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Oscar Pavlov & Mark Weder

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Oscar Pavlov*
School of Economics
The University of Adelaide
Australia

Mark Weder†
School of Economics
The University of Adelaide
Australia

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Abstract

The standard one-sector real business cycle model is unable to generate expectations-driven fluctuations. The addition of countercyclical markups and modest investment adjustment costs offers an easy fix to this conundrum. The simulated model generates quantitatively realistic business cycles with news shocks accounting for over half of the variance of technology shocks.

Keywords: Expectations-Driven Business Cycles, Markups.

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*Corresponding author. School of Economics, The University of Adelaide, Adelaide SA 5005, Australia. E-mail address: `oscar.pavlov@adelaide.edu.au`. Ph:+61 8 8313 6024. Fax:+61 8 8313 4190.

†School of Economics, The University of Adelaide, Adelaide SA 5005, Australia. E-mail address: `mark.weder@adelaide.edu.au`.

1 Introduction

News shocks have captivated the minds of many macroeconomists in recent years.[1] While this research's empirical branch suggests that news about shifts in future technology can be a significant source of business cycles, one of the main theoretical findings states that a plain-vanilla real business cycle model is unable to produce expectations-driven fluctuations. This conundrum boils down to the model's inability to generate the empirically-documented positive comovement between consumption and investment in response to news about future total factor productivity. Jaimovich and Rebelo (2009) propose to solve this conundrum by adding non-separable preferences that weaken the income effect on labor supply, but also require variable capital utilization and investment adjustment costs. While, recently, these preferences have proved to solve several economic enigmas, the empirical support for them is limited. The current paper illustrates an alternative approach that requires less alterations to the canonical model and, in particular, it does not require any departure from standard preferences. An endogenous labor wedge can solve the comovement puzzle. To show this, we apply Galí (1994) and Schmitt-Grohé's (1997) composition of aggregate demand model to introduce endogenous countercyclical markups as the stand-in for this wedge.[2] Yet, countercyclical markups are not sufficient for expectations-driven business cycles – while the comovement problem is solved, the arrival of news about technological innovations pushes the economy into a recession.[3] For this not to occur we introduce a second ingredient: modest investment adjustment costs. With these two empirically reasonable augmentations to the

[1] See Cochrane (1994), Beaudry and Portier (2004, 2006, 2007) and others.

[2] Empirical evidence suggests that markups are countercyclical. See Rotemberg and Woodford (1999) and Floetotto and Jaimovich (2008).

[3] See Eusepi (2009) and Guo, Sirbu and Suen (2011) for a clarification of his result.

standard model, expectations-driven business cycles arise.

In the plain vanilla model, the income (wealth) effect associated with the news of a technology improvement induces people to raise consumption and leisure; accordingly comovement problems arise and hence the introduction of preferences that weaken the income effect on labor supply. In contrast, the present model relies on the presence of income effects and the economic mechanism for our result can be understood as follows. Any change in the markup implies a change to economic distortions and, consequently, a shift in the production possibilities. Moreover, sufficiently countercyclical markups can result in an upwardly-sloping wage-hours locus, which solves the comovement puzzle.[4] Therefore, if the income effect associated with the news of a technology improvement is strong enough, the labor supply schedule shifts in and employment increases. Yet, because of an opposing substitution effect, positive news about the future cause recessions. The reason being that in anticipation of higher future real interest rates, agents decrease current consumption and increase labor supply with the effect of a drop in employment.[5] Yet, news-driven business cycles emerge if the income effect dominates. For this to become possible, agents must be given an incentive to invest today and this is done via adjustment costs to physical investment. If these adjustment costs are sufficiently large then the interest rate fluctuates by less and agents not only increase current consumption but the resulting inward shift of labor supply raises hours worked and investment. The economy begins to boom immediately.

[4]This part of the argument is not unlike indeterminacy models, yet, here we do not consider the case of sunspot equilibria. Wang (2011) shows a similar effect through deep habits. He also finds that employment drops below steady state at the realization of the shock.

[5]This stands in contrast to the standard real business cycle model where the wage-hours locus is downwardly sloping and the wealth effect dominates the substitution effect.

We also obtain simulated second moments from the model economy, and compare them with US time series data. It turns out that our model performs quite well at matching the main empirical regularities, that is the standard deviations and contemporaneous correlations of US cyclical fluctuations after 1948. In sum, this paper shows that with countercyclical markups, a one-sector real business cycle model is able to generate qualitatively, as well as quantitatively realistic business cycles driven by news shocks.

The rest of this paper proceeds as follows. Section 2 lays out the model. Section 3 presents conditions for comovement and expectations-driven business cycles are derived in Section 4. Calibration and simulations are presented in Section 5. Section 6 concludes.

2 Model

The artificial economy is based on the composition of aggregate demand model laid out by Schmitt-Grohé (1997). The model's key assumption is that monopolists cannot price-discriminate between the consumption and investment related demands of their products, hence, the composition of demand affects their market power. We will begin the model description by outlining the firms' side.

2.1 Firms

A perfectly competitive final good sector produces the final consumption good, C_t and the final investment good, X_t. The consumption good is consumed, while the investment good is added to the capital stock. The production functions relating the final outputs to intermediate goods are

$$C_t = N^{1-1/\sigma} \left(\int_0^N y_{i,c,t}^{\sigma} di \right)^{1/\sigma} \qquad \sigma \in (0,1)$$

and

$$X_t = N^{1-1/\eta} \left(\int_0^N y_{i,x,t}^{\eta} di \right)^{1/\eta} \qquad \eta \in (0,1)$$

where $y_{i,c,t}$ ($y_{i,x,t}$) stands for the amount of the unique intermediate good i used in manufacturing consumption (investment) goods, and N is the fixed number of intermediate good firms. This number is such that there are no long-run pure profits. This assumption is consistent with empirical findings reported in Rotemberg and Woodford (1999), Basu and Fernald (1997) and others. The constant elasticity of substitution between different intermediate goods in the production of the consumption (investment) good equals $\frac{1}{1-\sigma}$ $\left(\frac{1}{1-\eta}\right)$. The conditional demand for intermediate good i to be used in the production of the consumption good is

$$y_{i,c,t} = \left(\frac{p_{i,t}}{P_{c,t}} \right)^{1/(\sigma-1)} \frac{C_t}{N}$$

with the price index

$$P_{c,t} \equiv N^{(1-\sigma)/\sigma} \left(\int_0^N p_{i,t}^{\sigma/(\sigma-1)} di \right)^{(\sigma-1)/\sigma}$$

where $p_{i,t}$ is the price of intermediate good i. The monopolist faces a similar demand coming from the final investment good producers. Intermediate goods are produced using capital, $k_{i,t}$, and labour, $h_{i,t}$, both supplied on perfectly competitive factor markets. Each firm produces according to the production function

$$y_{i,t} = z_t k_{i,t}^{\alpha} h_{i,t}^{1-\alpha} - \phi \qquad 0 < \alpha < 1, \phi > 0$$

where ϕ stands for fixed overhead costs. All firms are equally affected by aggregate total factor productivity, z_t, that follows the process

$$\log z_t = \psi \log z_{t-1} + \zeta_t \qquad \psi \in [0,1] \tag{1}$$

$$\zeta_t = \xi_t + \epsilon_{t-l} \qquad\qquad l > 0$$

where ξ_t is the (standard) contemporaneous shock to productivity and ϵ_{t-l} is a news shock that affects productivity l periods later. Both are i.i.d. disturbances with variances σ_ξ^2 and σ_ϵ^2 respectively. Given the demand from the final goods sector, each monopolist sets the profit maximizing price such that the markup, $\mu_{i,t}$, equals

$$\mu_{i,t} = \frac{\frac{1}{\sigma-1} y_{i,c,t} + \frac{1}{\eta-1} y_{i,x,t}}{\frac{\sigma}{\sigma-1} y_{i,c,t} + \frac{\eta}{\eta-1} y_{i,x,t}}.$$

The implicit demands for input factors are

$$\frac{\mu_{i,t}}{p_{i,t}} = (1-\alpha)\frac{z_t k_{i,t}^{\alpha} h_{i,t}^{-\alpha}}{w_t} = \alpha \frac{z_t k_{i,t}^{\alpha-1} h_{i,t}^{1-\alpha}}{r_t} \tag{2}$$

where w_t is the real wage and r_t the rental price of capital services.

2.2 Symmetric equilibrium

We restrict our analysis to a symmetric equilibrium where all monopolists produce the same amount and charge the same price, $p_t = 1$. Aggregate output is thus

$$Y_t = z_t K_t^{\alpha} H_t^{1-\alpha} - N\phi$$

where $K_t = Nk_t$ and $H_t = Nh_t$. Lastly, we define s_t as the investment share in aggregate output, that is

$$s_t \equiv \frac{X_t}{Y_t}.$$

Then the optimal markup can be rewritten as a function of this share

$$\mu_t = \frac{\frac{1}{1-\sigma}(1-s_t) + \frac{1}{1-\eta} s_t}{\frac{1}{1-\sigma}(1-s_t) + \frac{1}{1-\eta} s_t - 1}.$$

Note that if the elasticities of substitution in the final goods' technologies are the same, i.e. $\sigma = \eta$, the markup is constant. If $\eta > \sigma$ the markup is countercyclical to s_t. Then, as demand shifts from consumption to investment, each monopolist faces a more elastic demand curve and this leads to a fall in the markup. We restrict the markup elasticity, $\varepsilon_\mu \equiv (\partial\mu/\partial s)(s/\mu)$, to permissible values via $\mu > 1$ and $\sigma, \eta \in (0, 1)$. Some algebra restricts ε_μ to fall into the range defined by

$$\frac{1-\mu}{\mu} < \varepsilon_\mu < \frac{\mu-1}{\mu}\frac{s}{1-s} \tag{3}$$

where μ and s are steady state values. We define countercyclical markups as situations in which $\varepsilon_\mu < 0$, yet, one can show that this implies that the markup is also countercyclical with aggregate output.

2.3 People

The representative agent maximizes

$$E_0 \sum_{t=0}^{\infty} \left(\frac{1}{1+\rho}\right)^t \left(\frac{1}{1-\chi}C_t^{1-\chi} - \frac{\upsilon}{1+\gamma}H_t^{1+\gamma}\right) \qquad \rho > 0, \chi > 0, \upsilon > 0, \gamma \geq 0$$

where E_t is the conditional expectations operator, ρ denotes the discount rate, χ stands for the inverse of the intertemporal elasticity of substitution in consumption, and γ is the inverse of the labor supply elasticity. The agent owns the capital stock and sells labor and capital services. He owns all firms and receive any profits, Π_t, generated by them. Then, the budget is constrained by

$$w_t H_t + r_t K_t + \Pi_t \geq X_t + C_t \tag{4}$$

and capital accumulation follows

$$K_{t+1} = (1-\delta)K_t + X_t\left[1 - \Delta\left(\frac{X_t}{X_{t-1}}\right)\right] \qquad 0 < \delta < 1 \tag{5}$$

where δ stands for the constant rate of physical depreciation of the capital stock and the adjustment cost function, $\Delta(.)$, obeys $\Delta(1) = \Delta'(1) = 0$, and

$\Delta''(1) \geq 0$.[6] The first-order conditions for the agent are

$$\upsilon H_t^{\gamma} C_t^{\chi} = w_t \tag{6}$$

$$\eta_t = \frac{1}{1+\rho} E_t \left[\lambda_{t+1} r_{t+1} + \eta_{t+1}(1-\delta) \right] \tag{7}$$

$$\lambda_t = \eta_t \left[1 - \Delta\left(\frac{X_t}{X_{t-1}}\right) - \frac{X_t}{X_{t-1}} \Delta'\left(\frac{X_t}{X_{t-1}}\right) \right] + \frac{1}{1+\rho} E_t \eta_{t+1} \left(\frac{X_{t+1}}{X_t}\right)^2 \Delta'\left(\frac{X_{t+1}}{X_t}\right) \tag{8}$$

where λ_t and η_t are the multipliers associated with (4) and (5). Equation (6) describes the household's leisure-consumption trade-off, (7) is the intertemporal Euler equation and (8) portrays the investment dynamics. In addition the usual transversality condition holds.

3 Conditions for comovement

In the first step of our analysis, we obtain a condition for positive comovement which we define as the situation in which today's consumption and investment will move in the same direction after agents learn about future productivity changes. The analytical expression for this comovement is given by[7]

$$\frac{dC_t}{dX_t} = -\frac{\alpha + \gamma + \varepsilon_\mu \mu (1-\alpha) \frac{\delta(1-\alpha)+\rho}{\delta\alpha}}{\mu(1-\alpha)[\chi \frac{Y}{C} - \varepsilon_\mu] + \gamma + \alpha}. \tag{9}$$

Under perfect competition, $\mu = 1$, or constant markups, $\varepsilon_\mu = 0$, $dC_t/dX_t < 0$ as in a standard real business cycle model, hence consumption and investment move in opposite direction at news' arrival. If the markup is countercyclical, the sufficient condition for comovement between investment and consumption is

$$\varepsilon_\mu < \varepsilon_\mu^* \equiv \frac{-\alpha\delta(\alpha+\gamma)}{\mu(1-\alpha)[\delta(1-\alpha)+\rho]} < 0. \tag{10}$$

[6] See Christiano, Eichenbaum and Evans (2005).

[7] We take a total derivative of all static equilibrium equations including the resource constraint $Y_t = C_t + X_t$ and set $dz_t = dK_t = 0$.

(10) implies that the wage-hours locus is upwardly sloping and steeper than the agent's labor supply curve (see Appendix A.1); it is the same as the necessary condition for indeterminacy in a continuous time Benhabib and Farmer (1994) model. Substituting in the lower limit of ε_μ from (3) yields the minimum steady state markup, $\mu_{\min}$, required for comovement:

$$\mu_{\min} > 1 + \frac{\alpha\delta(\alpha+\gamma)}{(1-\alpha)[\delta(1-\alpha)+\rho]}.$$

Clearly, if both consumption and investment rise, then output must rise as well. Since capital is predetermined and productivity does not change on the arrival of news, hours worked must also rise, and hence $\frac{dC_t}{dH_t} > 0$. (9) suggests that comovement is also possible if $\varepsilon_\mu > 0$, however, we do not discuss such situations any further since this requires empirically implausible parameter values (see Appendix A.2).

Why does a time-varying markup solve the comovement puzzle? The markup drives a wedge between the marginal product of labor and the marginal rate of consumption-leisure substitution. Combining (2) and (6) leads to

$$\upsilon\mu_t H_t^{\alpha+\gamma} C_t^{\chi} = (1-\alpha) z_t K_t^{\alpha}. \tag{11}$$

In a plain-vanilla real business cycle model, where the wedge is absent, news-driven business cycles cannot occur: the arrival of news does not affect technology in the current period and since capital is predetermined (the right hand side of equation 11), consumption and hours (and therefore investment) cannot move in the same direction. This is also the case with a constant wedge ($\sigma = \eta$ in the current model). However, if the markup is sufficiently countercyclical then comovement becomes possible. Note that investment adjustment costs are absent from these expressions, although, as is demonstrated next, they influence the direction of the comovement.

4 Conditions for news-driven business cycles

After having established the conditions for comovement, it remains to be shown if countercyclical markups alone can generate expectations-driven business cycles. That is, we ask if the arrival of positive news about productivity sets into motion an economic boom in the artificial economy.

To do this, we run the following news-shock experiment: in period $t = 1$, news arrives about a rise in productivity that will occur in period $t = 4$ (or $l = 3$). The increase in productivity will be temporary and $\psi = 0.90$. We calibrate standard parameters as $\chi = 1$, $\gamma = 0$, $\rho = 0.01$, $\alpha = 0.3$, and $\delta = 0.025$. While the minimum steady state markup required for comovement is $\mu_{\min} = 1.12$, for clear graphical illustration, Figure 1 sets $\mu = 1.3$ and the markup elasticity to $\varepsilon_{\mu} = -0.1$, which satisfies the sufficient condition for comovement (10). At first, no adjustment costs are assumed to affect the economy. Figure 1 shows this economy's response for two cases: the productivity increase is realized – expectations about the future turn out to be correct – and unrealized – expectations turn out to be incorrect – where agents learn at $t = 4$ that there is no change to productivity after all. In both scenarios, the model generates an initial recession: consumption, hours worked, and investment all fall on the impact of news (i.e. at $t = 1$). This can be understood as the result of two (conflicting) effects. Suppose that the news shock is realized, then period $t = 4$ is characterized by higher wage income than at the steady state. From this, we can back out the expectations of agents as of the moment they receive the news: the improvement in technology is interpreted as a rise in lifetime income. The additional consumption possibilities are smoothed over time. In particular, the corresponding wealth effect induces agents to consume more and to reduce their labor supply today. Given the upwardly sloping wage-hours locus, this would increase employment today. Yet, we do not observe this in the impulse response functions. Why is this the case? There is another factor operating that increases labor supply today: the opposing substitution effect. It arises from the high future interest rate, R_4, which induces lower consumption in periods running up to period $t = 4$. If the substitution effect dominates the wealth effect, which will be the case when the wage-hours locus is upwardly sloping, initial consumption will be low and this shifts out the labor supply schedule along the upwardly sloped wage-hours locus. Employment falls and this generates a recession in period $t = 1$.[8] It is worthwhile to note that this stands in contrast to $\varepsilon_\mu = 0$, where the wage-hours locus is downwardly sloping and the real interest rate moves by much less; this is why the wealth effect dominates in a standard real business cycles model. In fact, the wealth effect can be traced from the divergence of the two consumption paths after agents learn about the non-realization of news in period $t = 4$. If news turn out to be wrong, consumption remains below steady state, while it rises above if news are fulfilled.

In order for the income effect to dominate, we assume sufficient investment adjustment costs, i.e. an incentive to invest along the transition. Figure 2 plots this case with $\Delta''(1) = 1.3$ (from Jaimovich and Rebelo, 2009). Here consumption and hours rise on the arrival of news.[9] This is the consequence of a wealth effect: when hearing about the improvement of technology, agents are eager to consume at higher levels and to enjoy more leisure – the labor supply schedule shifts in. Yet, because the wage-hours locus is upwardly

[8] A rise in the markup shifts the downwardly sloping labor demand curve such that hours worked fall despite the outward shift of the labor supply curve.

[9] Note that $\Delta''(1) = 1.3$ is still high enough for hours worked to drop in $t = 4$ when the news is realized. This does not necessarily need to occur and can be circumvented with a lower $\Delta''(1)$ or more elastic markup.

sloping, the level of employment will rise and output increases.[10] This parallels the earlier considered case, so why is the substitution effect the relatively weaker one now? The reason is that adjusting investment became more costly and this has a negative impact on the return to investment. The impulse response functions show this: the interest rate is less responsive, it spikes up (down) when the technology increase is realized (unrealized) but is otherwise flat relative to the no-adjustment costs case. This behavior of the interest rate is consistent with other models utilizing such investment adjustment costs.

Figure 3 plots the three-way relationship between the markup elasticity, the steady-state markup, and the adjustment costs to investment required for expectations-driven business cycles, i.e. consumption, hours worked and investment is required to rise on impact of positive news. The Figure shows numerically that expectations-based business cycles are easier to obtain with higher markups, higher markup elasticities and higher adjustment costs. Are these parameter constellations reasonable? Under the current calibration, the second derivative of the adjustment cost function evaluated at the steady state, $\Delta''(1)$, must be 0.58 or greater. The Figure also suggests that the size of these adjustment costs can be significantly reduced by assuming a more elastic markup. For example, if $\Delta''(1) = 0.1$, positive comovement can be achieved with a markup elasticity of $\varepsilon_\mu = -0.14$. Hence, the combination of endogenous labor wedges and some investment adjustment costs solves the news-shock conundrum in real business cycle economies. Moreover, the degree of market power and the size of investment adjustment costs are within empirical estimates. Note that unlike other studies, capital utilization is fixed. Incorporating variable capital utilization will undoubtedly make it

[10] Here, a fall in the markup shifts the downwardly sloping labor demand curve such that hours worked rise despite the inward shift of the labor supply curve.

easier to obtain expectations-driven business cycles by reducing the required steady state markups and elasticities.

5 Simulations

So far, we have shown that a slightly modified one-sector real business cycle model is able to generate qualitatively realistic comovement of macroeconomic aggregates in response to an anticipated disturbance to future technology. This Section examines the corresponding statistical business cycle properties in comparison with those obtained from the Hodrick-Prescott (HP) filtered cyclical components of US quarterly time series for the period 1948:I-2010:IV.[11] With two exceptions, the calibration of key parameters remains as in the previous Section. We set $\Delta''(1) = 1.3$ as in Jaimovich and Rebelo (2009). In fact, it is much lower than the estimate suggested by Christiano, Eichenbaum and Evans (2005) – it is selected to minimize departures from the plain-vanilla model. Estimates of the level of markups in the US in value added data range from 1.2 to 1.4 and our choice of $\mu = 1.3$ lies in the middle of these numbers (see Floetotto and Jaimovich, 2008).

To begin with, our measure for total factor productivity must be adjusted for market power. Hence, the Solow residual is estimated via

$$\Delta \ln Y_t = \mu[\alpha \Delta \ln K_t + (1-\alpha)\Delta \ln H_t + \Delta \ln z_t]$$

where Δ is the first difference operator.[12] The persistence parameter and the standard deviation of the technology shock are recovered as: $\psi = 0.974$, $\sigma_\zeta = 0.0055$ and hence $\sqrt{\sigma_\xi^2 + \sigma_\epsilon^2} = 0.0055$. Since there is no direct evidence

[11] See Appendix A.3 for detailed information on the US data used in our quantitative analysis.

[12] See Hornstein (1993).

on the volatilities of the unanticipated and news components for the innovations to technology, we use the Simulated Method of Moments (SMM) to calibrate these parameters.[13] In addition, while there is reported evidence of countercyclical markups, no widely agreed aggregate value has emerged that would make it straightforward to pin down ε_μ. Therefore, we decided for SMM to select this specific value as well. Then, the parameter vector to be estimated (for some value of anticipation periods l) is $\Theta \equiv [\sigma_\epsilon^2, \varepsilon_\mu]$. Let us also define a vector of moments that includes the standard deviation of aggregate output and the correlation of investment and output: $M^i \equiv [\sigma_Y, \rho(X, Y)]$, $i = E, S$. Both of these moments provide information on the size of the markup elasticity and on the relative importance of the expected and unexpected shocks to productivity. In particular, the correlation between investment and output would be negative in response to news if $\varepsilon_\mu > \varepsilon_\mu^*$ from (10).

For a given parameter constellation, the model was simulated $N = 20$ times for 352 periods (corresponding to the 1948:I-2010:IV period, $T = 252$, plus 100 initial periods which were purged). This estimation procedure was replicated 500 times. Each of the replications generated a vector of parameter values $\hat{\Theta}$

$$\hat{\Theta} \equiv \arg\min_{\Theta} \frac{NT}{NT+1} \left(M^E - \frac{1}{N} \sum_{t=1}^{N} M_t^S(\Theta) \right) \Omega \left(M^E - \frac{1}{N} \sum_{t=1}^{N} M_t^s(\Theta) \right)'$$

that minimized the distance between the theoretical moments and empirical moments, M^E. Here $M_t^s(\Theta)$ is the theoretical (simulated) vector of moments from simulation t and Ω is the variance-covariance matrix of the empirical moments (see Appendix A.4). Finally, σ_ϵ^2 and ε_μ were calculated by taking the average across the replications.

[13] See Beaudry and Portier (2004) and Karnizova (2010).

Table 1 displays the estimated parameters (standard deviations in parenthesis) based on anticipation periods $l = 3$.[14] Two main results emerge. First, SMM confirms the efficacy of news shocks and the importance of countercyclical markups. In particular, news shocks account for just over half of the variance of the technology shock. Second, the markup elasticity is negative and, given its size and the calibration, expectations-driven business cycles exist.

Using the estimated parameter values, the model was then simulated 1000 times and its second moments were compared to that of the US economy. Tables 2 presents these empirical and artificial moments. The artificial economy, when driven by both shocks can replicate all of the empirically observed output volatility. News shocks alone can explain over 50 percent of output fluctuations. Overall, theory does a reasonably good job in quantitatively mimicking the ranking of cyclical volatilities in GDP, consumption, investment and labor hours, as well as the contemporaneous correlations with output.

Table 3 checks the robustness of the results by considering markup values of 1.2 and 1.4 and higher adjustments costs of $\Delta''(1) = 2.2$ (this value corresponds to Christiano, Ilut, Motto, and Rostagno, 2010). In all three cases, the estimation procedure picks ε_μ that is compatible with news-driven business cycles and news shocks account for more than 50 percent of the variance of the technology shock.

[14] We found that $l = 3$ provides a closer match to the empirical moments than $l = 2$ or 4. Note that higher anticipation periods require larger adjustment costs for news-driven business cycles.

6 Conclusion

News-driven business cycles cannot occur in the standard one-sector real business cycle model: in the absence of shifts to production possibilities, consumption and investment move in opposite directions. The current paper demonstrates that an endogenous labor wedge can solve this comovement puzzle. The wedge has to be sufficiently elastic in order to produce an upwardly sloping wage-hours locus that is steeper than the agents labor supply curve. To illustrate this idea, we introduce imperfect competition where the labor wedge is represented by an endogenous countercyclical markup. A change in the markup on the arrival of news causes a shift in production possibilities, and can allow for positive comovement between consumption, hours worked and investment. However, in order for positive news about the future to lead to an expansion, agents need an additional incentive to invest today (or equivalently to smooth consumption), which we model through investment adjustment costs. Overall, our model is able to generate quantitatively realistic business cycles by matching the relative standard deviations and contemporaneous correlations observed in US data.

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A Appendix

A.1 Wage-hours locus

Section 3's sufficient condition for comovement implies an upwardly sloping wage-hours locus that is steeper than the agent's labor supply curve. Since technology and the capital stock do not move on impact, $\hat{z}_t = \hat{K}_t = 0$ (hatted variables denote percent deviations from their steady state values), combining the log-linearized versions of equations that were used to find the comovement expression dC_t/dX_t yields the relationship between wages and hours in the first period

$$\hat{w}_t = \frac{-\alpha - \varepsilon_\mu \frac{\delta(1-\alpha)+\rho}{\alpha\delta}[\mu(1-\alpha) + \gamma/\chi]}{1 - \varepsilon_\mu \frac{\delta(1-\alpha)+\rho}{\alpha\delta}\chi^{-1}} \hat{H}_t.$$

Substituting in ε_μ^* from (10) implies that the term in front of $\hat{H}_t$ is equal to γ, which is also the slope of the agent's labor supply curve. Therefore, if this term is greater than γ, which will be the case if $\varepsilon_\mu < \varepsilon_\mu^*$, then the wage-hours locus is steeper than the labor supply curve and $\frac{dC_t}{dX_t} > 0$.

A.2 Comovement with $\varepsilon_\mu > 0$

Comovement between consumption and investment is possible if the markup is procyclical to the investment share, that is $\varepsilon_\mu > 0$, only if the intertemporal elasticity of substitution in consumption, χ^{-1}, and the steady state markup, μ, are implausibly high. If $\varepsilon_\mu > 0$, then the denominator in (9) must be negative for $\frac{dC_t}{dX_t} > 0$. Substituting in the upper limit of ε_μ from (3) in the denominator implies that

$$\chi\mu(1-\alpha)\frac{\rho+\delta}{\rho+\delta(1-\alpha)} + \frac{\alpha[\delta(1-\alpha)(2-\mu)+\rho]}{\rho+\delta(1-\alpha)} + \gamma < 0$$

must be satisfied.[15] With indivisible labor, $\gamma = 0$, as $\chi \to 0$ then it must be that $\mu > 2 + \rho/[\delta(1-\alpha)] > 2$ which constitutes an empirically implausible level of market power. Moreover, the impulse response functions show, once again, that positive news about the future lead to a recession at impact.

A.3 Data Sources

This Appendix details the source and construction of the US data used in Section 5. All data is quarterly and for the period 1948:I-2010:IV.

1. Personal Consumption Expenditures, Nondurable Goods. Seasonally adjusted at annual rates, billions of dollars. Source: Bureau of Economic Analysis, NIPA Table 1.1.5.

2. Personal Consumption Expenditures, Services. Seasonally adjusted at annual rates, billions of dollars. Source: Bureau of Economic Analysis, NIPA Table 1.1.5.

3. Personal Consumption Expenditures, Durable Goods. Seasonally adjusted at annual rates, billions of dollars. Source: Bureau of Economic Analysis, NIPA Table 1.1.5.

4. Gross Private Domestic Investment. Seasonally adjusted at annual rates, billions of dollars. Source: Bureau of Economic Analysis, NIPA Table 1.1.5.

5. Gross Domestic Product. Seasonally adjusted at annual rates, billions of dollars. Source: Bureau of Economic Analysis, NIPA Table 1.1.5.

6. Gross Domestic Product. Seasonally adjusted at annual rates, billions of chained (2005) dollars. Source: Bureau of Economic Analysis, NIPA Table 1.1.6.

7. Nonfarm Business Hours. Index 2005=100, seasonally adjusted. Source:

[15] Here $s = 1 - C/Y = \delta\alpha/(\rho+\delta)$.

Bureau of Labor Statistics, Series Id: PRS85006033.

8. Civilian Noninstitutional Population. 16 years and over, thousands. Source: Bureau of Labor Statistics, Series Id: LNU00000000Q.

9. GDP Deflator = (5)/(6).

10. Real Per Capita Consumption, $C_t = [(1) + (2)]/(9)/(8)$.

11. Real Per Capita Investment, $X_t = [(3) + (4)]/(9)/(8)$.

12. Real Per Capita Output, $Y_t = (10) + (11)$.

13. Per Capita Hours Worked, $H_t = (7)/(8)$.

14. Investment Share, $s_t = (11)/(12)$.

15. Labor Productivity, $Y_t/H_t = (12)/(13)$.

A.4 Weighting Matrix

We follow Karnizova (2010) in constructing the weighting matrix Ω. This matrix depends entirely on empirical data. First, we define the vector of empirical HP filtered moments as $\hat{m}_T = [var(Y_t), cov(X_t, Y_t), var(X_t)]'$, where $var(Y_t) = (1/T)\sum_{t=1}^{T} Y_t^2$. The variance-covariance matrix of these empirical moments is then computed using the Newey-West estimator with a Bartlett kernel with four lags, $p = 4$, of the series $m_t = [Y_t^2, X_tY_t, X_t^2]'$. The Newey-West estimator is calculated by

$$\hat{\omega} = \Gamma_0 + \sum_{j=1}^{p} \left(1 - \frac{j}{p+1}\right) \left(\Gamma_j + \Gamma_j'\right)$$

where

$$\Gamma_j = (1/T) \sum_{t=j+1}^{T} [m_t - \hat{m}_T][m_{t-j} - \hat{m}_T]'$$

Next, let a vector x consist of $x_1 \equiv var(Y_t)$, $x_2 \equiv cov(X_t, Y_t)$, and $x_3 \equiv var(X_t)$. The two moments that we are interested in are functions of these variances and covariances: $g_1(x) = \sqrt{x_1}$, $g_2(x) = x_2/\left(\sqrt{x_1}\sqrt{x_3}\right)$. Then the weighting matrix $\Omega = [\Delta G(x) * \hat{\omega} * \Delta G(x)']^{-1}$ where $\Delta G(x)$ is the gradient of the function $G(x) = [g_1(x), g_2(x)]'$.

Table 1		
Estimated Parameter Vector, $\hat{\Theta}$		
ε_μ	σ_ϵ^2	σ_ξ^2
-0.1813 (0.0022)	0.1553 (0.1074)	0.1467 (0.1074)

The estimated parameter vector is the average from 500 replications of the estimation procedure based on anticipation periods $l = 3$. Standard deviations are in parenthesis. σ_ϵ^2 and σ_ξ^2 are reported in percent terms.

Table 2								
Business Cycle Statistics								
	Data		Model		Model (σ_ϵ^2 only)		Model (σ_ξ^2 only)	
x	$\sigma_x \left(\frac{\sigma_x}{\sigma_Y}\right)$	$\rho(x,Y)$	$\sigma_x \left(\frac{\sigma_x}{\sigma_Y}\right)$	$\rho(x,Y)$	$\sigma_x \left(\frac{\sigma_x}{\sigma_Y}\right)$	$\rho(x,Y)$	$\sigma_x \left(\frac{\sigma_x}{\sigma_Y}\right)$	$\rho(x,Y)$
Y_t	2.42 (1)	1	2.44 (1)	1	1.76 (1)	1	1.67 (1)	1
X_t	6.57 (2.72)	0.98	8.08 (3.31)	0.98	5.78 (3.27)	0.98	5.61 (3.35)	0.98
C_t	0.89 (0.37)	0.71	1.05 (0.43)	0.91	0.77 (0.44)	0.92	0.71 (0.42)	0.90
H_t	1.94 (0.80)	0.81	2.05 (0.84)	0.93	1.45 (0.82)	0.93	1.44 (0.86)	0.93
s_t	4.23 (1.75)	0.95	5.71 (2.34)	0.96	4.06 (2.30)	0.96	3.98 (2.38)	0.96
Y_t/H_t	1.42 (0.59)	0.59	0.89 (0.36)	0.59	0.65 (0.37)	0.62	0.61 (0.36)	0.55
μ_t	-	-	1.03 (0.42)	-0.96	0.74 (0.42)	-0.96	0.72 (0.43)	-0.96

See Appendix A.3 for the source of US data. σ_Y denotes the standard deviation of output and $\rho(x,Y)$ is the contemporaneous correlation of variable x and Y. Blank entries for μ are due to data unavailability.

Table 3			
Robustness			
	$\mu = 1.2$	$\mu = 1.4$	$\Delta''(1) = 2.2$
ε_μ	-0.1666 (0)*	-0.1801 (0.0018)	-0.2202 (0.0034)
σ_ϵ^2	0.2195 (0.1335)	0.1883 (0.0938)	0.2144 (0.1036)
σ_ξ^2	0.1205 (0.1335)	0.0877 (0.0938)	0.0876 (0.1036)

*From (3), the selected ε_μ is at its (negative) limit.

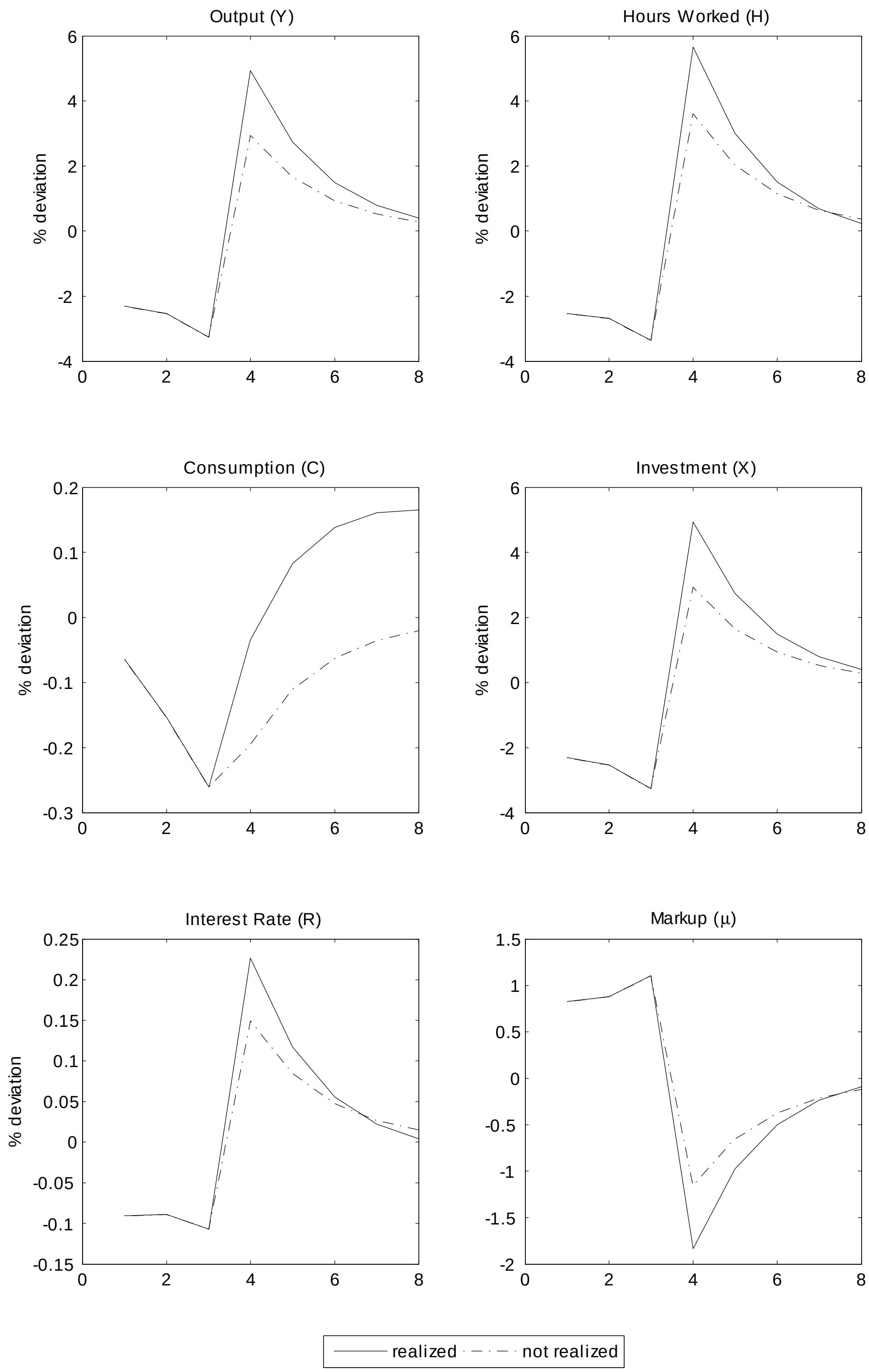

Figure 1: Response of the economy without investment adjustment costs to news arriving at $t = 1$ and a realization/non-realization at $t = 4$.

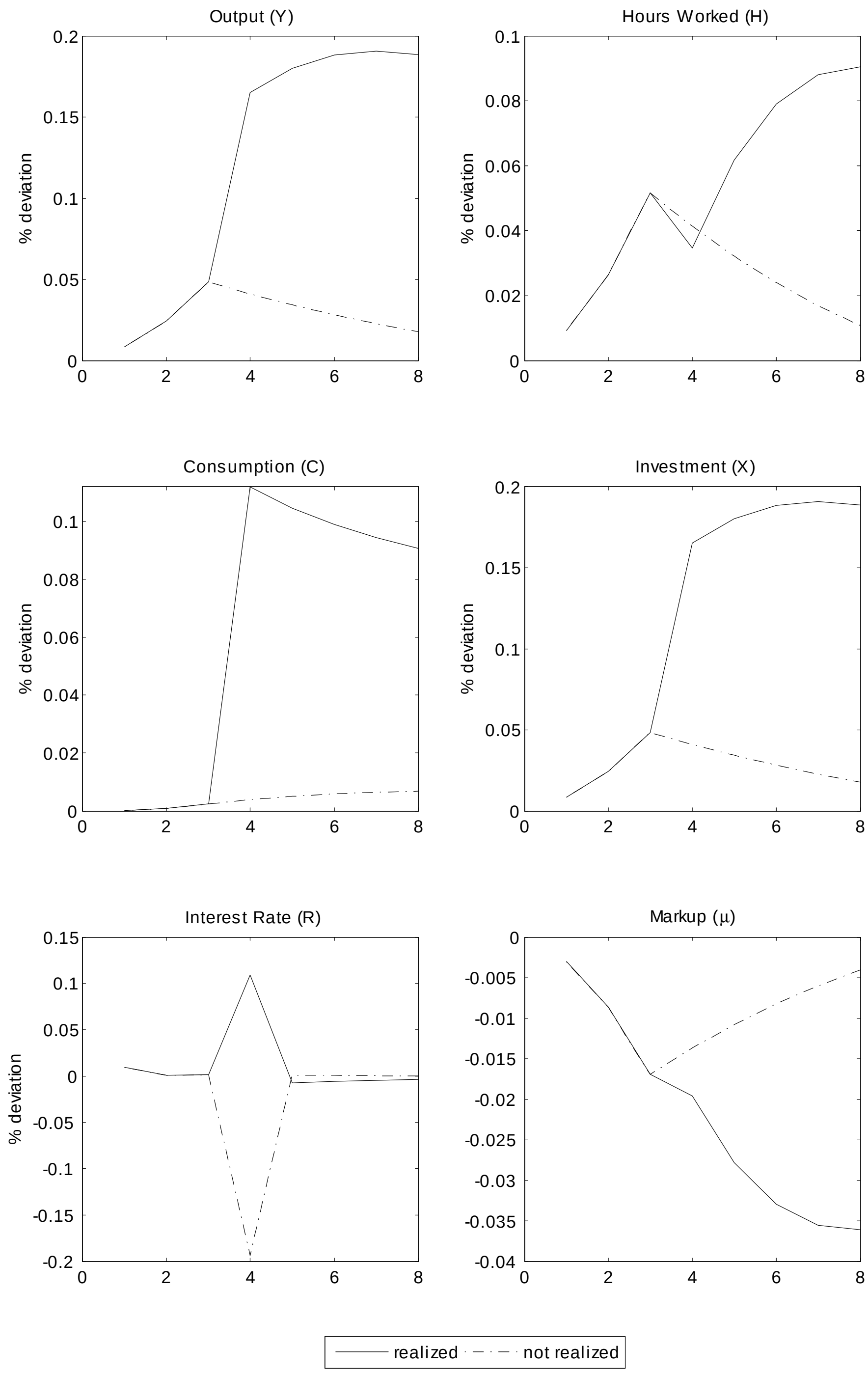

Figure 2: Response of the economy with investment adjustment costs to news arriving at $t = 1$ and a realization/non-realization at $t = 4$.

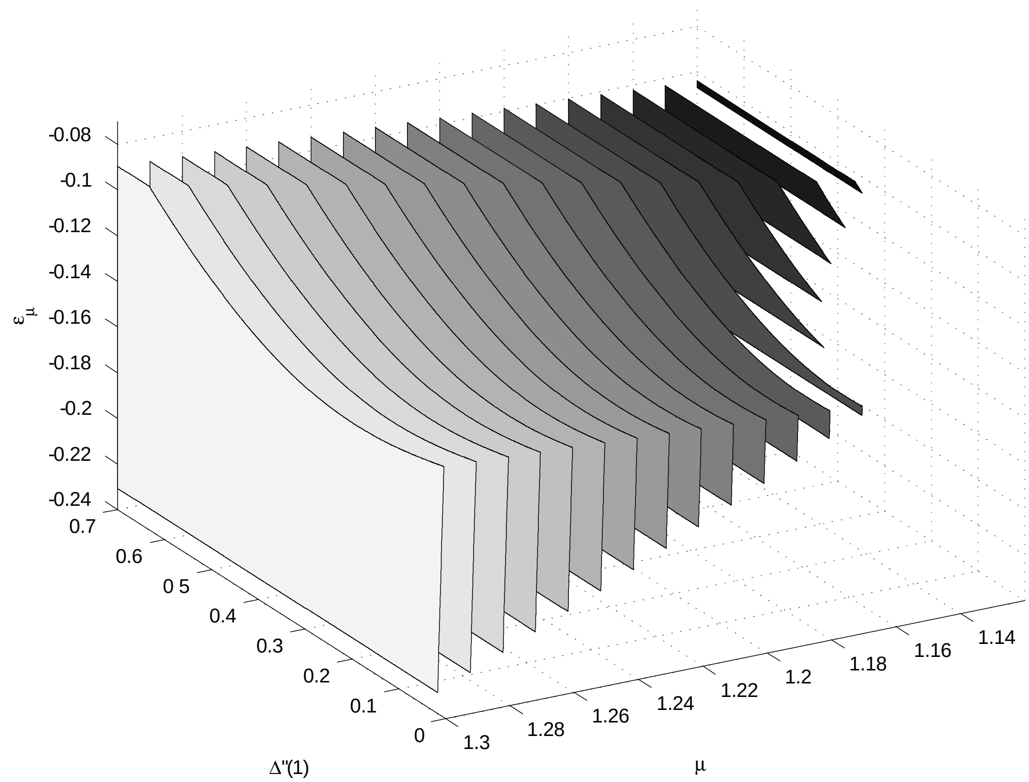

Figure 3: Markup elasticity, the steady-state markup, and the minimum adjustment costs to investment required for expectations-driven business cycles.