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Oscar Pavlov and 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 business cycles. The current paper shows that this conundrum can be solved by adding countercyclical markups and modest capital adjustment costs.

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1 Introduction

A plain-vanilla real business cycle model is unable to produce expectations-driven business cycles largely because of its inability to generate positive co-movement between consumption and investment in response to news about future total factor productivity.[1] Jaimovich and Rebelo (2009) solve this conundrum by adding three elements into the standard model: non-separable preferences that weaken the income effect on labor supply, variable capital utilization, and investment adjustment costs. The current paper illustrates an alternative approach that requires the addition of only two elements. First, an endogenous labor wedge can solve the co-movement puzzle. In the present paper, we use 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 defined as where the arrival of positive news about future technology would induce an economic boom. For this to occur we need to introduce a second ingredient: modest investment adjustment costs.

The economic mechanism for the result can be understood as follows. A change in the markup implies a change to economic distortions and, consequently, a shift in the production possibilities. A sufficiently countercyclical markup can result in an upwardly sloping wage-hour locus. This part of the argument is not unlike indeterminacy models, yet, here we do not consider the case of sunspot equilibria. Countercyclical markups solve the co-movement problem, however, positive news about the future now cause recessions as

[1] See Beaudry and Portier (2004, 2007).

[2] Empirical evidence suggests that markups are countercyclical. See Rotemberg and Woodford (1999) for a survey.

aggregate output falls on impact: in anticipation that the future wage-hour locus will shift leftward and reduce hours worked, agents decrease current consumption due to a dominating (negative) income effect.[3] Since the labor supply curve shifts downward, this also results in a fall in hours worked and investment. However, news-driven business cycles emerge if the substitution effect dominates. This is possible if agents are given an incentive to invest today by adjustment costs to capital investment. If these adjustment costs are sufficiently large then the substitution effect dominates the wealth effect and agents not only increase current consumption but the resulting upward shift of labor supply also raises hours worked and investment.

The rest of this paper proceeds as follows. Section 2 lays out the model. Section 3 presents conditions for co-movement and expectations-driven business cycles are derived in Section 4. Section 5 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 monopolistic suppliers cannot price-discriminate between the consumption and investment related demands of their products, hence, the composition of demand can affect their market power.

2.1 Technology

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 increases the capital stock. The production

[3] See also Guo, Sirbu and Suen (2011) and Eusepi (2009).

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 constant number of intermediate good firms. 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

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

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 i 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

$$\log z_t = (1-\psi)\log z + \psi \log z_{t-1} + \epsilon_{t-l} \qquad \psi \in [0,1]$$

where ϵ_{t-l} is an i.i.d. news shock that affects productivity l periods later. Given the demand from the final goods sector, the monopolist sets the profit maximizing price $p_{i,t}$ 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 demand for hours is

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

where w_t is the real wage.

We restrict our analysis to a symmetric equilibrium where all monopolists produce the same amount and charge the same price, $p_t = 1$. The number of monopolistic firms is such that there are no long-run pure profits. This assumption is consistent with Rotemberg and Woodford (1999) and others. Aggregate output is thus

$$Y_t = z_t K_t^{\alpha} H_t^{1-\alpha} - N\phi \tag{2}$$

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

$$s_t \equiv \frac{X_t}{Y_t}. \tag{3}$$

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

$$\mu_t = \frac{\frac{1}{1-\sigma}(1-s_t) + \frac{1}{1-\eta} s_t}{\frac{1}{1-\sigma}(1-s_t) + \frac{1}{1-\eta} s_t - 1}. \tag{4}$$

Note that if the elasticities of substitition 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

$$\frac{1-\mu}{\mu} < \varepsilon_\mu < \frac{\mu-1}{\mu}\frac{s}{1-s} \tag{5}$$

where μ and s are steady state values.

2.2 Preferences

The representative agent maximizes

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

where ρ is the discount rate, χ is 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 (potential) profits, Π_t, generated by them. Then, the budget is constrained by

$$w_t H_t + r_t K_t + \Pi_t \geq X_t + C_t \tag{6}$$

and capital accumulation follows

$$K_{t+1} = (1-\delta)K_t + X_t\left[1 - \Delta\left(\frac{X_t}{X_{t-1}}\right)\right] \qquad 0 < \delta < 1 \tag{7}$$

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 $\Delta''(1) \geq 0$.[4] The first-order conditions for the agent are

$$\upsilon H_t^{\gamma} C_t^{\chi} = w_t \tag{8}$$

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

$$\eta_t = \frac{1}{1+\rho} E_t \left[\lambda_{t+1} r_{t+1} + \eta_{t+1}(1-\delta) \right] \tag{9}$$

$$\lambda_t = \eta_t \left[1 - \Delta\left(\frac{X_t}{X_{t-1}}\right) - \frac{X_t}{X_{t-1}} \Delta'\left(\frac{X_t}{X_{t-1}}\right) \right] + \frac{1}{1+\rho} E_t \eta_{t+1} \left(\frac{X_{t+1}}{X_t}\right)^2 \Delta'\left(\frac{X_{t+1}}{X_t}\right) \tag{10}$$

where λ_t and η_t are the multipliers associated with (6) and (7), respectively. Equation (8) describes the household's leisure-consumption tradeoff, (9) is the intertemporal Euler equation and (10) portrays the investment dynamics. In addition the usual transversality condition holds.

3 Conditions for co-movement

In the first step of our analysis, we obtain a condition for positive co-movement 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 improvements. The analytical expression for this co-movement is given by[5]

$$\frac{dC_t}{dX_t} = -\frac{\alpha + \gamma + \varepsilon_\mu \mu (1-\alpha) \frac{\delta(1-\alpha)+\rho}{\delta\alpha}}{\mu(1-\alpha)[\chi \frac{Y}{C} - \varepsilon_\mu] + \gamma + \alpha}. \tag{11}$$

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 there is no positive co-movement. If the markup is countercyclical, $\varepsilon_\mu < 0$, the sufficient condition for co-movement between investment and consumption is

$$\varepsilon_\mu < \varepsilon_\mu^* \equiv \frac{-\alpha\delta(\alpha+\gamma)}{\mu(1-\alpha)[\delta(1-\alpha)+\rho]} < 0. \tag{12}$$

Substituting in the lower limit of ε_μ from (5) yields the minimum steady state markup, $\mu_{\min}$, required for co-movement:

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

[5] We take a total derivative of equations (1), (2), (3), (4), (8) and the resource constraint $Y_t = C_t + X_t$ and set $dz_t = dK_t = 0$. See also Beaudry and Portier (2004, 2007).

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 $\frac{dC_t}{dH_t} > 0$. This condition implies that the wage-hour locus is upwardly sloping and steeper than the agent's labor supply curve (see Appendix 6.1.); it is the same as the necessary condition for indeterminacy in a continuous time Benhabib and Farmer (1994) model. Co-movement 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 6.2.).

Why does a time-varying markup solve the co-movement puzzle? In the composition of aggregate demand model, the markup drives a wedge between the marginal product of labor and the marginal rate of consumption-leisure substitution. Combining (1) and (8), leads to

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

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

4 News-driven business cycles

After having established the conditions for co-movement, 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.

We run the following news-shock experiment: news arrives in period $t = 1$ about a rise in productivity that will occur in period $t = 4$. We calibrate $\chi = 1$, $\gamma = 0$, $\beta = 0.99$, $\alpha = 0.3$, and $\delta = 0.025$. Following Christiano, Ilut, Motto and Rostagno (2010) and Eusepi and Preston (2009), the increase in productivity will be temporary and $\psi = 0.90$. While the minimum steady state markup required for co-movement is $\mu_{\min} = 1.12$, for clear illustration we set $\mu = 1.2$ and its elasticity to $\varepsilon_\mu = -0.1$, which satisfies the sufficient condition for co-movement (12).

At first, no adjustment costs are assumed to affect the economy. The model generates a recession where consumption, hours worked, and investment all fall on the impact of news (i.e. at $t = 1$). The result is reminiscent of Guo, Sirbu and Suen (2011): due to an upwardly sloping wage-hour locus the news generates a negative wealth effect. Agents expect that at $t = 4$ the upwardly sloping wage-hour locus will shift upward due to the increase in productivity. Since this shift will result in a fall in hours worked and the real wage, lifetime income also falls. The wealth effect dominates the substitution effect and labor supply shifts downward, producing a simultaneous decline of consumption, hours and investment at $t = 1$.[6]

In order for the substitution effect to dominate, we assume adjustment costs to investment to give an incentive to invest today. The dominating

[6]Here, the markup rises. This causes the downwardly sloping labor demand curve to shift downwards sufficiently such that hours worked fall.

substitution effect then leads to an upward shift of the labor supply curve and produces a simultaneous rise in consumption, hours and investment.[7] Figure 1 plots the relationship between the markup elasticity, the steady-state markup, and the minimum adjustment costs to investment required for consumption, hours worked and investment to rise on impact of news.[8] Under the current calibration, the second derivative of the adjustment cost function evaluated at the steady state, $\Delta''(1)$, must be 0.47 or greater. Figure 1 also suggests that the size of these adjustment costs can be significantly reduced by assuming a more elastic markup. Figure 2 plots impulse response functions where $\varepsilon_\mu = -0.14$ and $\Delta''(1) = 0.1$ – this size of adjustment costs is very small when compared to the Christiano, Eichenbaum and Evans (2005) estimate or to Jaimovich and Rebelo (2009). The Figure demonstrates that consumption, hours worked and investment all rise on arrival of news and positively co-move before and after the realization of the productivity shock. Hence, the combination of endogenous labor wedges and investment adjustment costs solves the news-shock conundrum in real business cycle economies.

5 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 direction. The current paper demonstrates that an endogenous labor wedge between the equilibrium wage and the marginal product of labor can solve this co-movement puzzle. The

[7] In this case, the markup falls and the downwardly sloping labor demand shifts upward sufficiently such that hours worked rise.

[8] Changing this to positive co-movement across all periods leading up to the realization of the shock (i.e. for $t = 1, 2, 3$) produces a similar figure and is available upon request.

wedge has to be sufficiently elastic in order to produce an upwardly sloping wage-hour locus that is steeper than the agents labor supply curve and so the possibility of co-movement is directly related to the necessary condition for indeterminacy in one-sector continuous time real business cycle models. 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 postitive co-movement between consumption, hours worked and investment. However, in order for positive news about the future to lead to an expansion, agents need a sufficiently strong incentive to invest today, which we model through investment adjustment costs. While the model can produce qualitatively realistic business cycles driven by agent's expectations about future fundamentals, it remains to be seen whether it (and models with similar underlying mechanisms) can produce quantitatively realistic news-driven business cycle fluctuations. We plan to pursue this idea in future work.

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6 Appendix

6.1 Wage-hour locus

This appendix shows that the sufficient condition for co-movement from Section 3 implies an upwardly sloping wage-hour 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 co-movement 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 (12) 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-hour locus is steeper than the labor supply curve and $\frac{dC_t}{dX_t} > 0$.

6.2 Co-movement with $\varepsilon_\mu > 0$

This appendix demonstrates that co-movement 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 (11) must be negative for $\frac{dC_t}{dX_t} > 0$. Substituting in

the upper limit of ε_μ from (5) 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.[9] 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 today.

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

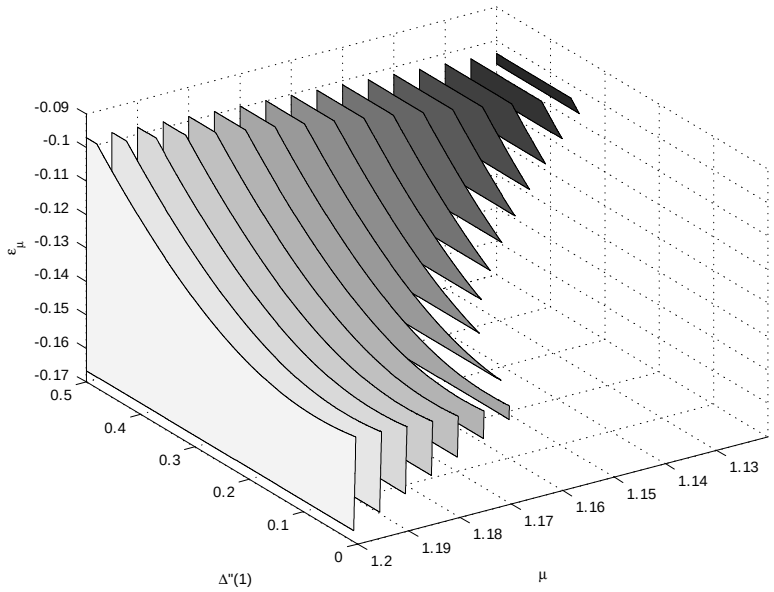


Figure 1: Markup elasticity, the steady-state markup, and the minimum adjustment costs to investment required for expectations-driven business cycles.

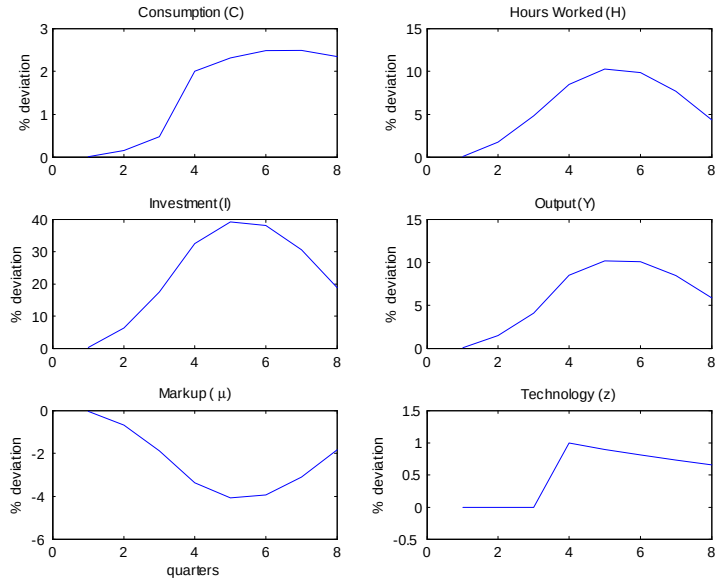


Figure 2: Impulse Response Functions