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News Shocks and Business Cycles

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The discussion surrounding the recent deep recession seems to have shifted the focus from currently used business cycle models to the standard Keynesian model (by which we mean the "old Keynesian," as opposed to the new Keynesian, model). In the Keynesian model, pessimism among consumers and investors about the economy will simultaneously lower aggregate consumption and aggregate investment, as well as aggregate output, through an increase in the rate of unemployment, and more generally through lower capacity utilization. Moreover, in the Keynesian model, pessimism and optimism are not determined within the model—they appear exogenously and they disappear exogenously. The analysis is then about how the economy reacts to these exogenous events. Undoubtedly, there are many indications that consumers and investors seemed pessimistic about their prospects during the recession, but does such pessimism necessitate the reversion back to the Keynesian model? The present article reviews and contributes to a recent strand of the "modern" business cycle literature, i.e., the literature that insists on building a model of the economy that is explicit about its microeconomic foundations and that addresses a related question: Can news shocks generate positive co-movement among our macroeconomic aggregates? An example of a negative news shock would be the sudden arrival of information indicating that future productivity will not be as high as previously thought. Thus, such a shock would generate current pessimism, and yet be grounded in real and fundamental developments. Another kind of news shock would be a government announcement about a policy change to be implemented on a future date (say, that taxes will be raised beginning next year). In this recent literature, thus, optimism and pessimism are examined as determinants of business

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cycle fluctuations, but as add-ons to otherwise microfounded macroeconomic models, and moreover they are tied in a systematic way to anticipated changes in the economy's fundamentals.

Models of business cycles that rely on microeconomic foundations generate fluctuations in economic activity in response to fluctuations in fundamentals, such as preferences, technology, or government policy. The first generations of these models (Kydland and Prescott 1982) relied on technology shocks, i.e., shocks to aggregate productivity; such a shock, if positive and persistent, would raise output directly, via an increase in aggregate employment, and as a consequence raise both consumption and investment, thus generating the kind of co-movement we observe in aggregate time series. Shocks to government expenditures have been considered as well, as have preference shocks (for consumption now versus consumption in the future), though these shocks alone do not easily generate co-movement in the remaining aggregate variables. For example, when government spending rises there is strong pressure on either consumption or investment to fall, unless hours worked (or perhaps capital utilization) rises significantly; hours worked might increase if there is a significant wealth effect in labor supply, but in standard parameterizations the wealth effects are not strong enough.

The new literature begins with Beaudry and Portier (2006, 2007), who analyze time-series data and conclude that news about future productivity may be an important driver of business cycles and then go on to discuss in what model economies news can generate co-movement. We briefly review the data analysis in Section 1. In Section 2, we explain why news shocks, like some other shocks, do not readily generate co-movement in standard neoclassical settings. Beaudry and Portier suggest their own setting, wherein news shocks have the desired effect, but there are other frameworks that generate co-movement in response to news shocks as well. Section 3 describes a very simple setting that we think has most, if not all, of the necessary qualitative effects: the Pissarides (1985) model. This model is a general-equilibrium description of labor markets with search/matching frictions in which unemployment is an equilibrium phenomenon. Capital does not play a major role in the simplest version of the model, though the number of firms, which is endogenous and depends on labor market conditions and on (current and future) productivity, can be given the interpretation of capital, and the creation of new firms can be interpreted as investment. We show that in this model, news about, say, a decline in future productivity—pessimism—will lead fewer firms to enter on impact. Thus, investment falls. Moreover, there is a rise in unemployment, along with a stock market bust, which we measure as the value of the firms in the market. If, in addition, the economy has access to a storage technology, or the economy is open, a fall in consumption can result as well. Thus, the model can generate co-movement in all macroeconomic variables. We then review, in Section 4, other settings proposed in the literature that achieve the same goals, and in Section 5 we offer conclusions.

1. EVIDENCE OF NEWS SHOCKS AND THEIR EFFECTS

Typical Business Cycle Co-Movements

What features of the business cycle might one expect models to capture? Perhaps the key characteristic of the business cycle is the co-movement of broad measures of economic activity. A business cycle expansion typically involves rapid growth of output, consumption, and investment and high levels of employment and hours worked. Another distinguishing feature of business cycles is the frequency of expansions and contractions. Business cycle fluctuations are typically thought to have a frequency of longer than one year but shorter than one decade. Finally, one might ask a model to match the magnitude of business cycle fluctuations in both absolute as well as relative terms. While an ideal model of the business cycle would be accurate along all these dimensions, the focus of the discussion here is on matching co-movements.

VARs and Other Evidence

Much of the interest in news shocks stems from the empirical work of Beaudry and Portier (2006, 2007), who present evidence that news of productivity shocks arrives in advance of actual changes to productivity. Their evidence is based on two structural vector autoregressions (VARs). The VARs use the same two variables, stock prices and total factor productivity (TFP), but they differ in their structural identification schemes. In the first VAR, the authors identify a shock to stock prices that is orthogonal to the current TFP shock. In the second VAR, they use a long-run restriction to identify shocks to long-run TFP. The authors find that the stock price shock from the first VAR and the long-run TFP shock from the second VAR are highly correlated, which suggests that stock market participants are able to predict future innovations to TFP. Information about future economic conditions should be reflected by many forward-looking variables beyond stock prices. Beaudry and Portier (2006) introduce consumption and hours into their VAR system and obtain similar results to their baseline bivariate VAR. Moreover, the authors show that these "news" shocks explain a substantial fraction of movements in consumption, investment, and hours worked at business cycle frequencies.

The empirical relevance of news and other informational shocks for business cycle analysis is an active area of research. Barsky and Sims (2008) consider another forward-looking variable: consumer confidence as measured by the Michigan Survey of Consumers. One of the questions in the Michigan survey asks respondents for their expectations of national economic conditions for the next five years. Barsky and Sims show that consumer confidence is a useful predictor of changes in macroeconomic variables. They consider two interpretations of this finding, which they term the "animal spirits" view and the "superior information" view. The animal spirits view is that consumer confidence, or confidence more broadly, directly causes an expansion of economic activity. The superior information view is that consumer confidence reflects early knowledge of future economic conditions. The authors use a VAR analysis to distinguish between these two possibilities. The key findings are that innovations to confidence are highly correlated with innovations to long-run output and not correlated with transitory innovations to output. These results suggest that the superior information channel is the operative one because output growth that is not associated with increases in potential output, as in the animal spirits view, should be short-lived. These results support the finding of Beaudry and Portier that agents receive signals about productivity changes ahead of the actual change in productivity.

Sims (2009) proposes a method for identifying news shocks that is an alternative to the Beaudry and Portier approach. He estimates a VAR with data on TFP (corrected for capacity utilization), output, consumption, hours, stock prices, inflation, and consumer confidence. The latter two variables are intended to augment the information about future productivity provided by stock prices. After estimating the reduced-form VAR, Sims identifies the unanticipated shock to TFP with the reduced-form innovation to TFP and then identifies the news shock as the linear combination of the reduced-form innovations that best explains the remaining movements in future TFP. The response of the economy to news shocks under Sims's identification is quite different from its response to news shocks under the Beaudry and Portier identification. Sims finds that a favorable news shock leads to an increase in consumption but declines in hours, investment, and output on impact. As we discuss in Section 2, these are the co-movements that the standard real business cycle (RBC) model would predict for a news shock.

Blanchard, L'Huillier, and Lorenzoni (2009) investigate news shocks in a context in which agents are unsure about the exact nature of the innovation to productivity. Their model features permanent shocks to productivity that build up gradually over time as well as transitory shocks to productivity. Agents are not able to observe the two components of productivity separately, but instead observe the level of productivity and a noisy signal about the permanent component of productivity. The noisy signal fluctuates for two reasons: news and noise. Here news shocks are the permanent productivity shocks that because of their gradual effect on productivity, are largely information about future productivity rather than changes in current productivity. Noise shocks, by contrast, are shocks to the signal that are unrelated to changes in productivity. Ideally agents would ignore the noise shocks, but they are unable to fully distinguish between noise and news. The authors assume that agents smooth consumption completely in the sense that they set consumption equal to their estimate of the permanent component of productivity. In response to a permanent productivity shock, consumption responds only gradually because the agents are unsure if the productivity shock is permanent, and over time they revise their estimates in favor of the shock being permanent. In response to a transitory shock or a news shock, consumption responds initially, but over time agents learn that the shock is transitory or nonexistent and consumption returns to its initial level. Importantly, the authors demonstrate that a VAR applied to data on productivity, consumption, and the productivity signal cannot produce impulse responses that match the true ones implied by the model. The reason is that the model posits that consumption is a random walk, and so the VAR, which makes use of current and past observations, cannot identify a shock that has a transitory impact on consumption. If it could identify such a shock, then the agents in the model, who have at least as much information as the econometrician, also would see the transitory dynamics in consumption and would adjust their consumption to eliminate them. Therefore, the consumption response to any shock the econometrician can identify must be flat. Moreover, it is not enough to allow the econometrician to use observations from the future. The problem that arises is related to the invertibility problems discussed by Fernández-Villaverde et al. (2007). When some state variables are hidden from the econometrician, an innovation in the statistical model may either be the result of an economic shock or the result of a discrepancy between the econometrician's beliefs about the state variables and the true state. Only if the econometrician can infer the value of the state with certainty can he or she be certain about what is a shock and what is a "mistake" about the state. Blanchard, L'Huillier, and Lorenzoni show numerically that even with a large amount of data from the future, the econometrician is still uncertain about the state and therefore still uncertain about the shocks that generated the data. While news and noise shocks cannot be identified using VAR analysis, the model can be estimated structurally and information about the shocks can be recovered using the Kalman smoother. By imposing more structure on the data, the authors are able to summarize, but not completely eliminate, the uncertainty about the state variables and the economic shocks. The resulting structural estimates imply that noise shocks are an important source of short-run volatility, accounting for 50 percent of the variance in consumption at a four-quarter horizon. The remaining 50 percent of the variance in consumption is attributable to permanent and transitory productivity shocks in roughly equal measures. The results suggest that the manner by which information about changes in productivity disseminates is an important part of business cycle analysis. An interesting avenue for further research would be to see how the importance of noise shocks holds up in a richer model.

Additional evidence that noise shocks might be factors in aggregate fluctuations comes from the work of Rodríguez Mora and Schulstad (2007). These authors observe that official estimates of gross national product (GNP) are revised over time, and the revisions are often quite substantial. They treat the final estimate of GNP as the true level of activity in a given quarter and the initial estimate as the perception of that level at the time. Their main finding comes from a regression of the true growth in GNP on the true growth and the perception of growth in the preceding quarter. They find that perceptions of growth in the previous quarter are useful in predicting future growth, but the true growth in the previous quarter is not. Moreover, they show that perceptions of growth in the previous quarter affect GNP growth through investment spending rather than consumption or government spending. These results suggest that the evolution of macroeconomic aggregates depends in part on perceptions of economic fundamentals that may not always be correct.

Finally, Schmitt-Grohé and Uribe (2009) investigate the importance of news shocks using a structural estimation approach. These authors estimate an RBC model that incorporates a number of real rigidities and structural shocks. Specifically, they include permanent and transitory shocks to TFP, investment-specific productivity shocks, and government spending shocks. Each of the shocks is composed of innovations that are anticipated at different horizons ranging from zero quarters (unanticipated) to three quarters. Their posterior mode attributes about 70 percent of the variance of output growth to anticipated shocks and the posterior probability that this share is less than 50 percent is essentially zero. Moreover, they find that output, hours, consumption, and investment all increase in response to a positive anticipated transitory shock. However, hours fall in response to a positive anticipated permanent shock. The results in this article strongly support anticipated technology shocks as sources of business cycle fluctuations.

All in all, much of the literature points to news and other informational shocks as potentially important drivers of aggregate fluctuations. However, it is far from clear yet how to best model and identify these disturbances. Relatedly, if one wanted operational measures of news shocks that could be fed into a model and used to predict aggregate economic variables over the near term, how would these shocks be constructed in practice (perhaps based on current events)? The empirical studies discussed above define the shocks as residuals based on an empirical (structural or semi-structural) specification; direct measurement is hard, and estimates via, say, surveys regarding "consumer confidence" would tend to mix news shocks with other shocks. This empirical problem, of course, is shared with, and arguably less severe than in, traditional Keynesian methods.

2. THEORETICAL CHALLENGES

In light of the evidence that changes in TFP can be anticipated to a significant extent, a natural question is to ask how such news shocks play out in the standard real business cycle model. The standard one-sector RBC model has time-additive preferences for consumption and leisure of the form

$$E_0\left[\sum_{t=0}^{\infty}\beta^t u\left(C_t, \bar{H}-H_t\right)\right], \tag{1}$$

where β is the discount factor, $u(\cdot,\cdot)$ is the period utility function, C_t is the flow of consumption, and H_t represents hours worked out of a maximum $\bar{H}$. In the standard model, output is produced according to a constant returns-to-scale production function that combines capital and labor. The stochastic disturbances that drive the business cycle enter through the production function in the form of technology shocks. The most commonly assumed functional form for the production function is Cobb-Douglas, which leads to

$$Y_t = F\left(K_t, H_t, z_t\right) = z_t K_t^{\alpha} H_t^{1-\alpha},$$

with K_t being the stock of capital at the beginning of the period and z_t being the level of technology in period t. Resources evolve according to

$$K_{t+1} = F\left(K_t, H_t, z_t\right) + (1-\delta)\, K_t - C_t. \tag{2}$$

This resource constraint implies that there is a single homogeneous good that is freely used for consumption or as capital.

As the standard model is frictionless, the equilibrium behavior of the economy can be found through solving a planner's problem. The planner chooses stochastic processes for C, H, and K to maximize expected utility according to equation (1) subject to equation (2), the stochastic process for z, and the initial condition for K_0. The first-order conditions of this problem can be expressed as the usual Euler equation

$$u_C\left(C_t, \bar{H}-H_t\right) = \beta E_t\left[R_{t+1} u_C\left(C_{t+1}, \bar{H}-H_{t+1}\right)\right], \tag{3}$$

where R_{t+1} is the marginal product (in equilibrium, the rental rate) of capital in period $t+1$:

$$R_{t+1} = F_K\left(K_{t+1}, H_{t+1}, z_{t+1}\right) + 1 - \delta, \tag{4}$$

and the efficiency condition for the labor-leisure tradeoff:

$$u_C\left(C_t, \bar{H}-H_t\right) w_t = u_H\left(C_t, \bar{H}-H_t\right), \tag{5}$$

where w_t is the marginal product of labor (in equilibrium, the wage rate) in period t:

$$w_t = F_H\left(K_t, H_t, z_t\right). \tag{6}$$

Though a full account of the effects of shocks requires a full solution of the stochastic general-equilibrium model and examination of its simulated time-series properties, one can obtain significant insight by looking at "unexpected shocks to steady states." That is, assume that an economy is in steady state and will stay there until there is an actual change in the technological opportunities that occurs with probability zero. The question at hand here is how knowledge of a future change in technology will affect the economy in the intervening periods before the changes actually occur. While the Beaudry-Portier evidence suggests that positive news about future productivity should lead to something of a business cycle expansion, the standard one-sector RBC model cannot generate such a response. To see why the standard model has trouble generating a business cycle expansion in response to a positive news shock, consider what is required of the four main variables in the model: output, consumption, investment, and hours. An expansion is marked by an increase in both consumption and investment. In the standard model there are no imports or exports and no government spending, so the aggregate resource constraint requires that output must rise to allow consumption and investment to rise simultaneously. The only option for an increase in output is for hours worked to rise as the technological opportunities are initially unchanged and the capital stock is predetermined by what was installed in the previous period. However, consumption and leisure are normal goods under standard preferences, so that at a given wage (marginal product of labor) a household will choose to adjust consumption and leisure in the same direction, i.e., consumption and hours in opposite directions. To see this mathematically, equation (5) can be used to implicitly differentiate H with respect to C. Doing so yields

$$H'(C) = -\frac{u_{CC}w - u_{CH}}{u_{HH} - u_{CH}w}, \tag{7}$$

and decreasing marginal utility ($u_{CC}, u_{HH} < 0$) together with the weak complementarity of consumption and hours ($u_{CH} \geq 0$) imply this expression is negative. So hours and consumption must move in opposite directions when wages are held constant. The only hope for the model is that in equilibrium wages increase so that the substitution effect raises hours, but, as was already noted, the capital stock and technology have not changed so increased hours will lead to lower wages in equilibrium. The implication is that the equilibrium response of the standard one-sector RBC model to a positive news shock does not look like a business cycle expansion.

If the model does not generate a boom in response to a news shock, what happens instead? If the preferences exhibit a strong wealth effect then positive news about future productivity will lead to an increase in consumption. This increase in consumption is associated with a decline in hours worked as before, which in turn implies a reduction in output and the aggregate resource constraint implies a reduction in investment. In contrast, with a weak wealth effect all of these implications can be reversed.[1]

It will be useful to consider an extreme case for preferences, both for the sake of understanding the workings of the basic model and for the sake of

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[1] Using a particular set of functional forms, Beaudry and Portier (2004) show that consumption and investment respond in opposite directions for any set of parameter values.

understanding the behavior of the model that is presented in Section 3, which is based on the Diamond-Mortensen-Pissarides framework. Consider a utility function that is just linear in consumption $u(C, H) = C$, so that leisure is not valued and labor supply is fixed exogenously. In this case, the return on capital is pinned down by the discount rate in all periods as shown by the Euler equation:

$$1 = \beta E_t \left[F_K \left(K_{t+1}, \bar{H}, z_{t+1} \right) + 1 - \delta \right]. \tag{8}$$

This Euler equation implies that in an experiment with perfect foresight, the capital stock will perfectly track the level of technology—K_t is only a function of z_t and parameters of the model. The result is that in response to a news shock the capital stock remains unchanged until the period before the change in productivity takes place when (for a positive news shock) consumption is reduced to raise the capital stock to its new steady-state level. While this case yields a simple transition to the new steady state, the dynamics it does generate have consumption and investment moving in opposite directions and with a delay.

An important element of the Beaudry and Portier analysis is the response of the stock market or, in terms of the model, the relative price of capital. In the standard one-sector model there is in essence a single good that is used for both consumption and capital. Therefore, the relative price of capital is fixed at one unit of the consumption good at all times. A truly satisfactory explanation of the Beaudry and Portier results would be able to replicate the behavior of the stock market as well as the usual macroeconomic aggregate quantities. Christiano et al. (2007), reviewed below, do discuss stock prices within their model.

3. A SEARCH MODEL

The overall question we discuss in this article is what kinds of theoretical settings can deliver co-movement in response to news shocks. In Section 4, we survey the recent literature and the range of models discussed there. Here, mostly for the purpose of illustration, we look at a specific, and very simple, model: one based on the Diamond-Mortensen-Pissarides search-and-matching model. What we present here is related to Den Haan and Kaltenbrunner (2009), who study a similar setting. The setting with search frictions offers something that the standard neoclassical model does not have: "free resources," namely, a set of unemployed agents who would gladly work if they could just find an employer. Therefore, it is at least imaginable that the frictions are such that when a news shock arrives, employment responds relatively quickly, provided that frictions are endogenous and respond to the news. The response of frictions in this model is governed by flows of firms in and out of the market for workers. The idea is, in principle, very simple: If there is positive news, firms flow in immediately and look for workers, which makes it easier for workers to find employment, leading to an increase in employment and higher production, so that the overall resources available are increased. Firms begin posting vacancies immediately upon learning the positive news because an employed worker is immediately more valuable since, with some probability, that worker will still be employed by the firm when productivity rises.

Model Framework

The model framework is the standard continuous-time Diamond-Mortensen-Pissarides search-and-matching model. A more detailed discussion of the model framework and the determination of steady-state values can be found in Pissarides (2000) or Hornstein, Krusell, and Violante (2005).

The model economy is populated by a unit continuum of workers. Workers have linear utility for consumption discounted at the rate r, which implies they are risk-neutral. The workers each supply one unit of labor inelastically. Workers can be either employed or unemployed. Employed workers receive a wage income of w and unemployed workers receive an unemployment benefit of b, which also can be interpreted as the value of home production during unemployment. The wage is an endogenous variable that will depend on, among other things, the tightness of the labor market. The unemployment benefit is an exogenous feature of the economic environment. Workers cannot save and consume their income flows immediately.

The economy is also populated by an endogenous number of firms that are also risk-neutral and discount future profits at rate r. Firms all have access to the same production technology so there are no productivity differences across firms. Firms are free to enter the labor market, but posting a vacancy involves a flow cost in the amount c. Production requires a single worker and a single firm and the amount of output produced by such a pair, $p(t)$, varies through time. It is assumed that production is always efficient in the sense that $p(t) > b$.

There is a search friction in the labor market so that, at any point in time, there will be a fraction $u(t)$ of workers who are unemployed and looking for firms and there will be a measure $v(t)$ of firms with vacant jobs looking for workers. These two groups meet at a rate, $m(t)$, that is determined by a constant-returns-to-scale matching function $M(u(t), v(t))$. We use a Cobb-Douglas matching function, $M(u, v) = Au^{\alpha}v^{1-\alpha}$. Given the rate at which new matches occur, the rate at which an unemployed worker finds a firm is $\lambda_w(t) = m(t)/u(t)$ and the rate at which a vacant firm finds a worker is similarly $\lambda_f(t) = m(t)/v(t)$. The gains from forming a productive worker-firm pair are divided between the worker and the firm by Nash bargaining, with β going to the worker and $1 - \beta$ going to the firm. Existing worker-firm pairs separate at the exogenous rate σ.

Steady State

To determine the steady-state values of unemployment and wages, we begin by writing the conditions that must be satisfied by the values for the employed worker, unemployed worker, matched firm, and vacant firm. Respectively, these are:

$$rW(t) = w(t) + \sigma\,[U(t) - W(t)] + \dot{W}(t) \tag{9}$$

$$rU(t) = b + \lambda_w(t)\,[W(t) - U(t)] + \dot{U}(t) \tag{10}$$

$$rJ(t) = p(t) - w(t) + \sigma\,[V(t) - J(t)] + \dot{J}(t) \tag{11}$$

$$rV(t) = -c + \lambda_f(t)\,[J(t) - V(t)] + \dot{V}(t), \tag{12}$$

where a dot over a variable represents the derivative with respect to time. Each of these equations can be interpreted in terms of the relationship between the flow value and the capital value of a state. For example, equation (9) states that the flow value of being an employed worker is equal to the income flow plus the expected value of the capital loss that occurs upon separation when the worker becomes unemployed and the change in value over time, possibly stemming from a changing environment.[2]

The total surplus of a worker-firm match is the sum of the worker's gain and the firm's gain, $S \equiv (W - U) + (J - V)$. The Nash-bargaining determination of wages implies that the total surplus is divided between workers and firms according to their bargaining powers:

$$W - U = \beta S \tag{13}$$

$$J - V = (1 - \beta)S. \tag{14}$$

A useful expression for S can be found by adding and subtracting equations (9)–(12) and using equations (13) and (14):

$$rS = p - b + c - \sigma S - \lambda_f\,(1 - \beta)\,S - \lambda_w \beta S + \dot{S}. \tag{15}$$

This can be viewed as an "asset-pricing" equation: The value of the match—the worker and the employer—equals a current payoff plus future payoffs, which are captured by the $\dot{S}$ term; they can, in principle, be successively substituted in so that the price of the asset equals the present value of all payoffs, present and future. The equation can be rearranged to yield

$$S = \frac{p - b + c + \dot{S}}{r + \sigma + \lambda_f\,(1 - \beta) + \lambda_w \beta}. \tag{16}$$

Now use the fact that firms are free to enter (and exit) the labor market, so the value of a vacant firm must be zero. Setting V equal to zero in equations (12)

[2] See footnote 12 in Hornstein, Krusell, and Violante (2005) for a detailed derivation of these conditions.

Table 1 Model Parameter Values

Symbol	Description	Value
p	Productivity	1.000
b	Unemployment benefit	0.950
α	Elasticity of the matching function	0.720
A	Matching function efficiency	1.350
β	Worker's bargaining share	0.050
r	Interest rate	0.012
σ	Separation rate	0.100
c	Vacancy posting cost	0.357

Notes: One unit of time is equal to one quarter. See Hornstein, Krusell, and Violante (2005) for additional details.

and (14) and combining the results yields

$$S = \frac{c}{\lambda_f (1-\beta)}. \tag{17}$$

Combining equations (16) and (17) yields one equation in the two meeting rates:

$$\frac{p - b + \dot{S}}{r + \sigma + \lambda_w \beta} = \frac{c}{\lambda_f (1-\beta)}. \tag{18}$$

As the matching function is constant returns to scale, the meeting rates can be expressed in terms of a single variable that represents labor market tightness:

$$\begin{aligned} \theta &\equiv v/u \\ \lambda_w &= M(u,v)/u = M(1,\theta) = A\theta^{1-\alpha} \\ \lambda_f &= M(u,v)/v = M(1/\theta,1) = A\theta^{-\alpha}. \end{aligned} \tag{19}$$

In steady state the total surplus is constant, $\dot{S} = 0$, so equation (18) is one equation in the unknown θ. Once θ has been found, the λs and values follow immediately from the equations above and equations (17), (14), and (11) can be used to find the wage as a function of θ and p.

The unemployment rate evolves slowly as workers gradually flow into and out of unemployment. The evolution of the unemployment rate follows

$$\dot{u}(t) = \sigma [1 - u(t)] - \lambda_w(t)u(t), \tag{20}$$

and in steady state, unemployment is simply equal to $\sigma / (\lambda_w + \sigma)$.

Solving for the steady state of the model requires solving a nonlinear equation in θ (equation [18], with $\dot{S} = 0$). We do this numerically after calibrating the model following Hagedorn and Manovskii (2008). This calibration leads to a steady-state unemployment rate of 6.9 percent and features stronger effects on firm entry of productivity shocks than in alternative calibrations such as Shimer (2005); for a discussion, see Hornstein, Krusell, and Violante (2005). The parameter values used in our calibration appear in Table 1.

Transition to Steady State

Before considering the effects of a news shock it is necessary to consider how the economy transitions to the steady state in a stationary environment. The key result for the transition dynamics is that labor market tightness immediately reaches its steady-state value regardless of the initial conditions for the economy. As unemployment is a predetermined variable, the response of the labor market is driven by a jump in posted vacancies. To see that this must be the case, rewrite equation (18) into

$$\dot{\theta} = \left[\frac{r+\sigma}{\alpha} + \frac{\beta A}{\alpha}\theta^{1-\alpha} - \frac{(p-b)(1-\beta)A}{c\alpha}\theta^{-\alpha} \right]\theta, \tag{21}$$

so that dynamics are expressed in terms of θ (thus including its time derivative $\dot{\theta}$).[3] Notice that the term inside the brackets is increasing in θ, so for θ below the steady-state value the time derivative is negative and for θ above the steady-state value the time derivative is positive; therefore, the steady state is unstable, and the only nonexplosive solution to the problem is for θ to jump immediately to the steady state.[4] It then follows that the λs also must jump to their new steady-state values and so then must the values W, U, J, V, and S. Given the new, constant level of λ_w, one can use equation (20) to trace out the evolution of the unemployment rate to its new steady-state value, and vacancies are then determined by the relationship $v = \theta u$. In the end, there are very limited transition dynamics resulting from an unexpected productivity shock, and if productivity is expected to remain constant in the future, then θ must be at its steady-state value.

News Shock (Recession)

We now consider how the model responds to a negative news shock. In particular we perform the following experiment: Before $t = 0$, the economy is in steady state and expected to remain there in perpetuity. At $t = 0$, news arrives that at time $T = 5$ productivity, p, will drop by 1 percent. The arrival of this news is a zero-probability event, which implies that agents put no weight

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[3] Equation (17) and its time derivative imply $\dot{S}\lambda_f(1-\beta) = -c\dot{\lambda}_f/\lambda_f$, and equation (19) can be used to relate $\dot{\lambda}_f$ to $\dot{\theta}$.

[4] Pissarides (2000) considers the system of differential equations formed by equations (20) and (21). The boundary conditions for this system are the initial condition on u and the requirement that the system converge. These conditions can only be met if θ immediately assumes its steady-state level.

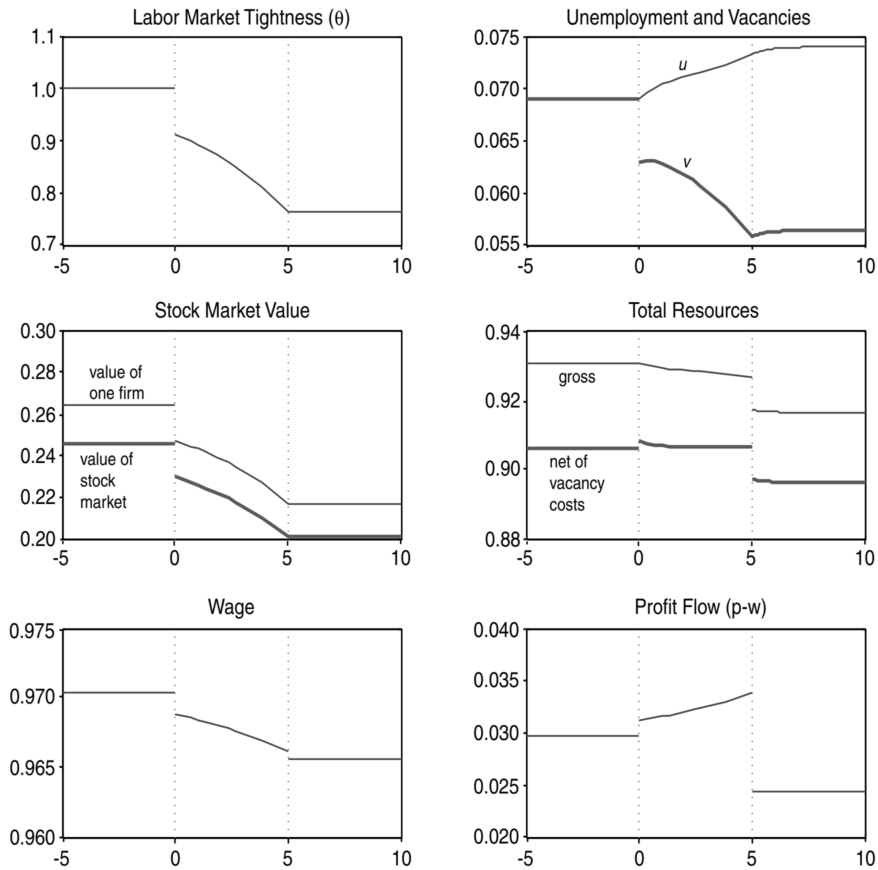
on the event in forming their expectations, but does not imply that it cannot occur.

To calculate the equilibrium response of the economy to this news, we use the fact that θ must be at its new steady-state value at time T when the change in productivity occurs because after that point the environment is expected to be stationary. We use this as a terminal condition and solve the ordinary differential equation (21) from time $t = 0$ to T. Having done so, we are able to calculate the λs, trace the evolution of the unemployment rate, and solve for all the other equilibrium quantities in the model. Interestingly, our version of the Pissarides model has nontrivial dynamics, whereas the standard model does not; in the standard model, there is always an immediate jump in θ in response to a change in productivity, since this change is known as it is realized. The slow-moving θ we look at, thus, comes from knowing that productivity will change at a known future date.

The results appear in Figure 1, and we begin by comparing the two steady states. The lower level of productivity results in a decrease in the total surplus of a match, one implication of which is that the value of a productive firm is lower. This induces fewer firms to enter the labor market until market tightness falls sufficiently and the probability of finding a new worker rises to keep the value of a vacant firm at zero. The weaker labor market leads to a lower job-finding rate for unemployed workers, which leads to a higher steady-state unemployment rate. In equilibrium the wage decreases, but by less than productivity, so profits also decrease eventually, though profits first rise since wages, which are forward-looking, fall and productivity has not yet fallen. Total resources fall smoothly, which is the effect sought: Firms leave in anticipation of future falls in profit, which creates additional unemployment—there are now even more "free resources" in the form of workers who are not working. The fact that fewer firms are posting vacancies means that fewer resources are spent on vacancy posting, which we interpret as investment. Resources net of investment costs rise somewhat during transition but then drop and are lower in the long run.[5] During the transition to the new steady state from time $t = 0$ to time T, the value of a productive firm drops initially and then smoothly falls toward the new steady-state value. Labor market tightness follows the same pattern, which is achieved by an initial jump and then decreasing path for vacancies. The weaker labor market decreases the speed at which workers flow out of unemployment and results in a gradual rise in the unemployment rate. Unlike the other variables, vacancies overshoot their steady-state level. This overshooting stems from the fact that unemployment

[5] A model in which there is endogenous separation—say, because workers or matches are heterogeneous so that only some firm-worker contacts lead to lasting matches—might generate another channel through which more resources are left idle since then some existing matches could also break up in reaction to negative news.

Figure 1 News about a Coming Fall in Productivity



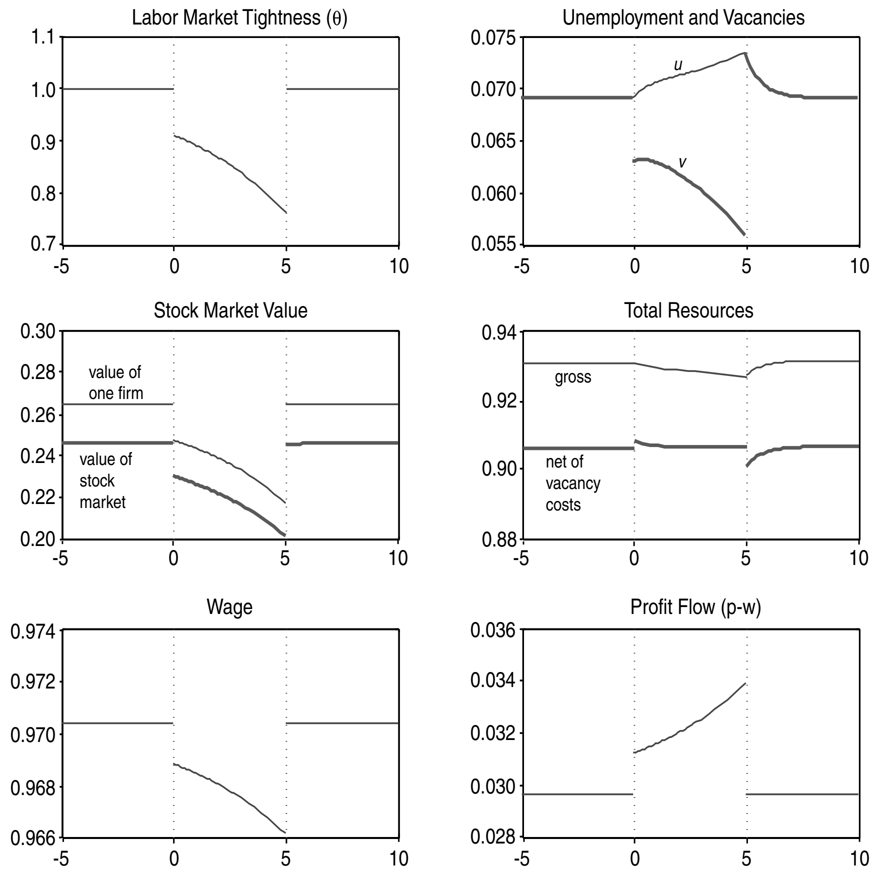
has not reached its steady state at time T, but is still below that level. Vacancies must then also be below their steady-state level at T so that labor market tightness can remain at its steady-state level from T onward. The increase in the unemployment rate mechanically leads to a decrease in output, and the level of output jumps when all employed workers become less productive at T.

The model is successful in generating a decline in employment, output, and the stock market. What about investment and consumption? If we interpret firm vacancy-posting costs as investment, then the model also generates a fall in investment. Consumption, however, must rise on impact if the economy is closed: No existing matches are broken up endogenously, so on impact no resources are lost, but investment falls, and thus consumption must rise. An open-economy version of the model with decreasing marginal utility would reverse this result, as consumers would then want to smooth consumption over time and use intertemporal international trade to achieve a smoothly declining path for consumption.

As Figure 1 shows, labor market tightness, θ, drops initially when the news is received and then converges to its new steady-state level at date T. This pattern will hold for any choice of parameter values. Quantitatively, however, the initial impact of the news on labor market tightness depends on the way the model is calibrated, and there are two ways that the parameters can affect this initial impact. First, different calibrations lead to different steady-state responses of θ to changes in p. This sensitivity is the focus of the literature that studies the implications of search-and-matching models for unemployment fluctuations in response to unanticipated productivity shocks (Shimer 2005; Hagedorn and Manovskii 2008; Pissarides 2009). The more θ must have changed by date T, the more it must jump initially. The second consideration is the speed with which the market tightness adjusts to its new steady-state level. If the model dynamics are such that θ moves rapidly when it is out of steady state, then a small drop in θ is needed at date 0 to achieve the same level of θ at date T. What then determines the speed of convergence and therefore the size of the initial impact of the news? Mathematically, if the right-hand side of equation (21) is increasing more quickly in θ, then the speed of convergence will be higher, and the initial impact of the news will be smaller. For example, differentiation of equation (21) shows that an increase in the interest rate, r, leads to a faster speed of convergence. This result is intuitive as an increase in the interest rate leads firms to discount the future more heavily and so the value of a firm depends more on the immediate future and less on the distant future. As the productivity change does not happen for some time after the news arrives, firms with high discount rates do not respond as much as firms with low discount rates. Similar logic holds when the separation rate is high. In this case, firms discount the future because the match is likely to be destroyed before the change in productivity occurs.

Differentiation of equation (21) also shows that the speed of convergence is increasing in the worker's bargaining share, β. Therefore, when workers have more bargaining power, the initial impact of the news is smaller. To see the importance of the worker's bargaining share, consider the case when β is set to zero. In that case, the worker's wage is always equal to the value of leisure, b, and the firm's flow profit is $p - b$, which is unchanged until date T when it jumps down. Now consider a positive bargaining share, $\beta > 0$. As shown in Figure 1, the worker's wage falls at date 0 and remains below its initial level thereafter. With a lower wage, flow profits actually rise between dates 0 and T. So with a positive β, firms are partially compensated for the future reduction in productivity by a short-term increase in profits. This

Figure 2 Misleading News about a Coming Decline in Productivity



short-term increase in profits motivates firms to post vacancies just after the news arrives, and this force reduces the initial drop in θ.

The News Shock Turns Out to Be Wrong

The second experiment that we consider is to ask what happens if the expected lower productivity is not realized at time T, but instead productivity remains at its initial level both before and after T. Specifically, we assume that after the news shock arrives, there remains a possibility that productivity fails to decline at time T, although this possibility has zero probability; thus, we consider what happens when that zero-probability event occurs. The experiment is displayed in Figure 2, with $T = 5$ again. Before time T the economy behaves exactly as in the case when the productivity shock is realized because agents fully expect that it will be realized. At time T, however, the productivity shock does not materialize and labor market tightness and the value of a productive job immediately return to their initial steady states. These developments imply a stock market boom and an immediate increase in posted vacancies. The new tightness in the labor market increases the rate at which unemployed workers find jobs and leads to a gradual fall in the unemployment rate. As employment rises output also rises, but, as before, the increase in vacancy posting costs is large enough that it offsets the rise in output so the resources available for consumption actually decrease.

Looking at this experiment, one might label the shock whose effects are displayed in Figure 2 "misleading." More generally, realizing that all shocks containing "news" do not necessarily always lead the economy in the right direction, one can speak of "noise" perhaps: shocks that are believed to have relevance for productivity but in the end do not. For example, the Internet technology bubble during the last years of the last millenium could have reflected beliefs that eventually turned out to be too optimistic (but may well have been rational). Thus, the literature on news shocks should be viewed as closely related to ideas about noise as well. The very recent literature (e.g., Angeletos and La'O [2009], or Blanchard, L'Huillier, and Lorenzoni [2009]) takes an explicit signal extraction approach and thus formalizes news and noise, as shocks driving business cycles, in a slightly different way.

4. OTHER APPROACHES IN THE LITERATURE

We now briefly discuss the main features of the different models, all with neoclassical underpinnings, that have been proposed as a way of generating co-movement in response to news shocks. In this discussion, we omit the very recent contributions to this literature that build on signal processing and "noise shocks."

Other Approaches to Labor Market Frictions

Den Haan and Kaltenbrunner (2009) present a version of the RBC model with a search friction in the labor market. Specifically, production occurs within "projects" that require an entrepreneur and a worker. Creating a new project is a time-consuming process as entrepreneurs and workers must search for one another. In response to a news shock, entrepreneurs and workers begin preparing for the future productivity increase by entering the labor market to begin the process of establishing relationships through which they can exploit the higher future productivity when it arrives, just as in Section 3. There are two main differences between the model in Section 3 and Den Haan and Kaltenbrunner's work. First, in Section 3 the labor supply is inelastic, while

Den Haan and Kaltenbrunner allow it to be elastic. With elastic labor supply, one of the effects of a news shock is an increase in the demand for leisure through the wealth effect, which might reverse the result that employment increases in response to the news shock. Den Haan and Kaltenbrunner show that this effect is sufficiently weak to be overcome by the household's motivation to enter the labor market to find a job in anticipation of higher productivity in the future. Therefore, the result that employment increases in response to a news shock is not an artifact of the inelastic labor supply. Second, the standard Diamond-Mortensen-Pissarides model considered in Section 3 does not include capital, so there are no predictions for the response of investment to a news shock. Den Haan and Kaltenbrunner show that investment does respond positively to a news shock except in the first period after the shock. Production is fixed in the first period because the capital stock and employment are predetermined, so it is impossible for consumption and investment to rise simultaneously in that period. However, the increase in employment that occurs in response to the news shock quickly increases output to finance higher investment as well as higher consumption in subsequent periods.

Multiple Sectors

The standard one-sector RBC model has a tight link between consumption and investment decisions: Investment directly reduces the resources available for consumption. Beaudry and Portier (2004) present a three-sector model with final goods, nondurable intermediate goods, and capital produced in different sectors. The latter two sectors use labor and a sector-specific fixed factor of production. In this model the link between consumption and investment is much weaker because output from the capital goods sector cannot be used for consumption and the presence of the fixed factors limits the extent to which the planner is willing to alter the amount of labor in the sectors. This uncoupling of the consumption and investment decisions allows consumption and investment to both increase in response to a positive news shock. Specifically, Beaudry and Portier assume the news concerns the future productivity of the nondurable goods sector, and the crucial assumption is that nondurable goods and capital are complementary in the production of final goods. Under these assumptions, the planner chooses to build up the capital stock in response to positive news about future nondurable goods productivity because the complementarity implies that capital will be more productive in the future because nondurables will be cheaper. The accumulation of capital, however, makes nondurables more valuable, which leads the planner to expand their production as well. In the end, the production of capital and nondurables increases, which is achieved through an expansion of hours worked in each sector and therefore in total. More capital and nondurables directly translate into more final output for which the only use is consumption. In this way the model delivers an expansion of consumption, investment, hours, and output in response to positive news about nondurables productivity.

Other Model Features

An alternative approach taken in the literature is to keep the single-sector framework, but modify the standard RBC model along several other dimensions. Jaimovich and Rebelo (2009) present a model with three key modifications. They assume a functional form for preferences that has extremely weak short-run wealth effects on labor supply. In fact, the preferences used nest those of Greenwood, Hercowitz, and Huffman (1988) in which there is no wealth effect on labor supply. The calibration used by Jaimovich and Rebelo is extremely close to this case. Since these preferences imply a zero wealth effect, they allow the model to generate an increase in hours despite a substantial increase in consumption. The second modification introduced by Jaimovich and Rebelo is an adjustment cost for the rate of investment, which serves to produce an investment boom in response to a positive news shock as the planner wishes to minimize adjustment costs by smoothing investment over time. Finally, the authors add variable capacity utilization to the model, which allows the amount of resources to be expanded in the initial periods in order to finance simultaneous consumption and investment booms. The resulting model succeeds in generating a sizable boom in response to news of a future increase in TFP and in response to news of future investment-specific technical change.

Christiano et al. (2007) make similar modifications to the standard model in order to generate a boom in response to a positive news shock. Their key modifications are to introduce habits in consumption and the adjustment cost to the flow of investment. Jaimovich and Rebelo also have non-time-separable preferences, but the calibration is such that the habit persistence is very weak. The habits and adjustment costs in Christiano et al.'s work motivate the planner to engineer a smooth transition to the new steady state and begin consuming and investing in advance of the change in productivity. Hours are able to increase to provide resources for the consumption and investment booms because there is no longer a tight link between current hours and current consumption in the presence of habit persistence.

A troubling feature of these models is the response of the price of capital to a news shock, which is a decline. As investment is raised to reduce adjustment costs in anticipation of higher investment in the future, there is, in a sense, an excess of capital before the shock occurs. The result is that the relative price of capital falls during the boom. Walentin (2009) presents a model that is close to that of Christiano et al. (2007), with the modification that there is limited enforcement of financial contracts. With limited enforcement, there is a wedge between the value of the firm and the cost of its capital and, in

Walentin's model, this wedge increases in response to a news shock so that the value of the firm increases despite the fall in the cost of capital.

Investment-Specific Technical Change

In a model with adjustment costs, the planner chooses to start investing early in order to minimize the cost of building up the capital stock in response to a sector-neutral productivity shock. If, however, productivity shocks are investment-specific, then the only way to take advantage of them is through investment. Flodén (2007) uses a vintage capital model to argue that the news that next period's vintage of capital will be very productive leads to a boom in the current period. The mechanism draws on the model elements presented by Greenwood, Hercowitz, and Krusell (2000), which are shocks to the relative price of capital and variable capacity utilization. The cost of more intensive utilization of the capital stock is typically modeled as faster depreciation. When the relative price of capital declines, the replacement cost of the depreciated capital stock falls. As a result, an investment-specific technology shock leads to more intensive utilization in the current period, which raises the marginal product of labor and elicits higher labor supply. The additional resources produced through the increases in utilization and labor supply allow consumption to increase at the same time as investment.

Flodén only considers news shocks at a horizon of one period. That is, the economy learns that the capital being installed in the current period will be more productive in the next period and thereafter. This short horizon makes the expectations-driven boom somewhat short-lived, but it may be possible to extend the boom by extending the period between the receipt of the news and the technological change.

There is some ambiguity about the timing of the technology shock in that investment-specific technical change relates to the evolution of resources between periods rather than the productivity within a period. For example, Greenwood, Hercowitz, and Krusell adopt the timing convention that the shock relates to the productivity of investment this period and is therefore a shock in the current period, while Flodén considers the same shock to be a shock to the productivity of the capital when it is used in the future, which is then a shock that arrives in the future but is learned about in the current period through the news shock. Both interpretations are valid, but an important consideration is the interpretation used in the construction of the National Income and Product Accounts (NIPA). In principle the NIPA investment data are adjusted for quality, and if the vintage of capital that is being installed is going to be more productive in the future, this may be accounted for in the measurement of current investment and current TFP. However, if the shock raises current TFP, it would not be classified as a news shock by Beaudry and Portier (2006) because news shocks are orthogonal to current TFP shocks.

Financial Frictions

Another way of modifying the model to generate expectations-driven business cycles is to introduce financial frictions. Chen and Song (2008) consider a model with two sectors, only one of which requires the use of working capital. In their model, entrepreneurs have the ability to divert working capital, and the optimal contract in response to this limited debt enforcement leaves the sector financially constrained. When a positive news shock arrives, the entrepreneurs' continuation value rises because future profits will be higher, which relaxes the financial constraint. By reducing financial frictions, the news of higher TFP in the future triggers a reallocation of capital between the two sectors and raises current TFP. The increase in current TFP leads to more output that can be used for both more consumption and more investment. The more efficient use of capital, as well as the accumulation of more capital, raises the marginal product of labor, which leads to an increase in hours under Greenwood-Hercowitz-Huffman preferences.

If financial frictions like the ones Chen and Song have proposed are important features of the macroeconomy, then there are implications for other issues besides expectations-driven business cycles. In particular, there would be a need for government policy to alleviate the financial constraints of firms. This could be achieved in a variety of ways; for the same reasons as future profit increases would improve the current allocation of capital, any policy that increases future profits would have a desirable effect (production subsidies would suffice for this purpose).[6] Whether the economy is subject to this strong inefficiency is perhaps questionable. If there is already government policy in place designed to correct the inefficiency, no reallocation of capital in response to news shocks will take place.

5. CONCLUSION

The news shocks literature has generated some interesting new insights about macroeconomic dynamics that seem relevant for understanding co-movement of macroeconomic aggregates. The above-discussed settings, including the simple Pissarides (1985) search/matching model used for illustration, do admit some channels that are promising ways forward. Some of these settings have more nonstandard features than others, and it is an open question whether they will survive more microeconomic scrutiny. It is also, as discussed in Section 1, still an open question how to identify news shocks and whether they really do lead to co-movements. All in all, this new literature does offer a challenge to

[6] Such policies might involve time inconsistency, since it is only by support of *future* policy that the desired effect is attained.

existing macroeconomic settings that do not admit co-movement in response to news shocks, and, as such, they should perhaps move our priors.

As also briefly mentioned above, a very recent strand of articles is now exploring explicit signal extraction channels by which news as well as noise can drive fluctuations. The focus here is on asymmetric information and, even though Lucas (1972) certainly sparked interest in the importance of this phenomenon for macroeconomics, there is no quantitatively oriented model available off the shelf to evaluate. A central reason for this is the theoretical difficulty of aggregation across agents with different information sets. Therefore, we may have to wait for a closer comparison between models relying on these ideas and existing representative-agent macroeconomic models.

Finally, the underlying notion in our discussion here is to examine whether co-movement is possible, in response to the arrival of information, in settings that are fully microfounded. It should be noted that none of these settings build on, or admit, coordination failures, which would seem to more easily admit strong effects of news or noise. With multiple equilibria, however, it is not clear how the movement across equilibria is supposed to occur, and there is nothing inherently more attractive about productivity-related shocks as coordination devices than other shocks, so it would seem that an approach based on coordination failures would have to be augmented with a theory of what triggers changes across equilibria. The earlier literature on sunspots (see Cass and Shell [1983] and later studies) offers an answer, but sunspots are just coordination devices, and it might be hard, in a reduced-form sense, to distinguish sunspots from true news shocks. If a news shock indicates high future productivity of capital, investment likely will go up today. Alternatively, in a model with multiple equilibria because of some form of increasing returns to capital, say, as an externality of capital use across firms, a sunspot would trigger either high or low investment, which would both be self-enforcing under the assumption of increasing returns. So this latter model would indeed justify later movements in productivity, not because of changes in technology, but through increasing returns and aggregate activity. Ultimately, these two "stories" could only be told apart by more detailed empirical scrutiny. One route is through better productivity measurements, perhaps finding ways of establishing what the returns to scale are on different levels of aggregation. Alternatively, a more detailed structural description of the model and examination of how the two kinds of economies respond to other shocks could help identification.

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