and the news relates to capital augmenting technological change, the effect of the news on the marginal productivity of capital will be greater than the average effects, thereby again creating clear incentives to invest in response to the news, as the substitution effect will dominate the income effect. A third way to proceed is to consider technological change more in a Schumpeterian tradition, where new opportunities tend to displace old ones, making the private gains to investing much greater than the social gain (which drives the income effect).[78] Accordingly, in response to news that favors creative destruction, the return to new investment can be high even if the net effect on output can be low. Such an avenue appears promising, but it doesn't fit easily into the standard DSGE framework.

4.1.2.2 *Jaimovich and Rebelo's (2009) Approach*

We have emphasized two types of challenges facing news-driven business cycles when trying to embed the idea within a simple DSGE structure. These challenges arise largely because we have been wanting to build a model where news-driven booms reflect a period where agents have an incentive to accumulate or install new capital early on, as to be ready when future demand materializes. However, this may be the wrong focus. Instead, it may be that good technological news in fact reduces the incentives to accumulate capital and instead favors a rapid depreciation of the current capital stock through increased utilization. In such a case, the induced increase in utilization could itself cause a boom. This alternative view of how news may affect the economy is most clearly captured in the work of Jaimovich and Rebelo (2009), and has the attractive feature that it can easily overcome some of

[76] In the model of section 2, we completely eliminate this interest rate effect by allowing for home production.

[77] This is the mechanism used in Beaudry and Portier (2004).

[78] See Beaudry, Collard, and Portier (2011) for an example along these lines.

the challenges faced by our preferred perspective, which relies on news increasing the incentive to accumulate capital during the anticipation stage.

In Jaimovich and Rebelo (2009), news is introduced in a quite standard one-sector representative agent business cycle model. The model includes two important elements: variable capacity utilization and adjustments costs to investment,[79] which are both quite reasonable assumptions. These two elements interact in a way that can give rise to news-driven business cycles where the main effect of the news is to encourage quicker capital depreciation today, as opposed to increasing the incentive for capital accumulation. The quicker capital depreciation results from an increased utilization rate which favors producing more today and thereby causing a boom. Since Jaimovich and Rebelo (2009) study the properties of the Walrasian equilibrium, equilibrium outcomes can be presented as the solution to a social planner's problem. In particular, the social planner's problem in their setup takes the following form

$$\max_{\{C_{t+i}, K_{t+1+i}, L_{t+i}, \mu_{t+i}\}_{i=0}^{\infty}} E_t \sum_{i=0}^{\infty} U(C_{t+i}, L_{t+i}),$$

$$\begin{aligned} \text{s.t } C_{t+i} + K_{t+1+i} &= F(\mu_{t+i} K_{t+i}, L_{t+i}, \theta_{t+i}) \\ &\quad + (1 - \delta(\mu_{t+i}))K_{t+i} \\ &\quad - \frac{\psi}{2}(I_{t+i} - I_{t-1-i})^2, \\ I_{t+i} &= K_{t+1+i} - (1 - \delta(\mu_{t+i}))K_{t+i}, \end{aligned}$$

where the depreciation rate of capital $\delta(\mu_{t+i})$ is an increasing function of utilization rate μ_{t+i}, and where $\psi(I_{t+i} - I_{t-1-i})^2$ captures the adjustment cost to investment.[80, 81] Let us again assume that agents get news one period in advance about θ, where $\theta_{t+1} = \rho\theta_t + \epsilon_t$, with ϵ_t being the news received at time t about technology at $t + 1$. To simplify this problem, and allow easy comparison with the framework we have already set out, it is useful again to summarize the future using a continuation value function. Given this setup, the expected continuation value function will depend on the capital stock coming into the period, last period's investment rate, last period's state of technology and the news (regarding innovation in next period's technology), so that the optimization problem becomes:

$$\max_{\{C_t, K_{t+1}, I_t, L_t, \mu_t\}} U(C_t, L_t) + V(K_{t+1}, I_t, \Theta_t, \epsilon_t),$$

$$\begin{aligned} \text{s.t. } C_t + K_{t+1} &= F(\mu_t K_t, L_t, \theta_t) \\ &\quad + (1 - \delta(\mu_t))K_t \\ &\quad - \frac{\psi}{2}(I_t - I_{t-1})^2, \\ I_t &= K_{t+1} - (1 - \delta(\mu_t))K_t. \end{aligned}$$

The equilibrium outcomes for $C_t, K_{t+1}, \mu_t, L_t, I_t$ is then given implicitly as the solution

[79] Jaimovich and Rebelo (2009) also emphasize a preference structure that minimizes wealth effects on labor supply. While this feature is important for the quantitative aspects of their model, it is not central to its qualitative properties and therefore, we will not emphasize it much here.

[80] In Jaimovich and Rebelo (2009), news about both labor-augmenting technological change and investment-specific technological change are allowed. For simpler exposition, here we focus only on news about labor-augmenting technological change.

[81] As in the case of labor adjustment costs, the empirical literature suggests that nonconvex costs to capital adjustment are also important (Cooper and Haltiwanger 2006). Furthermore, the flow specification of adjustment costs (cost to the change of investment and not of capital) is also quite debatable, as it seems not to be found significant in empirical studies (Groth and Khan 2007).

to the following equations plus the two constraints above

$$F_{\mu}(\mu_t K_t, L_t, \theta_t) = K_t \delta_{\mu}(\mu_t) \frac{V_K(K_{t+1}, I_t, \Theta_t, \epsilon_t)}{U_C(C_t, L_t)},$$

$$\frac{V_I(K_{t+1}, I_t, \Theta_t, \epsilon_t)}{U_C(C_t, L_t)}) = \psi(I_t - I_{t-1}) + \left(1 - \frac{V_K(K_{t+1}, I_t, \Theta_t, \epsilon_t)}{U_C(C_t, L_t)}\right),$$

$$\frac{-U_L(C_t, L_t)}{U_C(C_t, L_t)} = F_L(\mu_t K_t, L_t, \theta_t).$$

The first of these equations is the optimality condition for the setting of the utilization rate μ_t. It states that the utilization rate should be chosen such that its marginal productivity is equal to the marginal cost, where this cost is high if $V_K(\cdot)$ is high. So the effects of news on utilization depends on how ϵ_t affects $V_K(\cdot)$. In this model, it is the case that positive news about tomorrow's technology (i.e., an increase in ϵ_t) will generally be associated with a fall in $V_K(\cdot)$, because the economy is more productive in the future. In other words, good technological news in the setup proposed by Jaimovich and Rebelo (2009) reduces the incentives of agents to accumulate capital. However, due to the adjustment costs to investment, it creates an incentive to increase investment.[82] These two forces may, at first pass, appear contradictory, but with variable capacity utilization the two incentives can be met by increasing capacity utilization in response to the news, thereby reducing the capital shock while simultaneously having high investment. Hence, the first-order effect of positive news in this setup is to increase capacity utilization. Since labor is assumed to be complementary to capital services, this leads to an increase in labor demand and an expansion in the economy.[83] Because $V_K(\cdot)$ is lowered by the news and $V_I(\cdot)$ is increased, the expansion will be associated with an increase in both consumption and investment. The more difficult effect to sign in the model is the effect of the news on the capital stock taken into next period. Here there are offsetting effects. The increase in utilization tends to decrease K_{t+1}, while increased investment tends to increase it. The net effect depends on the precise parameters of the model. In our experience, the most standard parameterization causes a decrease in K_{t+1}, reflecting the direct effect of the news, which is to decrease the value to holding capital next period.

Jaimovich and Rebelo's (2009) model thereby offers an alternative perspective on how technological news may affect the economy. In contrast to a narrative based on a stronger incentive to accumulate and install new capital (or start new firms), their narrative is based on the inverse incentive, one where there is an incentive to decrease capital in response to news by increasing the utilization rate. This mechanism becomes more forceful when one considers news about technological change that directly affects the future production of capital, and they emphasize this in their paper. One of the very attractive features of Jaimovich and Rebelo's (2009) mechanism is that it fits very nicely within the confines of standard quantitative DSGE models.

One dimension where the implications of the Jaimovich and Rebelo (2009) model differ substantially from the one we presented at the beginning of this paper relates to the state of the economy after a period where agents falsely anticipated fast technological progress. In Jaimovich and Rebelo's (2009)

[82] The same mechanism is also found in Floden (2007).

[83] In contrast to the Barro and King (1984) observation, both consumption and employment increase in this case because the increased capacity utilization acts like an increase in current productivity.

setup, the economy will generally arrive in such a state with a low capital stock due to the high depreciation induced by the news, and therefore on realizing their errors, agents will want to start rebuilding this stock. Hence, prediction errors in the Jaimovich and Rebelo (2009) setup are unlikely to lead to a recession induced by liquidation incentives. Looking at the relevance or not of liquidation forces after a speculative boom seems to be a fruitful area to evaluate these different views.

4.2 *Evaluating the Relevance of News Using Structural Models*

The are two main approaches that have been used for evaluating the relevance of news using structural models. The first focuses on a set of facts of interest, then asks whether a model with news can explain such observations. The second starts from a model with many shocks and examines the relative role of news in explaining the general properties of the data. In this section, we will discuss both types of contributions in sequence.

4.2.1 *Can News Explain Recessions and Excessive Booms?*

One of the key features of U.S. macroeconomic data is the presence of recessions; that is, the existence of periods where we observe broad-based declines in economic activity. There are many proposed explanations in the literature for recessions, including contractions in monetary policy, increases in oil prices and technological regress. The news view of business cycles offers an alternative perspective on recessions—one that can be referred to as a fall in aggregate demand induced by a revision in expectations. The question of whether technological news can help explain recessions is a central focus of the papers by Beaudry and Portier (2004) and Jaimovich and Rebelo (2009). There are many similarities in how these papers explain recession; in particular, both papers rely on noise shocks as a central force causing the recession.[84] However, the mechanisms in the paper are quite different, which leads to somewhat different implications.

In Beaudry and Portier (2004), recessions are presented foremost as liquidation cycles. The narrative is essentially the one given in section 2 of the paper. Recessions arise after a period of fast capital accumulation, where the expectations driving the expansion are eventually revised downward because agents were reacting to noise, as opposed to valid news. Once agents realize that they have been overly optimistic about future prospects, economic activity drops and remains depressed until the excess capital accumulated during the anticipation stage is depleted. The model has a two-sector structure, where capital and technological change in the consumption sector are strong complements. This complementarity allows for news about future technological change to create a demand for capital, and the two-sector structure assures that consumption does not fall in response to the increased investment demand. The technological change in the model is set up to always be positive, so as to rule out technological regress as a force behind recessions. Agents receive signals about future productivity growth, which forces them to solve a signal-extraction problem in order to form expectations of the economy's future needs in terms of capital. The effects of news and noise are examined for the Walrasian equilibrium of the model with no nominal rigidities.[85] The parameters of the model are

[84] Rodriguez Mora and Schulstad (2007) found evidence of news/noise phenomenon in the fact that official estimates of gross national product are substantially revised over time and that, once announcements are taken into account, the true value of GNP growth at time t has no predictive power in determining growth at any future time. All the predictive power lies in the announcements, and not in the true level of growth.

[85] See Hairault, Langot, and Portier (1997) for an early attempt to introduce news and noise in an otherwise standard estimated *RBC* model.

obtained by a combination of calibration and estimation (a simulated method of moment estimation). In particular, the parameters of news and noise processes are estimated, since it is unclear how far ahead of time agents get information regarding future technological progress and how precise signals are. The estimated parameters are set to minimize the distance between model-generated and data-generated standard business cycle moments. The best fit of the model arises when agents receive information five quarters ahead of actual technological progress and when signals are correct 82 percent of the time. Given the estimated parameters, the paper then evaluates the extent to which the model produces recessions that are similar to the ones observed in the data. In particular, the paper looks at whether the estimated model reproduces the frequency, depth, and duration of U.S. recessions. The main result of the paper is to show that such a model is capable of explaining recessions of the right size and duration in a Walrasian setting without needing technological regress. Note that the results rely heavily on the estimation of a very strong degree of complementarity between capital and technological change in the consumption good sector.

Jaimovich and Rebelo's (2009) paper shares many of the features and goals of Beaudry and Portier's (2004) paper. For example, they also explore the extent to which a Walrasian model with news and noise can explain recessions without relying on technological regress.[86] The main difference between the two papers are the mechanisms relating news to economic activity. In Jaimovich and Rebelo's (2009) model, the main force driving a recession remains the realization that past expectations were overly optimistic, and that the downward revision of expectation changes behavior. However, the recession does not arise after a period of fast capital accumulation. Instead it arises after a period of fast capital depreciation (with positive gross investment but negative net investment) induced by high-capacity utilization. The original news favors fast depreciation, as producing capital in the future is expected to be less costly. Hence, in this model the recession is not associated with liquidation. Instead, the recession simply arises due to the downward revision in future wealth which leads to a fall in consumption, a reduction in capital depreciation and a fall in gross investment. Jaimovich and Rebelo (2009) show that a reasonably calibrated version of their model is capable of reproducing important features of economic downturns without needing to rely on the liquidation forces emphasized in Beaudry and Portier (2004). As mentioned previously, an attractive feature of Jaimovich and Rebelo's (2009) paper is that it builds on a model environment that is commonly used in the DSGE literature.

The paper by Christiano et al. (2010) moves away from the recession focus and instead examines the role of news in generating excessive expansions. In particular, they argue that standard monetary policy rules are not well designed and that focusing on stabilizing inflation when an expansion is driven by news can lead to excessive output growth. The paper is motivated by the observation that many expansions, especially those with strong stock market booms, are simultaneously associated with periods of below-trend inflation. The goal of their model is to show how news can explain such a pattern. To this end, they take a sticky price model in the New Keynesian tradition (similar to that in Christiano, Eichenbaum, and Evans 2005) and add technological news. Agents in their model receive information ahead of time about innovations to *TFP*. On receiving

[86] The reason these papers focus on explaining recessions in an environment where technological regress does not arise is that models that do rely on technological regress to explain recessions are viewed by most macroeconomists as rather unconvincing.

the news, agents foresee an expansion of the economy and, given the smoothing tendencies of monetary policy, they predict inflation to be low in the future. This prediction of low future inflation leads firms to immediately set lower prices as a means of adjustment in a sticky price world. The change in current pricing behavior in turn causes current inflation to fall. When the monetary authorities see current inflation fall, they react by decreasing interest rates and stimulating the economy. As a result of the stimulative policy, the economy starts experiencing a boom on the arrival of the news.[87] Note that the model is such that, in the absence of sticky prices, news should have caused a recession by favoring an increase in consumption and a decrease in labor supply. Accordingly, the expansion that arises ahead of the actual change in technology is excessive and suboptimal in this setup. The optimal monetary policy would actually be to increase interest rates in response to the news instead of letting them fall. To look at the relevance of this mechanism, the authors use a carefully calibrated New Keynesian model and show that it can replicate the subtrend behavior of inflation observed in many expansions. The model delivers a boom in both activity and stock prices following news, while at the same time producing a fall in inflation of a magnitude similar to that documented in the motivation section of the paper. The authors also discuss how monetary policy could be improved so as not to let news generate an excessive expansion. By showing how news and monetary policy can interact to create unwarranted booms, the paper makes a very important contribution to both our understanding of macroeconomic fluctuations and to the design of optimal policy. For example, the paper suggests that a measure of credit could be added to a standard rule, and that increasing interest when credit expands will allow monetary authorities to get closer to the optimal policy.

4.2.2 *Letting News Compete with Other Shocks Using Structural Models*

One means of evaluating the relevance of news in macroeconomic fluctuations is to consider a fully specified DSGE model where there are both conventional shocks and news shocks, and then use an estimated version of such a model to calculate the fraction of output or hours variation that is due to news. Such an exercise has been performed, among others,[88] by Schmitt-Grohé and Uribe (2012); Fujiwara, Hirose, and Shintani (2011); and by Khan and Tsoukalas (2012).

Schmitt-Grohé and Uribe (2012) performed their exploration within a real setting, while the two others work within a New-Keynesian environment with sticky prices. In all three cases, the models are estimated using Bayesian methods.[89] Schmitt-Grohé and Uribe (2012) consider an environment similar in structure to that

[87] Fujiwara (2008) shows that positive comovements are harder to obtain in such a model when the *TFP* process is non stationary.

[88] Davis (2007) is estimating a model closely related to Christiano, Eichenbaum, and Evans (2005) with news shocks and an emphasis on the term structure. Born, Peter, and Pfeifer (2011) analyzes the contribution of anticipated capital and labor tax shocks to business cycle volatility in an estimated New Keynesian DSGE model. Milani and Treadwell (2012) estimate a New Keynesian model that incorporates news about future policies to try to disentangle the anticipated and unanticipated components of policy shocks. They show that news shocks play a larger role in influencing the business cycle than unanticipated policy shocks. Perendia and Tsoukis (2012) incorporate a fiscal rule in the Smets and Wouters (2007) model and study the impact of news shocks, modeled as revisions of expectations in the consumption Euler equation. Milani and Rajbhandari (2012a) run a horserace in a DSGE model in which expectations are either rational with or without news, formed with adaptive learning or taken from observed survey. See Milani (2012) for a survey of the various way of modeling expectations in DSGE models.

[89] Schmitt-Grohé and Uribe (2012) also use maximum likelihood.

presented in Jaimovich and Rebelo (2009),[90] while Fujiwara, Hirose, and Shintani (2011) and Khan and Tsoukalas (2012) use a model more closely related to that of Smets and Wouters (2007); Christiano, Eichenbaum, and Evans (2005); and Christiano et al. (2010). Schmitt-Grohé and Uribe (2012) allow for seven sources of shocks, and for each shock they allow for an unexpected component, a component that is known to agents four quarters in advance, and a shock that is known to agents eight quarters in advance.[91] So in total there are twenty-one types of shocks in their model. Their main finding is that news shocks account for close to 50 percent of output fluctuations. However, it should be noted that relevance of news regarding technology innovations is rather limited, with most of the effects of news they report being associated with news about preference shocks and news about wage mark-up shocks. This result is echoed in Khan and Tsoukalas (2012). Although the setup is different, Khan and Tsoukalas (2012) also find that technological news plays a very limited role in business cycle fluctuations. Fujiwara, Hirose, and Shintani (2011) find a slightly greater role for technological news in driving fluctuations than in Khan and Tsoukalas (2012), even if the two environments are very similar. The difference is likely due to the fact that Fujiwara, Hirose, and Shintani (2011) do not allow for news about nontechnological factors, and they do not allow for a shock to the marginal efficiency of investment (which is a shock that Justiniano, Primiceri, and Tambalotti 2010 and 2011 have argued plays an important role in fluctuations). Overall, the literature based on estimating fully specified DSGE models with many shocks provides very little support to the idea that technological news may be a key driver of fluctuations. One criticism of the literature, since it may indicate misspecification, is that it attributes a very large fraction of hours variance to wage markup shocks (either of the unanticipated or anticipated variety). For example, in Schmitt-Grohé and Uribe (2012), 69 percent of hours fluctuations are due to wage markup shocks, in Fujiwara, Hirose, and Shintani (2011) it is close to 80 percent and in Khan and Tsoukalas (2012) it is 60 percent. As wage markup shocks are considered by many to be an unconvincing explanation to hours fluctuations, this raises the question of how the results from such an approach should be interpreted.

In the set of papers examined, only Schmitt-Grohé and Uribe (2012) include stock prices in the information set for the estimation, although VAR analysis suggest that such a variable is crucial for identification of news. Furthermore, the response of stock prices to news shocks allows discrimination between models, as models built on Jaimovich and Rebelo (2009) will typically generate countercyclical Tobin's q,[92] while some sticky price models or models with varying gains from trade (Beaudry and Portier 2013) will generate procyclical sock prices. Additional research needs to be done to estimate DSGE models with information on asset prices.

[90] Avdjiev (2011) repeats Schmitt-Grohé and Uribe (2012) with the inclusion of asset prices in the dataset.

[91] Leeper and Walker (2011) study the property of Schmitt-Grohé and Uribe's (2012) estimated framework when news are "correlated." Let z be an exogenous variable. Instead of assuming a process of the type $z_t = \rho z_{t-1} + \sum_{q=0}^{Q} \varepsilon_{q,t-q}$ where ε_q is the news that arrives q period ahead, they assume a process of the form $z_t = \rho z_{t-1} + \sum_{q=0}^{Q} \zeta_q \varepsilon_{t-q}$ where the ζ_q are real numbers. They show that "correlated news" generates hump-shaped responses.

[92] In an unpublished version of their article, Jaimovich and Rebelo (2009) note that the observed stock price is an average q, not a marginal one. They provide an increasing returns version of their model in which the (observed) average q is procyclical, and therefore fits the data, although the (unobserved) marginal q is countercyclical.

4.2.3 *Examining the Importance of Noise*

Although the papers by Schmitt-Grohé and Uribe (2012); Fujiwara, Hirose, and Shintani (2011); and Khan and Tsoukalas (2012) allow for very many shocks, they do not allow for noise shocks. In all three cases, news takes the form of perfect information about different components of future innovations. In contrast, part of the attraction of the news view of fluctuations is that it can give rise to periods where the economy is reacting to invalid information due to noise in agents' signal extraction problem. In response to such a noise shock, the economy will likely go through a period of inappropriate decisions in terms of consumption and investment. The net effect of a noise shock would be temporary, but possibly long lived. These properties of noise shocks have motivated researchers to search for ways of evaluating their relevance in fluctuations. While noise shocks are present in both the papers of Beaudry and Portier (2004) and in Jaimovich and Rebelo (2009), neither paper tried to quantify the precise relevance of noise in generating overall business cycles, as both papers focused mainly on understanding recessions using news shocks containing noise. The main focus of the papers by Blanchard, L'Huillier, and Lorenzoni (2009) and by Barsky and Sims (2012) is to quantify the relevance of noise shocks in fluctuations. However, Blanchard, L'Huillier, and Lorenzoni (2009) show that VAR methods cannot be used to evaluate the effects of noise shocks because of a fundamental noninvertibility problem, and for this reason it is necessary to adopt a structural estimation approach when addressing this question. Before discussing the application of structural methods to the evaluation of noise shocks, it is helpful to indicate why VAR approaches cannot be used to quantify their relevance, while more structural methods can. In particular, we want to show that the nature of the invertibility problem associated with noise shocks is different from the one we previously discussed in section 3 and may be considered more problematic.

To understand the problem of identifying noise stocks, consider a very simple environment where we have an agent that controls a decision y_t and faces a signal extraction problem. The signal extraction problem is the key element which will cause the noninvertibility problem. The exogenous driving force, denoted θ_t, at the heart of the signal extraction problem has a temporary component and a persistent component as given by

$$\theta_t = \epsilon_t + \nu_t + (1+\alpha)\epsilon_{t-1}, \tag{44}$$

where ϵ_t and ν_t are mean zero iid Gaussian processes with variances σ_ϵ^2 and σ_ν^2. Now suppose the agent's optimal decision is of the form

$$y_t = E[\theta_{t+1} \mid \Omega_t], \tag{45}$$

where Ω_t is the agent's information set at time t. The agent's optimal decision is simply to set y_t to match his expectation of θ_{t+1}. To introduce the signal extraction problem, let us suppose that the agent's information set at t is composed of θ_t, ϵ_{t-1}, and ν_{t-1}, that is, the agent at time t does not see ϵ_t and ν_t separately but instead must infer their values from his knowledge of θ_t and ϵ_{t-1}. ν_t is qualified as noise because it blurs the observation of the persistent shock ϵ. In this case, the agent's expectation of θ_{t+1} will be given by

$$\begin{aligned} E[\theta_{t+1} \mid \Omega_t] &= \psi(1+\alpha)(\theta_t - (1+\alpha)\epsilon_{t-1}), \\ \psi &= \frac{\sigma_\epsilon^2}{\sigma_\epsilon^2 + \sigma_\nu^2}. \end{aligned} \tag{46}$$

The structural moving average representation for θ_t and y_t can then be written in matrix form as

$$(47)\quad \begin{pmatrix}\theta_t\\ y_t\end{pmatrix} = \begin{pmatrix}1 & 1\\ (1+\alpha)\psi & (1+\alpha)\psi\end{pmatrix} \times \begin{pmatrix}\epsilon_t\\ \nu_t\end{pmatrix} + \begin{pmatrix}(1+\alpha) & 0\\ 0 & 0\end{pmatrix} \times \begin{pmatrix}\epsilon_{t-1}\\ \nu_{t-1}\end{pmatrix}.$$

The problem with this moving average representation is that the impact matrix is singular, which implies that it is not invertible. Hence, this process cannot be written as a VAR with innovations that are linear combinations of ϵ_t and ν_t. In other words, if one estimates a VAR on these two variables, the innovations of the VAR will not be linear combinations of the structural shocks ϵ_t and ν_t and therefore, there is no orthogonalization of the VAR innovations that will recuperate the structural innovations. Since VAR-based methods reduce to choices of orthogonalization, they cannot be used to evaluate the respective roles of ϵ_t and ν_t in generating movements in y_t. Note that the singularity of the impact matrix is a direct and robust consequence of the signal-extraction problem, since it derives from the fact that the agent's decision variable and the observed signal move in proportion to each other. It is not per se related to the news structure of the model. To see this, consider first the case where the forcing variable is not news rich, i.e., $-1 < \alpha < 0$. It is clear from the inspection of (47) that the impact matrix is singular, even absent of a news component. Second, consider a situation where the forcing process is news rich, $\alpha > 1$, but in which ε_t and $\nu - t$ are separately observable, and therefore both elements of Ω_t. In such a case, $y_t = E[\theta_{t+1} \mid \Omega_t] = (1+\alpha)\varepsilon_t$ and the model solution can be written as:

$$\begin{pmatrix}1 & \frac{-1}{1+\alpha} - L\\ 0 & 1\end{pmatrix}\begin{pmatrix}\theta_t\\ y_t\end{pmatrix} = \begin{pmatrix}0 & 1\\ 1+\alpha & 0\end{pmatrix}\begin{pmatrix}\varepsilon_t\\ \nu_t\end{pmatrix},$$

which can be solved for the structural shocks to give

$$\begin{pmatrix}\varepsilon_t\\ \nu_t\end{pmatrix} = \begin{pmatrix}0 & \frac{1}{1+\alpha}\\ 1 & \frac{-1}{1+\alpha} - L\end{pmatrix}\begin{pmatrix}\theta_t\\ y_t\end{pmatrix}$$

Even if the forcing process is news rich, the two structural shocks are fundamental as they can be expressed as current and past values of the observable variables. Let us now go back to the problem when the information set is the one of Blanchard, L'Huillier, and Lorenzoni (2009). While the presence of a signal extraction problem generally makes VAR-based methods inappropriate for recuperating structural shocks,[93] the structural shocks can be recovered using other methods. For example, in the case at hand, the three parameters of the model—α, σ_ϵ^2, and σ_ν^2—can be recovered by a simple method of moments approach which equates the variance of θ_t, the variance of y_t and the first order autocorrelation of θ_t to its model counterpart.[94] With these parameters in

[93] Forni et al. (2013b) propose to achieve identification by means of dynamic rotations of the reduced form residuals in such a case of nonfundamentalness. While a contemporaneous linear combination of the VAR residuals cannot deliver the structural shock, a dynamic combination, i.e., a combination of present and future residuals, can. They show that, once the reduced form VAR has been estimated, the structural shocks and the corresponding impulse response functions can be obtained by applying Blaschke transformations to the residuals and the reduced-form impulse response functions. In simple words, structural shocks are recovered as function of *future* reduced form ones, not current ones. The same idea is applied in Forni et al. (2013a) in the context of an asset price model.

[94] Even when the solution is fundamental, it is possible that the model's parameter cannot be identified when news shocks hit the economy, as shown by Sorge (2013).

hand, then the noise shock in the agents decision problem, which in this case is ν_t, is then calculated as

$$(48) \qquad \nu_t = \frac{y_t}{\alpha\psi} + \frac{y_{t+1}}{\alpha^2\psi} - \frac{\theta_{t+1}}{\alpha},$$

$$\psi = \frac{\sigma_\epsilon^2}{\sigma_\epsilon^2 + \sigma_\nu^2}.$$

Note that the calculation of ν_t uses information at $t+1$, which is not available to the agents at t, which in part explains why it can't be recuperated by a VAR.

The papers by Blanchard, L'Huillier, and Lorenzoni (2009) and by Barsky and Sims (2012) aim at evaluating the effects of noise shocks and have many similarities. Both consider a New Keynesian environment in which the representative agent receives noisy signals about future productivity growth. They also both use a moment-matching approach to examine the role of the noisy signal in generating business cycle fluctuations.[95] However, the two papers arrive at quite different conclusions. On the one hand, Blanchard, L'Huillier, and Lorenzoni (2009) find that noise shocks account for a large fraction of the higher-frequency movement in consumption and output. On the other hand, Barsky and Sims (2012) find that noise (which they refer to as animal spirits) plays a very minor role even though they attribute a substantial fraction of fluctuations to news. While there are many small differences between these two studies that likely contribute to the different findings, we believe that the key difference relates to the nature of the signal extraction problem. The information problem faced by agents in Blanchard, L'Huillier, and Lorenzoni (2009) is much more intense than that faced by agents in Barsky and Sims (2012). In both cases, agents are trying to forecast future technology based on past information and a signal, but in Blanchard, L'Huillier, and Lorenzoni's (2009) formulation agents have much less information than in Barsky and Sims's (2012) formulation, and so learn at a lower speed. It is the slow learning speed that allows noise to have large effects. To see this most clearly, let us denote the technology index at time t by θ_t. Then the growth in θ_t in both papers can be written as

$$\Delta\theta_t = \sum_{i=0}^{\infty} \rho_1^i \epsilon_{1t-i} + \epsilon_{2t} + (\rho_2 - 1)\sum_{i=0}^{\infty} \rho_2^i \epsilon_{2t-i-1},$$

where ϵ_{1t} and ϵ_{2t} are mean zero i.i.d. processes, with $0 \le \rho_1 < 1$ and $0 \le \rho_2 \le 1$. If $\rho_2 < 1$, this is a process with both permanent and temporary shocks to the level of θ_t, with both shocks having prolonged effects of the growth rate. In the special case where $\rho_2 = 1$, the process is one with a random walk component driven by ϵ_{1t}, and where ϵ_{2t} has only a one-period effect on the growth rate. Barsky and Sims (2012) consider this latter special case, while Blanchard, L'Huillier, and Lorenzoni (2009) consider the more general case allowing ρ_2 to be estimated.[96] However, since Blanchard, L'Huillier, and Lorenzoni (2009) estimate ρ_2 to be rather close to one, this is not where the two differ most. The main difference relates to the nature of the signal. Blanchard, L'Huillier, and Lorenzoni (2009) endow agents with a noisy signal of ϵ_{1t}, while Barsky and Sims (2012) endow agents with a noisy signal of $\sum_{i=0}^{\infty} \rho_1^i \epsilon_{1t-i}$. Hence, in Barsky and Sims (2012) agents know more and therefore learn very quickly what forces are affecting a_t and accordingly do not make

[95] Blanchard, L'Huillier, and Lorenzoni (2009) also use a maximum likelihood method.

[96] The first section in Blanchard, L'Huillier, and Lorenzoni (2009) focuses on a special case where $\rho_1 = \rho_2$. In this special case, the univariate process for θ_t can be a random walk.

very persistent mistakes. This explains why the noise in agents' signals is not found to explain business-cycle-type movements. In contrast, agents in the Blanchard, L'Huillier, and Lorenzoni (2009) setup have rather limited information and learn much more slowly, which allows noise to have very persistent effects on their behavior. Accordingly, in Blanchard, L'Huillier, and Lorenzoni (2009), agents can be mistaken about their interpretation of the environment for long periods of time, which explains why, in their framework, noise shocks can be found to have substantial effects on fluctuations. In summary, the evaluation of the role of noise shocks in fluctuations seems to depend critically on the nature of the information-processing problem assumed to be faced by agents. If the problem is not too difficult, agents will learn quickly and noise will have very temporary effects, while if the information-processing problem is very difficult, then noise has the potential to have important effects. Building and estimating models that embed the two possibilities, and letting the data decide on the best approach, appears needed to make further progress on the issue.

5. *Frontiers and Concluding Comments*

There are many questions that a news view of business cycles raises that have only begun to be explored.

Although most of the literature has focused on a closed economy setting, extensions to an international setting have been developed. Among the papers that have examined news-driven business cycles in an international setting are Devereux and Engel (2006); Jaimovich and Rebelo (2008); Matsumoto et al. (2008); Corsetti, Dedola, and Leduc (2009); Den Haan and Lozej (2010); Fratzscher and Straub (2010); Beaudry, Dupaigne, and Portier (2011); Sakane Kosaka (2013) and Lambrias (2013). Fluctuations in the future growth prospects have implications on the current account of an economy, as good news typically imply a current account deficit. This link is explored by Cao and L'Huillier (2012) and Hoffmann, Krause, and Laubach (2013). Adding financial frictions, Gunn and Johri (2013b) explore the possibility that changing expectations about future sovereign default themselves can lead to financial stress (as measured by credit spreads) and recessionary outcomes. Changes in expectations are modeled in the "news-shock" framework, as sovereign debt-holders receive imperfect signals about the portion of debt that a sovereign may default on in the future.

The role of financial market imperfections in propagating and amplifying the effects of news appears extremely promising, as suggested by the work of Jermann and Quadrini (2007); Kobayashi and Inaba (2006); Kobayashi and Nutahara (2007); Chen and Song (2013); Kobayashi, Nakajima, and Inaba (2012); Guo (2011); and Walentin (2009). Therefore, pursuing this line further may have great promise for our understanding of macroeconomic fluctuations. One example is given by the recent work of Gunn and Johri (2013a). The authors examine a situation with financial intermediation where the news relates to changes in the technology of the banking sector. They use the model to examine, among other things, the behavior of credit spreads leading up to the financial crisis of 2008. Görtz and Tsoukalas (2011) have developped a two-sector DSGE model with financial intermediation. They find that news about future capital quality is a significant source of aggregate fluctuations, accounting for around 37 percent in output variation in cyclical frequencies.

Extensions to housing price dynamics have also been considered in the recent years. Lambertini, Mendicino, and Punzi (2010) analyzes housing market boom–bust cycles driven by changes in households' expectations. Lambertini, Mendicino, and Punzi (2011) study the potential gains of monetary and macroprudential policies that lean against news-driven boom–bust cycles in housing prices and credit generated by expectations of future macroeconomic developments. Kanik and Xiao (2011) propose a model based on the work of Iacoviello (2005) and Iacoviello and Neri (2010). They construct a general equilibrium model in which credit-constrained borrowers use their housing assets as collateral to finance their purchases. Optimistic news raises these agents' expected future net worth, expands their borrowing capacity, and allows them to purchase more housing and consumption goods. Higher housing demand raises housing prices and creates a housing boom. Gomes and Mendicino (2012) also extend Iacoviello and Neri's (2010) model of the housing market to include news shocks and estimate it using Bayesian methods and U.S. data. On the empirical side, Soo (2013) develops a measure of sentiment across local housing markets by quantifying the positive and negative tone of housing news in local newspaper articles. She finds that this housing sentiment index forecasts the boom and bust pattern of house prices at a two year lead, and can predict over 70 percent of the variation in aggregate house price growth.

Some historical episodes are particularly interesting to look at from a news-shock perspective. The Japanese economy in the 1990s is such an episode. Beaudry and Portier (2005) identify a series of downward revisions of growth in the early 1990's. Portier (2006) shows how a downward revision of growth prospects can explain the main patterns of the Japanese "lost decade" in a sticky price model with a zero lower bound or in the flex price model of Beaudry and Portier (2004). Tyers (2012) reviews the claimed sources of Japan's stagnation, and identify error-prone forward-looking expectations as the main cause of the boom and bust cycle of the late 1980s and early 1990s. This is confirmed by the studies of Ko, Miyazawa, and Vu (2012) and Karnizova (2013).[97]

One of the areas that appears to us especially promising is to exploit the synergies between the literature of dispersed information and social learning with the literature on news.[98] One important paper that has pursued this line of research is Lorenzoni (2009). As emphasized in Lorenzoni (2009), dispersed information tends to substantially slow down the capacity of agents to infer or learn the state of the economy, and this allows noise shocks to have long-lasting effects on economic activity. More generally, if agents are trying to infer the future state of the economy by looking at current economic activity, this could give rise to important feedback effects that come close to creating self-fulfilling prophesies. For example, if a subset of agents start to hire and produce more because they are optimistic about the future, and others look at aggregate activity to form their expectations, this will have a reinforcing effect which could spark and sustain a prolonged boom before the reality of the situation is properly inferred. [99] This type of narrative is very close to that given in Pigou (1927). Another step is made by Angeletos

[97] See also Karnizova (2012) for an account of the 1995–2003 U.S. boom–bust cycle with unrealized *TFP* news estimated from the data. More generally, whether news shocks amplify or not fluctuations has been studied by Fève, Matheron, and Sahuc (2009) in an abstract framework, by Wohltmann and Winkler (2009) and Winkler and Wohltmann (2012) within the Smets and Wouters' 2003 model and by Matsumoto et al. (2011).

[98] The literature on dispersed information and social learning is vast. Important contributions include Zeira (1987), Zeira (1994), Banerjee (1992) and Chamley and Gale (1994). See also the excellent books by Chamley (2004) and Veldkamp (2011). Lorenzoni (2011) proposes a survey of models with news shocks, with a particular focus on the different assumptions about the agents' information structure.

[99] Nimark (2013) considers the model structure of Lorenzoni (2009) and enriches it by assuming that information structures in which some types of signals ("man-bites-dog" signals) are more likely to be observed after unusual events.

and La'O (2010), who develop a theory of fluctuations in a unique-equilibrium, rational-expectations, macroeconomic model, but that accommodate the notions of "animal spirits" and "market sentiments." They introduce trading frictions and imperfect communication between agents that receive heterogeneous information about the aggregate shocks hitting the economy. Correlated errors in expectations of the underlying technology shocks act as a demand shock that triggers positive co-movements between employment, output, and consumption. Angeletos and La'O (2013) show that with trading frictions and imperfect communication, correlation in the agents' beliefs of their idiosyncratic economic outcomes creates business cycle fluctuations.

However, building explicit models that capture the richness of dispersed information and social learning and which can be brought to data is still in its infancy, and therefore offers room for productive research.

In conclusion, in this survey we have presented a baseline model of economic fluctuations driven by news, in order to motivate the empirical analysis and the theoretical developments we have reviewed. We hope to have given a comprehensive tour of the contributions to the news view of business cycles. How credible and relevant is the "news view"? At this point in time, it is still hard to say. On one hand, the theoretical literature has clarified many channels by which news can cause booms and busts in aggregate economic activity, the empirical literature has documented several data patterns that support this force as an important contributor to macroeconomic fluctuations, and the underlying narrative is echoed often in the business press. On the other hand, the evidence advanced in support of the news view of business cycles is questioned by many because of invertibility problems, identification issues, and methodological weaknesses. In light of this state of affairs, where should research direct its attention? There are at least two directions that appear promising to us. Exploring further the interaction between news and social learning will likely give new insights about how dispersed information regarding the future evolution of the economy may affect expectations, and thereby cause macroeconomic fluctuations. Pursuing further the use of tight structural methods for evaluating the role of news in fluctuations appears especially fruitful if this approaches builds on environments that do not a priori constrain the role of news, but instead allow the data to decide on its relative importance.

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