Essays on Expectations-Driven Business Cycles

Oscar Pavlov

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Abstract

This thesis addresses the role of imperfect competition in business cycles driven by expectations and beliefs about the future state of the economy. It consists of three self-contained papers.

The first paper examines the roles of composition of aggregate demand and taste for variety in a real business cycle model with endogenous entries and exits of monopolistically competitive firms. It finds that taste for variety can alone make the economy susceptible to endogenous (sunspot driven) business cycles. Importantly, in light of recent research suggesting that aggregate markups in the U.S. are procyclical, sunspot equilibria emerge with procyclical markups that are within empirically plausible ranges.

The second paper considers aggregate markup variations in business cycles driven by news about future total factor productivity. It shows that the addition of endogenous countercyclical markups and investment adjustment costs allows the standard one-sector real business cycle model to generate empirically supported expectations-driven fluctuations. The simulated model reproduces the regular features of U.S. aggregate fluctuations.

The third paper investigates the role of product variety effects and variable markups in expectations-driven business cycles. It demonstrates that taste for variety and investment adjustment costs allow the otherwise canonical real business cycle model to display quantitatively realistic fluctuations in response to news about future total factor productivity. Moreover, the interaction between price-cost decisions and firm entry and exit allows such business cycles to occur for empirically plausible levels of procyclical markups and variety effects.

Declaration

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Signature of Author: Date:

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I Introduction

The aim of this thesis is to contribute to our understanding of expectations-driven business cycles by investigating primarily the features of imperfect competition in a dynamic stochastic general equilibrium model. In the following papers I provide a number of plausible channels by which the economy can generate realistic business cycles driven by news about future fundamentals and by animal spirits. The main points that motivate and unify the three self-contained papers included in this thesis are: (i) recent research suggesting that changes in expectations, in particular through news about future fundamentals, are an important source of economic fluctuations, (ii) the evidence for monopoly power in many economies and (iii) that markups and the composition of aggregate demand vary over the business cycle. Empirical evidence for the procyclical movement of firms and products and more recent work suggesting that aggregate markups may not be countercyclical provide further motivations for two of the papers.

The first paper investigates the role of markup variations, taste for variety, and entry and exit of monopolistic firms in endogenous (sunspot driven) business cycles. Changes in the composition of aggregate demand affect intermediate good firms' optimal markups due to the differences in the production technologies of final goods. Taste for variety matters since a rise in the number of differentiated products from the free entry of monopolistic firms leads to gains in endogenous aggregate productivity. That is, final goods are produced more efficiently when there are a greater number of different intermediate goods. Unlike many related papers, this variety effect is completely disentangled from parameters that determine the market power of firms. The paper finds that if the gains to variety are sufficiently large then the economy's equilibrium is indeterminate. Sunspots (aka animal spirits) can influence business cycles and hence many possible equilibria exist across states with identical fundamentals. Intuitively, upon optimistic expectations about potential income, with leisure being a normal good, higher consumption shifts the labor supply curve inward. The increase in demand for higher output leads to the entry of firms, which through the variety effects shifts the labor demand curve outward such that both the wage and labor hours rise. The optimistic expectation thus is self-fulfilled. In contrast to existing literature, the economy is susceptible to these endogenous business cycles even if markups are procyclical and within empirically plausible ranges. This result arises due to higher markups inducing greater firm entry and is particularly noteworthy in light of recent research suggesting that aggregate markups in the U.S. are procyclical. The simulated model shows that self-fulfilling beliefs can generate business cycles that resemble empirically observed fluctuations.

In the second paper I examine the role of countercyclical markups in a real business cycle economy driven by news about future total factor productivity (TFP). The standard one-sector real business model is unable to generate expectations-driven fluctuations. That is, the empirically documented positive comovement between consumption and investment in the absence of changes to the economy's fundamentals. The paper demonstrates that the addition of endogenous countercyclical markups and modest investment adjustment costs addresses this problem. Variable markups shift economic distortions via an endogenous labor wedge between the marginal product of labor and the marginal rate of consumption-leisure substitution, while adjustment costs imply that it is optimal to smooth investment intertemporally. Therefore, upon hearing good news about future technology, there is an incentive to increase production and to invest immediately. If the optimal markups set by monopolistic producers are countercyclical then markups fall with increased output and the demand for labor increases. If markups are sufficiently elastic then the resulting positive wealth effect also raises consumption. The model is simulated by anticipated shocks to TFP and is able to replicate the regular features of U.S. business cycles.

The third paper goes back to the idea that taste for variety may be an important mechanism for understanding expectations-based fluctuations. First, it shows that the addition of product variety effects and investment adjustment costs enable the otherwise standard real business cycle model to generate news-driven business cycles.

It turns out that firm entry and exit in the presence of positive variety effects works much like a countercyclical markups. With adjustment costs giving an incentive to build up the capital stock in anticipation of higher future TFP, the procyclical entry of firms generates a rise in efficiency and hence an outward shift of the labor demand curve. If the wealth effect associated with the higher current productivity is strong enough then the rise in consumption shifts the labor supply curve inward such that positive comovement between consumption, hours and investment is achieved. Second, the paper demonstrates that these business cycles arise easily even if aggregate markups are procyclical. By itself, a higher profit maximizing markup reduces labor demand and opens up profit opportunities. However, due to the free entry that occurs until all such opportunities are exhausted, a higher markup implies greater firm entry than what would otherwise occur. As the number of firms and differentiated products rises, the gains from variety work against (and in some cases dominate) the usual contractionary effect of the higher markup. Finally, the model's key parameters are estimated by the Simulated Method of Moments and the statistics of its artificial business cycles are compared to their quarterly U.S. counterparts. The model performs well at matching the empirical ordering of cyclical volatilities and contemporaneous correlations.

Statement of Authorship

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Author Contributions

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Name of Principal Author (Candidate)	Oscar Pavlov		
Contribution to the Paper	Performed all modelling, analytics, interpretation of results, computations and simulations. Wrote the manuscript and produced all figures and tables.		
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Name of Co-Author	Mark Weder		
Contribution to the Paper	Supervised development of work and helped to evaluate and write the manuscript for publication. Concept and solution for analytical indeterminacy/determinacy regions, traces and determinants. Acted as corresponding author.		
Signature		Date	13/3/13

II Variety Matters

Countercyclical markups are a key transmission mechanism in many endogenous business cycle models. Yet, recent findings suggest that aggregate markups in the U.S. are procyclical. The current model addresses this issue. It extends Galí's (1994) composition of aggregate demand model by endogenous entry and exit of firms and by product variety effects. Endogenous business cycles emerge with procyclical markups that are within empirically plausible ranges.

1 Introduction

Beginning with Benhabib and Farmer (1994), Farmer and Guo (1994) and Galí (1994) to name just three, a large body of work now exists in which a standard real business cycle model is modified to generate indeterminate equilibria driven by sunspot shocks. The two central mechanisms that produce this indeterminacy result are increasing returns to scale technologies and countercyclical markups. While the existence of scale economies has undergone much empirical testing, empirical work on the aggregate markup's behavior over the business cycle remains less evolved. Moreover, Nekarda and Ramey (2010) suggest that markups in the U.S. are procyclical or acyclical. Hence, the Nekarda-Ramey findings put doubt on the plausibility of endogenous business cycle models that build on countercyclical markups.[1] The current paper addresses this issue by laying out an artificial economy that is susceptible to endogenous business cycles even if markups are procyclical.

Specifically, we investigate the roles of composition of aggregate demand and taste for variety in a general equilibrium economy with endogenous entries and exits of monopolistically competitive firms.[2] These firms supply differentiated intermedi-

[1] The finding is not uncontroversial and Rotemberg and Woodford (1999), for example, claim that markups are countercyclical.

[2] The procyclicality of firm entry and its implications for the business cycle has been discussed by Chatterjee and Cooper (1993), Devereux, Head and Lapham (1996), and more recently by

ate goods that are used in the production of final consumption goods and investment goods. The technologies of assembling the two final goods differ, hence, the composition of demand affects the degree of market power of the monopolistic firms. At this stage, the model resembles Schmitt-Grohé (1997) and Galí (1994). However, we are able to show that endogenous net business formation eliminates the existence of sunspot equilibria. For these equilibria to re-emerge, we introduce taste for variety.[3] Variety effects connote the idea that a greater number of differentiated products enhances efficiency. A rise in product variety then leads to a fall in aggregate prices (relative to the price of intermediate goods) or equivalently to an endogenous rise in the efficiency wedge, which can be interpreted as a rise in productivity. If the taste for variety is sufficiently large (in a well defined way) then economic fluctuations can be driven by self-fulfilling beliefs. Moreover, we show that these belief shocks generate artificial business cycles that resemble empirically observed fluctuations. Returning to Nekarda and Ramey's (2010) findings, artificial markups can be either procyclical or countercyclical. In fact, we identify situations where procyclical markups (in the empirically plausible range) make indeterminacy easier to obtain. Moreover, for countercyclical markups, our model generates indeterminacy at internal returns to scale of about 1.09 without having to assume decreasing marginal costs, and with fixed capital utilization and only infinitesimally small variety effects in the final investment good.

Several studies affirm the presence of variety effects. This empirical evidence includes Funke and Ruhwedel (2001) who report a positive relationship between an index of product variety and per capita income. Feenstra and Kee (2008) and Feenstra (2010) find similar effects in the trade context. Ardelean (2009) estimates consumer's love for variety and suggests that variety matters for both imported and domestically produced goods. Drescher, Thiele and Weiss (2008) present evidence on consumers' preferences for variety in food consumption. While these authors affirm the presence of variety effects, we cannot find a general agreement on point

Jaimovich (2007) who also offers empirical support.

[3] Also known as love of variety, variety gains, increasing returns to variety, returns to specialization.

estimates. Hence, we do not calibrate our artificial economy to such an estimate, rather, our strategy is to ferret out indeterminacy situations that require this effect to be as small as possible.

The economic mechanism that concocts the indeterminacy is easily understood in terms of the equilibrium wage-hours locus: expectations about the future turn out to be self-fulfilling if this locus is upwardly sloping and steeper than the labor supply curve. Technologically increasing returns are not the reason for the positive slope. Instead, a combination of taste for variety and changes of the markup delivers this result. With a constant number of firms, a countercyclical markup leads to a procyclical efficiency wedge and thus can give rise to an upwardly sloping wage-hours locus. In this case, a countercyclical efficiency wedge due a procyclical markup cannot give rise to indeterminacy. However, in the presence of positive variety effects, endogenous firm entry and exit implies that an increase in the number of firms leads to an increase in productivity. Then a procyclical markup, despite itself lowering the efficiency wedge, can induce greater firm entry. Alternatively, a countercyclical markup improves the efficiency wedge, but has a negative impact on firm entry. In reduced form, these work like increasing returns at the aggregate level, and hence, the wage-hours locus can become upwardly sloping.[4]

Related work includes Benhabib and Farmer (1994), Farmer and Guo (1994) and Wen (1998) who show that technological increasing returns lead to sunspot equilibria in real business cycle models. However, these authors rely on declining marginal costs, which does not receive empirical support.[5] Schmitt-Grohé (1997), Weder (2000), and Jaimovich (2007) lay out models that generate indeterminacy through countercyclical markups.[6] Seegmuller (2007) shows that taste for variety can be the source of sunspot equilibria in an overlapping generations model with constant markups. Markups are also constant in Chang, Hung and Huang (2011)

[4] Note that the aggregate labor demand curve is still downwardly sloping and variations in the markup and the number of firms work like productivity shifters.

[5] For example, see Basu and Fernald (1997).

[6] See also Dos Santos Ferreira and Dufourt (2006) as well as Dos Santos Ferreira and Lloyd-Braga (2008).

who additionally assume production externalities, i.e. declining marginal costs. The variety effect in their paper is tightly linked to the elasticity of substitution, while we follow Benassy (1996) by disentangling this effect from the elasticity parameters that determine the market power of monopolistic firms. Moreover, to our knowledge, the current paper is the first in which indeterminacy can be obtained when markups are procyclical with respect to aggregate output.[7]

The rest of this paper proceeds as follows. Section 2 lays out the model. Section 3 analyzes the local dynamics. Variable capital utilization is introduced in Section 4. Section 5 checks robustness regarding the formulation of the variety effect. Simulations are presented in Section 6. Section 7 concludes.

2 Model

The artificial economy is based on the composition of aggregate demand model laid out by Schmitt-Grohé (1997) and originally put forth by Galí (1994). Each intermediate good firm produces a differentiated intermediate good and acts as a monopolist competitor for this good. These goods are bought by a final sector that welds them together into two different final goods. One final good is consumed, while the other increases the capital stock. Monopolistic competitors cannot price-discriminate between the consumption and investment related demands, hence, the composition of demand affects their market power. Our model differs from Schmitt-Grohé (1997) and Galí (1994) in two important ways. First, the number of intermediate good varieties, N_t, is endogenously determined each period: free entry takes place up to the point where the zero profit condition holds. Empirically, zero or close to zero pure profits seem to be a reasonable assumption. Second, we allow for variety effects. These effects imply that net business formation induces productivity increases. Unlike other work on indeterminacy, including Chang et al. (2011), the only source of

[7] Galí's (1994) composition of demand model can produce indeterminacy with markups that are procyclical to the investment share, however, the markups are negatively correlated to aggregate output. Schmitt-Grohé (1997) shows that this is due to his specification of preferences, which are linear in consumption. In addition, Galí requires markups that are outside of the empirically plausible range.

technological increasing returns are fixed costs to operate the firms. Time evolves continuously. We will begin with the presentation of the economy's technology.

2.1 Firms

The final goods sector is perfectly competitive and produces the final consumption good, C_t and the final investment good, X_t. The production functions linking the final outputs to intermediate goods are

$$C_t = N_t^{1+\omega} \left(\frac{1}{N_t} \int_0^{N_t} y_{i,c,t}^{\sigma} di \right)^{1/\sigma} \qquad \omega \geq 0, \sigma \in (0,1)$$

and

$$X_t = N_t^{1+\tau} \left(\frac{1}{N_t} \int_0^{N_t} y_{i,x,t}^{\eta} di \right)^{1/\eta} \qquad \tau \geq 0, \eta \in (0,1)$$

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. The specific functional form implies constant elasticities of substitution between intermediate goods equal to $1/(1-\sigma)$ and $1/(1-\eta)$. Parameters ω and τ govern the strength of the variety effects, which are absent when $\omega = 0$ and $\tau = 0$. Our formulation follows Benassy (1996): the variety effect is independent of the elasticity of substitution parameters σ and η. Intermediate good producers are not able to price discriminate regardless of whether their goods will be used in the production of consumption or investment goods, thus, they charge the identical price $p_{i,t}$ to both demands (see also Galí, 1994). Then, the conditional demand for intermediate good i to be used in the production of the consumption good is

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

with the price index

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

Similarly, investment demand becomes

$$y_{i,x,t} = \left(\frac{p_{i,t}}{P_{x,t}} \right)^{1/(\eta-1)} N_t^{\frac{\eta(1/\eta-1-\tau)}{\eta-1}} X_t \tag{2}$$

and

$$P_{x,t} = N_t^{(1-\eta)/\eta-\tau} \left(\int_0^{N_t} p_{i,t}^{\eta/(\eta-1)} di \right)^{(\eta-1)/\eta}.$$

Intermediate goods are produced using capital, $k_{i,t}$, and labor, $h_{i,t}$, both supplied on perfectly competitive factor markets. Each firm i produces according to the production function

$$y_{i,t} = k_{i,t}^{\alpha} h_{i,t}^{1-\alpha} - \phi \qquad 0 < \alpha < 1, \phi > 0 \tag{3}$$

where ϕ stands for fixed overhead costs. The presence of ϕ implies internal increasing returns to scale. Each monopolist faces demands (1) and (2) and sets the profit maximizing price $p_{i,t}$ such that the markup, $\mu_{i,t}$, equals

$$\mu_{i,t} = \frac{\frac{1}{\sigma-1} y_{i,c,t} + \frac{1}{\eta-1} y_{i,x,t}}{\frac{\sigma}{\sigma-1} y_{i,c,t} + \frac{\eta}{\eta-1} y_{i,x,t}}. \tag{4}$$

The implicit demands for labor and capital are

$$\frac{\mu_{i,t}}{p_{i,t}} w_t = (1-\alpha) \frac{k_{i,t}^{\alpha} h_{i,t}^{1-\alpha}}{h_{i,t}} \tag{5}$$

and

$$\frac{\mu_{i,t}}{p_{i,t}} r_t = \alpha \frac{k_{i,t}^{\alpha} h_{i,t}^{1-\alpha}}{k_{i,t}} \tag{6}$$

where w_t is the wage and r_t is the rental rate earned by agents for their labor and capital services. Free entry into the intermediate goods sector leads to zero profits (net of fixed costs) for each active firm in every period. Entry and exit decisions are static and simply depend on the current period's profits.

We restrict our analysis to a symmetric equilibrium where all monopolists produce the same amount and charge the same price. Therefore, $y_{i,c,t} + y_{i,x,t} = y_{i,t} = y_t$, $k_{i,t} = k_t$, $h_{i,t} = h_t$, $\mu_{i,t} = \mu_t$, $p_{i,t} = p_t$ and aggregate capital and hours are $K_t = N_t k_t$ and $H_t = N_t h_t$. When choosing the consumption good as the numeraire, we find

$$p_t = N_t^{\omega}$$

and the relative price of the investment good, P_t, becomes

$$P_{x,t} = N_t^{\omega-\tau} \equiv P_t.$$

P_t moves with the number of firms if the variety effects in final goods differ. If $\omega = \tau$, the relative price remains constant. Using (3), (5), and (6) with the zero profit condition leads to

$$y_t = \frac{\phi}{\mu_t - 1}$$

and to aggregate output

$$Y_t = \frac{P_t N_t^{\tau}}{\mu_t} K_t^{\alpha} H_t^{1-\alpha}. \tag{7}$$

The efficiency wedge, $P_t N_t^{\tau}/\mu_t$, is therefore a positive function of the relative price and the number of firms and it is negatively related to the markup. The number of firms moves positively with aggregate output and the markup:

$$N_t = \left(\frac{Y_t}{P_t} \frac{\mu_t - 1}{\phi} \right)^{1/(1+\tau)}.$$

Lastly, we define s_t as the share of the value of investment in aggregate output, that is

$$s_t \equiv \frac{P_t X_t}{Y_t} = 1 - \frac{C_t}{Y_t}.$$

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

$$\mu_t = \frac{\frac{1}{1-\sigma}(1 - s_t) + \frac{1}{1-\eta} s_t}{\frac{1}{1-\sigma}(1 - s_t) + \frac{1}{1-\eta} s_t - 1}. \tag{8}$$

The price elasticity of demand is given by $\frac{1}{\sigma-1}(1 - s_t) + \frac{1}{\eta-1} s_t$. Note that when $\sigma = \eta$ the markup is constant. If $\sigma > \eta$ the markup is procyclical to s_t, then a shift in demand from consumption to investment means that each monopolist faces a more inelastic demand curve and this leads to a rise 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

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

where μ and s are the steady state values of the markup and the investment share. While the parameter ε_{μ} strictly governs the markup's relationship with the investment share (not aggregate output), in the Appendix we show that the investment share is always procyclical. That is, under indeterminacy and in the absence of changes to fundamentals, when $\varepsilon_\mu > 0$ ($\varepsilon_\mu < 0$), the markup is also procyclical (countercyclical) with respect to output.[8]

2.2 Agents

The representative agent derives lifetime utility from the function

$$U = \int_0^\infty e^{-\rho t} u(C_t, H_t) dt \qquad \rho > 0$$

where ρ denotes the subjective discount rate. Period utility is separable in consumption and hours worked and takes on the functional form

$$u(C_t, H_t) = \ln C_t - \upsilon \frac{H_t^{1+\chi}}{1+\chi} \qquad \upsilon > 0, \chi \geq 0.$$

where χ determines the Frisch labor supply elasticity. Logarithmic utility in consumption is standard as it is the only form that is compatible with balanced growth. The agent owns the capital stock and sells labor and capital services. He owns all firms and receives any (potential) profits, Π_t, generated by them. Then, the representative agent's budget is constrained by

$$w_t H_t + r_t K_t + \Pi_t \geq P_t X_t + C_t.$$

Capital accumulation follows

$$\dot{K}_t = X_t - \delta K_t \qquad 0 < \delta < 1.$$

Here, time derivatives are denoted by dots and δ stands for the constant rate of physical depreciation of the capital stock. Optimality implies

$$\frac{P_t}{C_t} = \lambda_t \tag{9}$$

$$\upsilon H_t^\chi = \frac{w_t}{C_t} \tag{10}$$

[8] Therefore, unlike Galí (1994), situations with $\varepsilon_\mu > 0$ but a countercyclical investment share do not occur in our model.

$$\frac{\dot{\lambda}_t}{\lambda_t} = \delta + \rho - \frac{1}{C_t}\frac{r_t}{\lambda_t} \tag{11}$$

where λ_t is the current value multiplier. Equations (9) and (10) describe the agent's leisure-consumption trade-off, while (11) is the intertemporal Euler equation. In addition the usual transversality condition holds.

3 Dynamics

Next we analyze the local dynamical property of the artificial economy. In particular, we take a log-linear approximation to the equilibrium conditions. The dynamical system boils down to

$$\begin{bmatrix} \dot{K}_t/K_t \\ \dot{\lambda}_t/\lambda_t \end{bmatrix} = \mathbf{J} \begin{bmatrix} \hat{K}_t \\ \hat{\lambda}_t \end{bmatrix}.$$

Hatted variables denote percent deviations from their steady-state values and $\mathbf{J}$ is the 2×2 Jacobian matrix of partial derivatives. Note that λ_t is a non-predetermined variable and that K_t is predetermined. Hence, indeterminacy requires that the two roots of $\mathbf{J}$ to be negative, or simply Det$\mathbf{J} > \mathbf{0} >Tr\mathbf{J}$.

3.1 Constant markup

We first consider the case where the markup is constant, meaning that $\mu = 1/\eta = 1/\sigma$ and $\varepsilon_\mu = 0$.[9] Then, the determinant of $\mathbf{J}$ is given by

$$\frac{(1-\alpha(1+\tau))(\delta(1-\alpha)+\rho)(\rho+\delta)(1+\chi)}{\alpha[\tau(1-\alpha)-(\alpha+\chi)]}$$

and the trace of $\mathbf{J}$ equals

$$\frac{\rho(\alpha+\chi)(1+\tau)+\tau\delta(1+\chi)}{(\alpha+\chi)-\tau(1-\alpha)}.$$

Note that the markup, μ, as well as the variety effect in the assembling of consumption goods, ω, are completely absent here, hence, they have no effect on the stability of the steady state. Indeterminacy is driven by the variety effect in investment alone. This result is reminiscent of Harrison's (2001) and Harrison and Weder's (2002) findings for two-sector models: the increasing returns originating in

[9] The model reduces to a one-final-good model if $\omega = \tau$.

the consumption goods sector are irrelevant for the stability of the steady state.[10] Indeterminacy requires Det$\mathbf{J} > 0 >$Tr$\mathbf{J}$, which occurs for $\tau(1-\alpha) > \alpha + \chi$.[11]

Proposition 1 *If $\varepsilon_\mu = 0$, then indeterminacy arises if* $\tau > \dfrac{\alpha+\chi}{1-\alpha} > 0$.

From Proposition 1, it is clear that indeterminacy requires a higher τ as labor supply becomes less elastic. In the absence of a variety effect, $\tau = 0$, Det$\mathbf{J} < 0$ and Tr$\mathbf{J} > 0$, and the model is saddle path stable.

Lemma 1 *If $\varepsilon_\mu = 0$ and $\tau = 0$, then indeterminacy cannot arise.*

The condition for indeterminacy is similar to Benhabib and Farmer (1994) and rests on an upwardly sloping wage-hours locus now generated by the variety effect: the minimum returns to variety equal $(\alpha+\chi)/(1-\alpha)$ or numerically, 0.428 (with $\alpha = 0.3$ and $\chi = 0$).[12] Figures 1 and 2 show this case along their $\varepsilon_\mu = 0$-axis. Note that the firm's internal increasing returns to scale equal μ which can be pushed towards unity without affecting the indeterminacy condition. Hence, in Chang et al (2011), the markup affects indeterminacy only because it determines the size of taste for variety.[13] In contrast, a constant markup in the current model implies that market power has no effect on dynamics (and this is due to the instantaneous adjustment to zero profits, see Kim, 2004). Thus, unlike Benhabib and Farmer (1994) and others, indeterminacy is possible in the absence of decreasing marginal costs and at essentially zero increasing returns to scale at the firm level. Given the very limited evidence of significant returns to scale (e.g. Basu and Fernald, 1994), taste for variety offers a potentially more plausible mechanism to generate sunspot equilibria.[14] Next, we allow indeterminacy to arise for smaller values of τ.

[10] To be more precise, this holds only if period utility is logarithmic in consumption. If this is not the case, then ω could influence the stability of the steady state.

[11] We restrict $\alpha(1+\tau) < 1$ to rule out endogenous growth.

[12] See Section 3.2 for the wage-hours locus.

[13] Proposition 1 in their paper involves the size of the markup to determine indeterminacy.

[14] This being said, existing empirical work on variety effects is sparse and we do not have good point estimates yet, and therefore we abstain for this reason to make any suggestion that the values used here are reasonable.

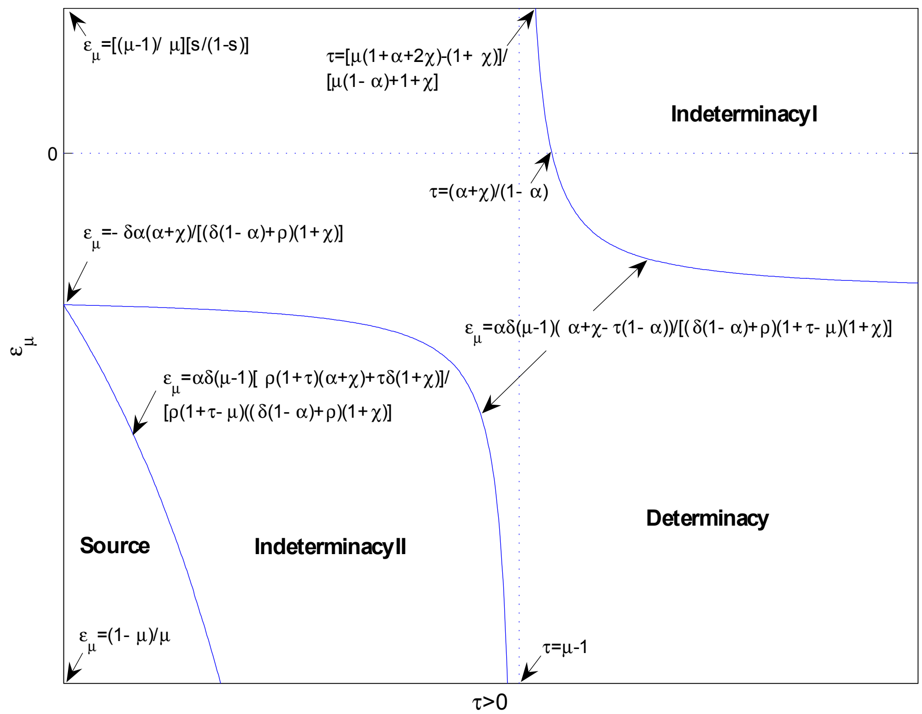

Figure 1: $\mu < 1 + (\alpha + \chi)/(1 - \alpha)$.

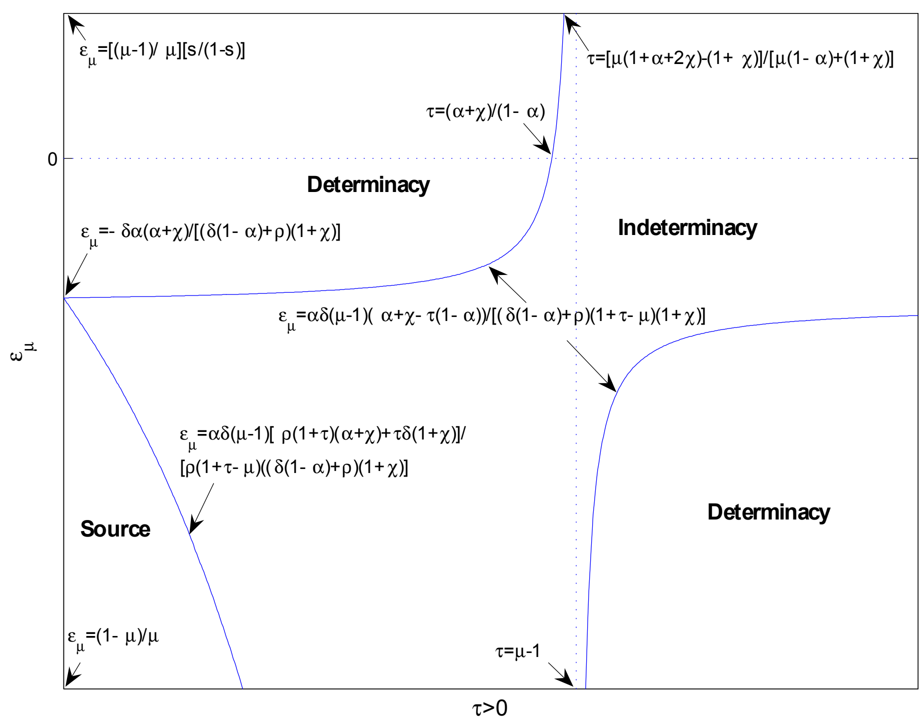

Figure 2: $\mu > 1 + (\alpha + \chi)/(1 - \alpha)$.

3.2 Variable markup

We now consider variable markups, that is $\varepsilon_\mu \neq 0$. Then, the determinant of $\mathbf{J}$ equals

$$\frac{(1-\alpha(1+\tau))(\delta(1-\alpha)+\rho)(\delta+\rho)(1+\chi)}{\alpha[\tau(1-\alpha)-(\alpha+\chi)]+\dfrac{\gamma}{\delta(\mu-1)}}$$

and the matrix's trace is given by

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

where $\gamma=\varepsilon_\mu(1+\tau-\mu)(\delta(1-\alpha)+\rho)(1+\chi)$.

Again, the variety effect in consumption, ω, does not appear in these expressions. This suggests that relative price movements have no effect on the occurrence of sunspot equilibria, rather, the indeterminacy mechanism must come from variety effects and markup variations. Indeterminacy cannot emerge if there is no variety effect in investment, i.e. $\tau = 0$: a positive determinant, which occurs if $\varepsilon_\mu < -\delta\alpha(\alpha+\chi)/[(\delta(1-\alpha)+\rho)(1+\chi)] < 0$ will go in hand with Tr$\mathbf{J}=\rho$ (the steady state is a source). Phrased alternatively, net business formation eliminates sunspot equilibria in Schmitt-Grohé (1997).[15]

Lemma 2 *If $\varepsilon_\mu \neq 0$ and $\tau = 0$, then indeterminacy cannot arise. The steady state is either a saddle path or a source.*

We plot the stability zones in Figure 1 and 2. In both figures, the function that divides the indeterminacy and determinacy regions is given by $\varepsilon_\mu = \alpha\delta(\mu-1)(\alpha+\chi-\tau(1-\alpha))/[(\delta(1-\alpha)+\rho)(1+\tau-\mu)(1+\chi)]$. This borderline is discontinuous at $\tau=\mu-1$ and this results in two separate indeterminacy regions if $\mu < 1+(\alpha+\chi)/(1-\alpha)$. That is, the regions are separate when the discontinuity occurs at lower variety values than Proposition 1's critical level of τ. This situation is plotted in Figure 1, where we denote the two regions Indeterminacy I and II. The two regions are merged in Figure 2. There are several important results to this. First, market power now affects indeterminacy. Second, sunspot equilibria arise for procyclical and countercyclical

[15] Again, our results hold for logarithmic utility.

markups – this stands in contrast to Schmitt-Grohé (1997), Jaimovich (2007) and others who require countercyclical markups. The result is noteworthy in light of Nekarda and Ramey's (2010) claim on U.S. markup dynamics.

Proposition 2 *Indeterminacy appears for procyclical and countercyclical markups.*

Third, for $\mu < 1 + (\alpha + \chi)/(1 - \alpha)$, the determinacy-indeterminacy borderline is downwardly sloping. For indeterminacy region I, this suggests that the minimum τ from $\varepsilon_\mu = 0$ can be reduced by increasing ε_μ, and in a sense, a more procyclical markup makes indeterminacy easier to obtain. To move from determinacy into region II, the (negative) elasticity of the markup has to be increased. In the empirically less appealing case of $\mu > 1 + (\alpha + \chi)/(1 - \alpha)$, the borderline is upwardly sloping. Here, a larger procyclical ε_μ then requires a stronger variety effect. Fourth, while Lemma 2 suggests the need of a strictly positive but potentially infinitesimal variety effect, the internal increasing returns needed here are significantly lower than in Schmitt-Grohé's (1997) composition of demand model. Using the same calibration as in our model, she reports a minimum returns to scale of 1.37. Yet, Figure 1's Indeterminacy I zone involves minimum internal increasing returns of only 1.09.[16] That is, while endogenous entry and exit requires some variety effect, it magnifies the impact of countercyclical markups enormously.

The economic mechanism that creates the continuum of solutions in our model is easily understood in reference of the equilibrium wage-hours locus. For example, upon optimistic expectations about the future, the agent anticipates higher prospective income. Today's consumption expenditures will rise. As a consequence, the labor supply curve shifts inwards. If the wage-hours locus slopes upwardly and is steeper than the labor supply curve, employment and investment will jump up today.[17] The future capital stock, output and consumption will be high and the initial optimistic expectations are self-fulfilled. Note that the upwardly sloping wage-hours

[16] To find this value, recall from Section 2.1 that $\varepsilon_\mu \to (1-\mu)/\mu$ in its negative limit. To be more precise, for direct comparison we would need to use a discrete time version of our model. In this case the minimum returns to scale, given by μ, rise slightly to 1.10.

[17] Here, variations in the number of firms and the markup shift the downwardly sloping labor demand curve upward sufficiently such that employment rises.

locus is a necessary (not sufficient) condition for indeterminacy. For example, a sufficiently countercyclical markup can achieve this without any variety effects but by Lemma 2 the steady state is then a source.

There are essentially two ways to generate an upwardly sloping wage-hours locus: variety effects and variable markups. This thought can be organized via the log-linearized wage-hours locus[18]

$$\hat{w}_t = (1+\tau)\alpha\hat{K}_t + \left[\tau(1-\alpha) - \alpha + \varepsilon_\mu \frac{(1+\tau-\mu)(\delta(1-\alpha)+\rho)(1+\chi)}{\alpha\delta(\mu-1)}\right]\hat{H}_t.$$

Indeterminacy requires the term in front of $\hat{H}_t$ to be greater than the slope of the labor supply curve, χ. When is this the case? If $\varepsilon_\mu = 0$, then $\tau(1-\alpha) - \alpha > \chi$ guarantees indeterminacy as in Proposition 1. If $\varepsilon_\mu(1+\tau-\mu) > 0$, then τ may be lowered; the third term in squared brackets is positive and works in the same direction as the variety effect. Therefore, a procyclical (countercyclical) markup endogenously expands the efficiency wedge if $\tau > \mu - 1$ ($\tau < \mu - 1$). The former is possible because a higher markup induces net firm entry. If the variety effect is sufficiently large, this entry will dominate the contractionary clout of a procyclical markup and, in effect, will work like an improvement of the efficiency wedge. If $\tau < \mu - 1$, as in region II, indeterminacy arises even at very low values of τ. Here, a countercyclical markup leads to a procyclical efficiency wedge. Next, we show how to decrease minimum τ even further.

4 Capital utilization

Section 1 mentioned papers report empirical evidence of variety effects. However, there seems to be no general agreement on point estimates, hence, our strategy is to make the size of the effect as small as possible. For countercyclical markups, variety effects can be close to zero. For indeterminacy to arise with a procyclical markup, we need larger magnitudes. To see this, we calibrate the model as in Farmer and Guo (1994) and Wen (1998): $\alpha = 0.3$, $\rho = 0.01$, $\delta = 0.025$, $\chi = 0$. Then, indeterminacy requires $\tau > 0.176$ when μ is close to unity (and hence ε_μ is close to zero). This

[18] To be precise, here we set $\tau = \omega$.

value can be significantly reduced by introducing endogenous capital utilization. To do this, we amend the model such that an intermediate good producer i operates the production technology

$$y_{i,t} = (u_t k_{i,t})^{\alpha} h_{i,t}^{1-\alpha} - \phi$$

and aggregate capital accumulation follows

$$\dot{K}_t = X_t - \delta_t K_t = X_t - \frac{1}{\theta} u_t^{\theta} K_t \qquad \theta > 1$$

where u_t stands for the intensity of capital utilization set by the capital stock's owners. The rate of depreciation, δ_t, is an increasing function of the utilization rate. Figures 3 and 4 show numerical indeterminacy regions; the qualitative pattern parallels the constant utilization model and the source of sunspot equilibria remains an upwardly sloped wage-hours locus.[19] The constant markup case, $\varepsilon_{\mu} = 0$, delivers indeterminacy if $\tau > [\alpha\rho + \chi(\delta(1-\alpha)+\rho)]/[\rho(1-\alpha)+\delta(1+\alpha\chi)] = 0.094$. Hence, indeterminacy is independent of μ and ω; it is driven by the variety effect in the investment technology only. When the markup is variable, $\varepsilon_{\mu} \neq 0$, market power again affects indeterminacy and sunspot equilibria arise for procyclical and countercyclical markups. In Figure 3, the steady state markup equals 1.05, which is also the size of firm level scale economies. At this level of market power, there are two regions of indeterminacy and for slightly procyclical markups, e.g. the upper limit $\varepsilon_{\mu} = 0.013$, the variety effect can be as low as 0.072. Figure 4 assumes $\mu = 1.10$ which is of magnitude that is commonly assumed in New Keynesian models. Here, the two indeterminacy regions are merged; analogous to the constant utilization model, this occurs if $\mu > 1 + [\alpha\rho + \chi(\delta(1-\alpha)+\rho)]/[\rho(1-\alpha)+\delta(1+\alpha\chi)]$. Overall, with the addition of variable capital utilization we have shown that indeterminacy does not require implausibly high levels of market power and that the size of the required variety effects can be significantly lowered. Before addressing the business cycle dynamics, we present an alternative formulation of the variety effect.

[19] We provide analytical results in Appendix A.3.

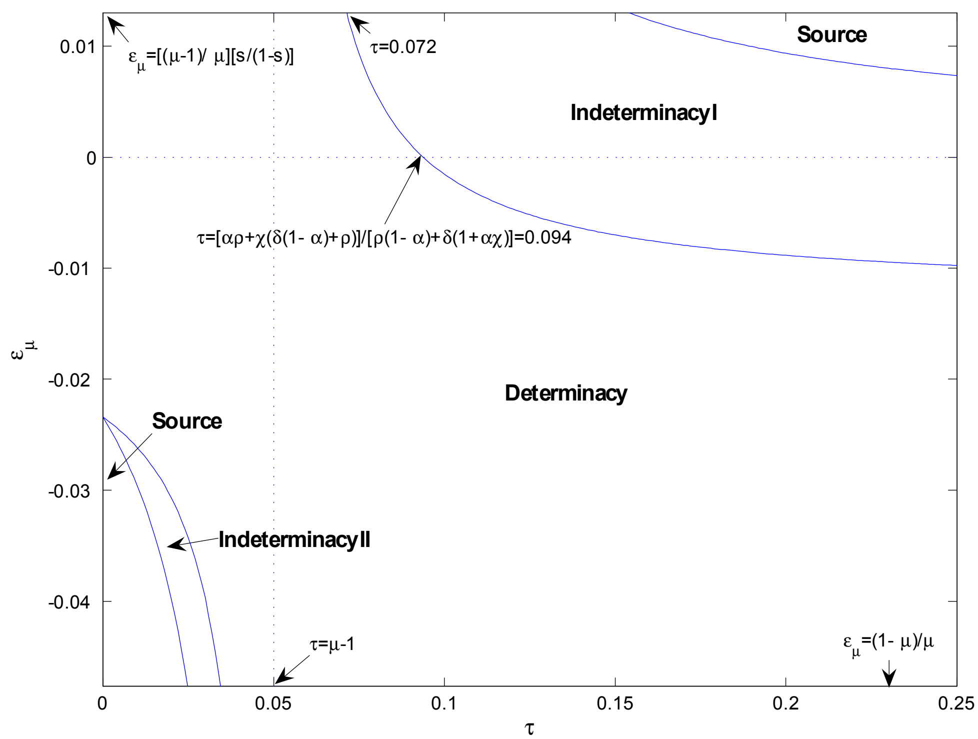

Figure 3: Variable capital utilization, $\mu = 1.05$, $\chi = 0$.

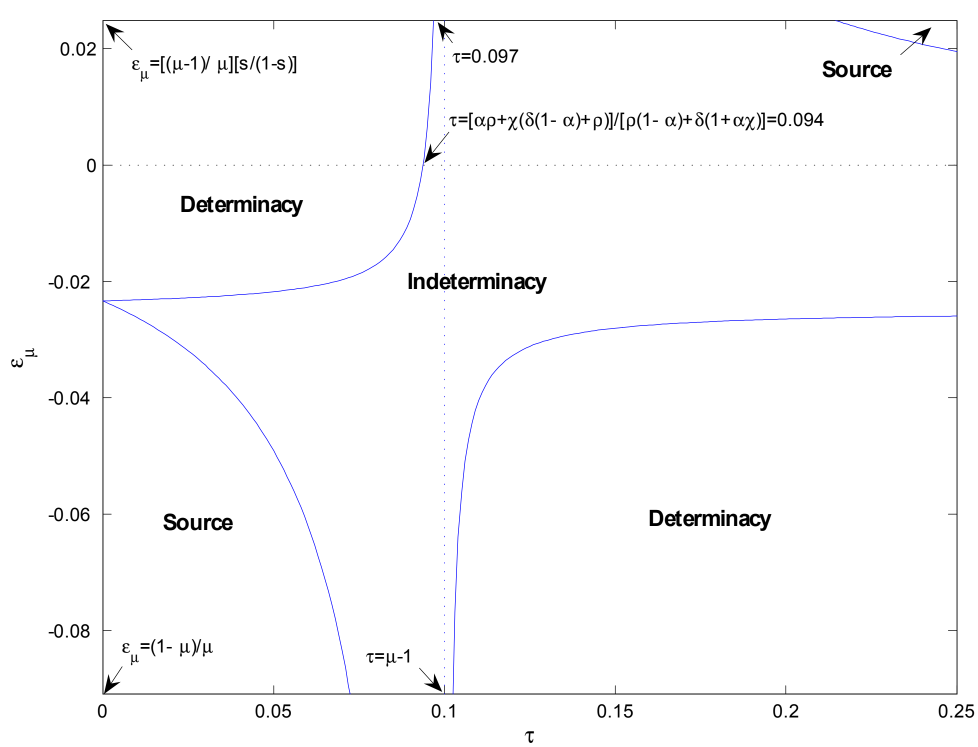

Figure 4: Variable capital utilization, $\mu = 1.10$, $\chi = 0$.

5 Alternative formulation of variety

Here we demonstrate that our results are robust to the formulation of taste for variety. So far, we have assumed that the variety effect does not depend on the degree of elasticity of substitution as suggested by Benassy (1996). Chang et al. (2011) and others assume a different formulation where the variety effect depends on parameters σ and η. For example, consumption is produced via

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

where the variety effect, ω, is equal to $1/\sigma - 1 > 0$. The intuition for setting the model this way could be that σ and η are an indication of product differentiation and higher product differentiation then implies a greater love for variety. On the other hand, we believe that there is no *a priori* reason for assuming such a strong connection between them. Also, note that under this formulation both variety effects must be strictly positive.

Figure 5 plots the indeterminacy zone for this model with the markup on the horizontal axis.[20] Formulating variety this way does not change our results: indeterminacy occurs with procyclical and countercyclical markups. When the markup is constant, $\sigma = \eta$, the model includes as a special case Chang et al. (2011), yet, without their production externalities. Figure 5 makes it clear that these production externalities are not required for indeterminacy: if the markup is constant the sufficient condition for indeterminacy is now $\mu > (1+\chi)/(1-\alpha)$, which corresponds to our Proposition 1. It is easy to see from Figure 5's indeterminacy zone that procyclical markups make sunspot equilibria easier to obtain than countercyclical markups: if $\varepsilon_\mu > 0$ (i.e. $\sigma > \eta$), then $\mu^{\min} \to 1$, albeit in only a small region. Note that at very low markups there still may be a substantial difference between σ and η and under this alternative formulation $\sigma > \eta$ implies that the variety effect is larger in investment. Therefore the variety effect in investment can still be sufficiently large to cause indeterminacy even if μ is very close to unity.[21] To sum up, our results are

[20] Capital utilization is set as constant and the calibration remains as in Section 4.

[21] This is the reason why we used the more flexible modelling approach in the preceding sections.

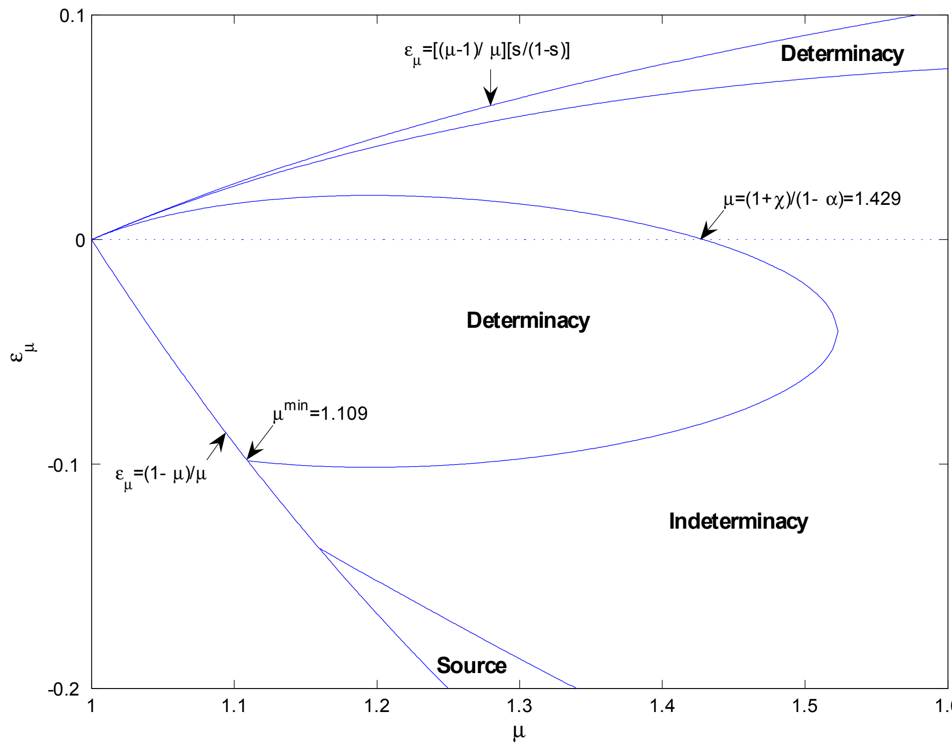

Figure 5: Alternative formulation of variety (constant capital utilization), $\chi = 0$.

robust with respect to the exact formulation of the variety effect.

6 Business cycle dynamics

We have shown that the taste for variety can generate indeterminacy with procyclical and countercyclical markups. Although that could be viewed as progress alone, this remains void as long as these models cannot replicate at least basic business cycle facts. This is done next by comparing second moments for the U.S. data and the model.

We simulate a discrete time economy under our original formulation of the variety effect by shocking it by i.i.d. sunspot shocks only. For direct comparison, the calibration remains as in Section 4 and the discount factor is $\beta = (1+\rho)^{-1}$. To illustrate that excessive market power is not crucial to our findings, we set the steady state markup to 1.05, which is also the firm level increasing returns to scale, and calibrate its elasticity to $\varepsilon_\mu = 0.01$, which is relatively close to its upper boundary

Table 1: Business Cycle Dynamics

Variable x	U.S. data σ_x/σ_Y	U.S. data $\rho(x,Y)$	U.S. data AR(1)	Model σ_x/σ_Y	Model $\rho(x,Y)$	Model AR(1)
Y_t	1	1	0.84	1	1	0.88
C_t	0.38	0.71	0.81	0.08	0.67	0.94
P_tX_t	3.62	0.97	0.78	4.50	0.99	0.88
H_t	0.84	0.83	0.90	0.95	0.99	0.88
s_t	2.66	0.94	0.76	3.50	0.99	0.88
Y_t/H_t	0.55	0.54	0.72	0.08	0.67	0.94
N_t	-	-	-	1.58	0.99	0.88
μ_t	-	-	-	0.04	0.99	0.88

See Appendix A.4 for the source of U.S. data. σ_Y denotes the standard deviation of output and $\rho(x,Y)$ is the correlation of variable x and Y. Blank entries are due to data unavailability.

given by the restrictions in Section 2. Since we do not have any clear estimates for the variety effects, τ and ω, we set them to 0.1, which is lower than the production externalities required by Wen (1998).[22] Table 1 presents HP-filtered second moments of the U.S. data and of the artificial economy. The model correctly reproduces the order of relative volatilities and positive correlations. Persistence, measured by the first order autoregressive process, is also well replicated. Moreover, the markup, the number of firms and, unlike in Galí (1994), the investment share are all strongly positively correlated with aggregate economic activity.[23]

7 Conclusion

Recent research suggests that markups in the U.S. are largely procyclical or acyclical. While this issue is clearly not settled, it puts doubt on the plausibility of many endogenous business cycle models in which countercyclical markups are the key in-

[22] In the discrete time model with constant markups the required τ for indeterminacy is 0.1036. With $\mu = 1.05$ and $\varepsilon_\mu = 0.01$ the required τ is 0.0797.

[23] The low volatility of consumption is the sole outlier with regards to the model's predictions. This problem is the consequence of the additional utilization margin and has been noted by Jaimovich (2007) and Wen (1998). We are able to show that a higher variety effect and/or markup elasticity improves the model's performance in this aspect as it results in a steeper wage-hours locus. A shift of the flat labor supply curve will produce a smaller change in hours the steeper the wage-hours locus.

gredient. The current paper offers a theory that allows a procyclical markup in endogenous business cycles. In fact, given a certain level of product variety effects, a procyclical markup can make it easier for indeterminacy to occur. Taste for variety is critical in generating sunspot equilibria, and hence, variety matters. In comparison to many other studies, especially where increasing returns to scale generate sunspot equilibria, we believe that the mechanism that drives our results is potentially more plausible. First, the variety effect that drives this result does not imply countercyclical marginal costs. Second, a variable markup, and in particular a procyclical markup, means that the required size of the variety effect is significantly lower than the externalities required by many other studies. Finally, the size of the required markups is well within empirical estimates.

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Appendix A

A.1 Derivation of the optimal markup

The cost minimization problem of an intermediate good producer i is

$$\min_{h_{i,t},k_{i,t}} w_t h_{i,t} + r_t k_{i,t} \qquad s.t. \qquad k_{i,t}^{\alpha} h_{i,t}^{1-\alpha} = y_{i,t} + \phi.$$

Shephard's Lemma yields the cost minimizing demand for labor and capital

$$h_{i,t} = (y_{i,t} + \phi) w_t^{-\alpha} r_t^{\alpha} \alpha^{-\alpha} (1-\alpha)^{\alpha} \quad \text{and} \quad k_{i,t} = (y_{i,t} + \phi) w_t^{1-\alpha} r_t^{\alpha-1} \alpha^{1-\alpha} (1-\alpha)^{\alpha-1}$$

with the associated cost function

$$C_{i,t}^F = (y_{i,t} + \phi) w_t^{1-\alpha} r_t^{\alpha} \alpha^{-\alpha} (1-\alpha)^{\alpha-1}.$$

From the above it can be seen that marginal cost is independent of the scale of production. Each monopolist maximizes profits:

$$\max_{p_{i,t}} p_{i,t} y_{i,t} - C_{i,t}^F = p_{i,t}(y_{i,c,t} + y_{i,x,t}) - C_{i,t}^F$$

where $y_{i,c,t}$ and $y_{i,x,t}$ are given by (1) and (2). As usual, it is assumed that while each monopolist i sets the price $p_{i,t}$ for his good, they are unable to affect the aggregate prices $P_{c,t}$ and $P_{x,t}$. Rearranging the first-order condition from the above maximization problem yields

$$\frac{p_{i,t}}{MC_{i,t}} = \frac{\frac{1}{\sigma-1}\left(\frac{p_{i,t}}{P_{c,t}}\right)^{\frac{1}{\sigma-1}} N_t^{\frac{\sigma(1/\sigma-1-\omega)}{\sigma-1}} C_t + \frac{1}{\eta-1}\left(\frac{p_{i,t}}{P_{x,t}}\right)^{\frac{1}{\eta-1}} N_t^{\frac{\eta(1/\eta-1-\tau)}{\eta-1}} X_t}{\frac{\sigma}{\sigma-1}\left(\frac{p_{i,t}}{P_{c,t}}\right)^{\frac{1}{\sigma-1}} N_t^{\frac{\sigma(1/\sigma-1-\omega)}{\sigma-1}} C_t + \frac{\eta}{\eta-1}\left(\frac{p_{i,t}}{P_{x,t}}\right)^{\frac{1}{\eta-1}} N_t^{\frac{\eta(1/\eta-1-\tau)}{\eta-1}} X_t}$$

where $MC_{i,t} = w_t^{1-\alpha} r_t^{\alpha} \alpha^{-\alpha} (1-\alpha)^{\alpha-1}$ is marginal cost and $\mu_t \equiv \frac{p_{i,t}}{MC_{i,t}}$. Using (1) and (2) this markup equation reduces to (4). In symmetric equilibrium, the final good production functions are $C_t = N_t^{1+\omega} y_{c,t}$ and $X_t = N_t^{1+\tau} y_{x,t}$. Multiplying the numerator and denominator of the markup expression (4) by $N_t^{1+\omega}/Y_t$ we obtain

$$\mu_t = \frac{\frac{1}{\sigma-1}\frac{C_t}{Y_t} + \frac{1}{\eta-1}\frac{P_t X_t}{Y_t}}{\frac{\sigma}{\sigma-1}\frac{C_t}{Y_t} + \frac{\eta}{\eta-1}\frac{P_t X_t}{Y_t}}.$$

Finally, defining $s_t \equiv P_t X_t / Y_t = 1 - C_t/Y_t$ and some algebra yields (8).

A.2 Markup movements with respect to output

This Appendix shows that under indeterminacy (i) if $\varepsilon_\mu > 0$ ($\varepsilon_\mu < 0$) the markup is procyclical (countercyclical) and (ii) the investment share, s_t, is always procyclical. This is demonstrated for the model of Section 2 (to keep notation simple; see also Figures 1 and 2); we obtain a relation between aggregate output and the markup[24]

$$\hat{Y}_t = (1+\tau)\alpha \hat{K}_t + \left[\frac{\alpha\delta(1+\tau)(1-\alpha)}{\varepsilon_\mu(\delta(1-\alpha)+\rho)(1+\chi)} + \frac{1+\tau-\mu}{\mu-1} \right] \hat{\mu}_t. \qquad \text{(A1)}$$

Let us first consider the case of $\tau < \mu - 1$. In (A1), for any $\varepsilon_\mu < 0$ the term in squared bracket is negative and hence the markup is always countercyclical. For a positive ε_μ the markup is procyclical as long as

$$\varepsilon_\mu < \varepsilon_\mu^* \equiv \frac{\alpha\delta(1+\tau)(\alpha-1)(\mu-1)}{(\delta(1-\alpha)+\rho)(1+\tau-\mu)(1+\chi)}.$$

(Note that $\partial\varepsilon_\mu^*/\partial\tau > 0$.) Indeterminacy requires that

$$\varepsilon_\mu < \varepsilon_\mu^{**} \equiv \frac{\alpha\delta[\alpha+\chi-\tau(1-\alpha)](\mu-1)}{(\delta(1-\alpha)+\rho)(1+\tau-\mu)(1+\chi)}$$

which implies a positively sloped wage-hours locus steeper than the labor supply curve. It is then easy to see that $\varepsilon_\mu^{**} < \varepsilon_\mu^*$ for any positive $\tau < \mu - 1$. Next, $\tau > \mu - 1$. Here indeterminacy requires that $\varepsilon_\mu > \varepsilon_\mu^{**}$. In this case, the markup is procyclical if $\varepsilon_\mu > 0$ or if $\varepsilon_\mu < \varepsilon_\mu^* < 0$. Clearly $\varepsilon_\mu^{**} > \varepsilon_\mu^*$ for any $\tau > \mu - 1$. Hence the markup is always procyclical (countercyclical) under indeterminacy for any $\varepsilon_\mu > 0$ ($\varepsilon_\mu < 0$). Lastly, from $\widehat{\mu}_t = \varepsilon_\mu \widehat{s}_t$, the investment share is always procyclical.

[24]We set $\tau = \omega$ to simplify notation.

A.3 Sections 4 and 5's analytical results

This Appendix presents the analytical dynamics that underlie the models from Sections 4 and 5 respectively. With variable capital utilization, if $\varepsilon_\mu = 0$, the determinant of $\mathbf{J}$ is

$$\frac{\rho(1-\alpha(1+\tau))(\delta(1-\alpha)+\rho)(\rho+\delta)(1+\chi)}{\alpha[\tau(\rho(1-\alpha)+\delta(1+\alpha\chi))-\chi(\delta(1-\alpha)+\rho)-\rho\alpha]}$$

and the trace is governed by

$$\frac{\rho(1+\tau)(\alpha\rho+\chi(\delta(1-\alpha)+\rho))}{\rho\alpha-\tau(\rho(1-\alpha)+\delta)+\chi(\delta(1-\alpha(1+\tau))+\rho)}.$$

If $\varepsilon_\mu \neq 0$, and $\chi = 0$, the determinant is

$$\frac{\rho\delta(\mu-1)[\delta(1-\alpha)+\rho](\delta+\rho)[1-\alpha(1+\tau)]}{\gamma_1\rho^2+\delta^2[\gamma_1(1-\alpha)+\alpha\tau(\mu-1)]+\rho\delta[2\gamma_1+\alpha(\tau(\mu-1)-\gamma_1)-\alpha^2(\mu-1)(1+\tau)]}$$

and the trace is

$$\frac{\rho[\delta\rho(\alpha^2(\mu-1)(1+\tau)+\gamma_1(\alpha-2))-\gamma_1\delta^2(1-\alpha)-\gamma_1\rho^2]}{\rho\delta[\alpha^2(\mu-1)(1+\tau)+\alpha(\gamma_1+\tau(1-\mu))-2\gamma_1]-\gamma_1\rho^2-\delta^2[\gamma_1(1-\alpha)+\alpha\tau(\mu-1)]}$$

where $\gamma_1 = \varepsilon_\mu(1+\tau-\mu)$.

With the alternative formulation of the variety effect and constant capital utilization (as used in Section 5), if $\varepsilon_\mu = 0$, the determinant of $\mathbf{J}$ is

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

and the trace is given by

$$\frac{\delta(1-\mu)(1+\chi)-\rho\mu(\alpha+\chi)}{(1-\alpha)\mu-(1+\chi)}.$$

If $\varepsilon_\mu \neq 0$, and $\chi = 0$, the determinant is

$$\frac{\gamma_2[\alpha^2\delta\mu(\mu+\varepsilon_\mu-1)+\varepsilon_\mu\mu(\delta+\rho)-\alpha(\delta(2\varepsilon_\mu\mu+\mu-1)+\varepsilon_\mu\mu\rho)]}{\alpha^3\delta^2\mu(\mu+\varepsilon_\mu-1)+2\alpha\delta\mu\varepsilon_\mu^2(\delta+\rho)-\varepsilon_\mu^2\mu(\delta+\rho)^2-\gamma_3}$$

and the trace is

$$\frac{\alpha^3\delta^2\mu\rho(\mu+\varepsilon_\mu-1)+2\varepsilon_\mu^2\alpha\delta\mu\rho(\delta+\rho)-\varepsilon_\mu^2\mu\rho(\delta+\rho)^2+\gamma_4}{\alpha^3\delta^2\mu(\mu+\varepsilon_\mu-1)+2\varepsilon_\mu^2\alpha\delta\mu(\delta+\rho)-\varepsilon_\mu^2\mu(\delta+\rho)^2-\gamma_3}$$

where $\gamma_2 = \delta[(1-\alpha)\delta+\rho](\delta+\rho)$, $\gamma_3 = \alpha^2\delta[\delta(1+(\varepsilon_\mu^2+\varepsilon_\mu-2)\mu+\mu^2)+\varepsilon_\mu\mu\rho]$, and $\gamma_4 = \alpha^2\delta[\delta^2(\mu-1)^2-\delta\varepsilon_\mu\mu\rho(1+\varepsilon_\mu)-\varepsilon_\mu\mu\rho^2]$. These expressions make obvious why we concentrated on numerical results.

A.4 Data sources

This Appendix details the source and construction of the data used for calculating U.S. second moments in Section 6. All data is quarterly and for the period 1948:I-2006: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. Gross Private Domestic Investment. Seasonally adjusted at annual rates, billions of dollars. Source: Bureau of Economic Analysis, NIPA Table 1.1.5.

4. Gross Domestic Product. 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 chained (2005) dollars. Source: Bureau of Economic Analysis, NIPA Table 1.1.6.

6. Nonfarm Business Hours. Index 2005=100, seasonally adjusted. Source: Bureau of Labor Statistics, Series Id: PRS85006033.

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

8. GDP Deflator = (4)/(5).

9. Real Per Capita Consumption, $C_t = [(1) + (2)]/(8)/(7)$.

10. Real Per Capita Investment, $P_t X_t = (3)/(8)/(7)$.

11. Real Per Capita Output, $Y_t = (9) + (10)$.

12. Per Capita Hours Worked, $H_t = (6)/(7)$.

13. Investment Share, $s_t = (10)/(11)$.

14. Labor Productivity, $Y_t/H_t = (11)/(12)$.

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Name of Co-Author	Mark Weder		
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III Countercyclical Markups and News-Driven Business Cycles

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 replicates the regular features of U.S. aggregate fluctuations.

1 Introduction

News shocks have captivated the minds of many macroeconomists in recent years. News stand for the idea that expectations about future fundamentals drive aggregate fluctuations. The concept has old roots and goes back at least to Pigou (1927). Yet, while this research's empirical branch suggests that news about shifts in future technology can indeed be a significant source of business cycles – in the order of fifty percent or higher – one of the main theoretical findings states that a plain-vanilla real business cycle (RBC) model is unable to re-produce expectations-driven fluctuations.[1] This casts doubt on the validity of either the empirical work or theory.

On the theoretical side, the aspect of this paper, the puzzle boils down to the standard RBC model's inability to generate the empirically-documented positive co-movement between consumption and investment in response to news about future total factor productivity (TFP). 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.[2] The current paper illustrates an

[1] Empirical work can be found in Cochrane (1994), Beaudry and Portier (2006), Schmitt-Grohé and Uribe (2012) and others.

[2] See Imbens, Rubin and Sacerdote (2001) for example.

alternative approach that requires less alterations to the canonical model and, in particular, it does not require any departure from conventional preferences as we assume additive-separable utility compatible with balanced growth. We apply Galí's (1994) and Schmitt-Grohé's (1997) composition of aggregate demand model to introduce endogenous countercyclical markups to the artificial economy.[3] 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 an initial recession.[4] For this not to occur we introduce modest investment adjustment costs. Our simulations reveal that the news shock driven artificial economy performs well at matching the main empirical aggregate regularities of U.S. cyclical fluctuations.

In the plain vanilla model, the income (or 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 by Jaimovich and Rebelo (2009). In contrast, this income effect remains in the present model and the economic mechanism for our result can be understood as follows. Any change in the markup implies a shift to economic distortions through an endogenous labor wedge between the marginal product of labor and the marginal rate of consumption-leisure substitution. Moreover, countercyclical markups can result in an upwardly-sloping wage-hours locus, which implies a positive relationship between wages and hours in the absence of changes to fundamentals.[5] 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

[3] Empirical evidence suggests that markups are countercyclical. See Rotemberg and Woodford (1999) and Floetotto and Jaimovich (2008). We acknowledge that there are other ways to render the markup variable, but for exposition we concentrate on a specific model here. Essentially, the results could also be realized with increasing returns technologies, yet, since the debate regarding their empirical evidence is still ongoing, we concentrate on market power.

[4] See Eusepi (2009) and Guo, Sirbu and Suen (2012) for a clarification of this result.

[5] This part of the argument is not unlike indeterminacy models, yet, here we do not consider the case of sunspot equilibria. Wang (2012) shows a similar effect through deep habits. He also finds that employment drops below steady state at the realization of the shock.

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.[6] However, 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.

The comovement issue is related to Barro and King's (1984) thesis that under conventional assumptions on technology and preferences, standard technology shocks must be the main driver of business cycles. The strict kinship between wages and the marginal product of labor is the underlying reason for the conundrum. Woodford (1991) relaxes this relationship and is able to produce a positive investment-consumption comovement in the presence of sunspot equilibria, i.e. no shocks to fundamentals are needed. Benhabib and Farmer (1994) show that increasing returns technologies archive a parallel outcome. As in the current paper, the mechanism is an upwardly sloping wage-hours locus. An important difference applies, however. Equilibria are unique here and therefore only standard and anticipated disturbances to fundamentals can induce economic fluctuations.

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. Section 5 introduces variable capital utilization and simulates the model. 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

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

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

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

and

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

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. 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 labor, $h_{i,t}$, both supplied on perfectly competitive factor markets, 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. These costs are such that, for a given number of firms, 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. All firms are equally affected by aggregate total factor productivity, z_t, that follows the process

$$\log z_t = \psi \log z_{t-1} + \zeta_t \qquad 0 \leq \psi < 1$$

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

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. Given the demand from the final goods sector, each monopolist sets the profit maximizing price such that the markup, $\mu_{i,t}$, equals

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

Finally, the implicit demands for input factors are

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

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

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

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

where $K_t = Nk_t$ and $H_t = Nh_t$. Lastly, we define $s_t \equiv X_t/Y_t$ as the investment share in aggregate output. Then the optimal markup can be rewritten as a function of this share

$$\mu_t = \frac{\frac{1}{1-\sigma}(1-s_t) + \frac{1}{1-\eta} s_t}{\frac{1}{1-\sigma}(1-s_t) + \frac{1}{1-\eta} s_t - 1}. \tag{3}$$

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. Log-linearizing (3) yields

$$\hat{\mu}_t = \frac{s\left(\frac{1}{1-\sigma} - \frac{1}{1-\eta}\right)}{\left(\frac{1}{1-\sigma}(1-s) + \frac{1}{1-\eta}s - 1\right)\left(\frac{1}{1-\sigma}(1-s) + \frac{1}{1-\eta}s\right)}\hat{s}_t \equiv \varepsilon_\mu \hat{s}_t$$

where hatted variables denote percent deviations from the steady state in which the investment share is $s = \alpha\delta/(\delta+\rho)$. Using this together with the steady state version of (3) we restrict the markup elasticity, ε_μ, to permissible values via $\mu > 1$ (the steady state markup) and $\sigma, \eta \in (0,1)$. Some algebra restricts ε_μ to fall into the range defined by

$$\frac{1-\mu}{\mu} < \varepsilon_\mu < \frac{\mu-1}{\mu}\frac{s}{1-s}. \tag{4}$$

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.[7]

2.2 Households

The representative agent maximizes

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

where E_t is the conditional expectations operator, ρ denotes the discount rate and χ is the inverse of the Frisch elasticity of labor supply to wages. This functional form of additive-separable period-preferences is compatible with balanced growth. The agent owns the capital stock and sells labor and capital services. He owns all firms and receives any profits, Π_t, generated by them. Then, the budget is constrained by

$$w_t H_t + r_t K_t + \Pi_t \geq X_t + C_t \tag{5}$$

and capital accumulation follows

$$K_{t+1} = (1-\delta)K_t + X_t\left[1 - \Phi\left(\frac{X_t}{X_{t-1}}\right)\right] \qquad 0 < \delta < 1 \tag{6}$$

[7] Pavlov and Weder (2012).

where δ stands for the constant rate of physical depreciation of the capital stock and the adjustment cost function, $\Phi(.)$, obeys $\Phi(1) = \Phi'(1) = 0$, and $\Phi''(1) \geq 0$.[8] The first-order conditions for the agent are

$$\upsilon H_t^{\chi} C_t = w_t \tag{7}$$

$$\varrho_t = \frac{1}{1+\rho} E_t \left[\lambda_{t+1} r_{t+1} + \varrho_{t+1}(1-\delta) \right] \tag{8}$$

$$\lambda_t = \varrho_t \left[1 - \Phi\left(\frac{X_t}{X_{t-1}}\right) - \frac{X_t}{X_{t-1}} \Phi'\left(\frac{X_t}{X_{t-1}}\right) \right] + \frac{1}{1+\rho} E_t \varrho_{t+1} \left(\frac{X_{t+1}}{X_t}\right)^2 \Phi'\left(\frac{X_{t+1}}{X_t}\right) \tag{9}$$

where λ_t and ϱ_t are the multipliers associated with (5) and (6). Equation (7) describes the household's leisure-consumption trade-off, (8) is the intertemporal Euler equation and (9) portrays the investment dynamics. In addition the usual transversality condition holds.

3 Conditions for comovement

In the first step of our analysis, we derive an analytical 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 (while holding current technology constant). For the concrete model, the analytical expression for this comovement is obtained after log-linearizing all the static equilibrium equations[9]

$$\widehat{C}_t = -\frac{\varepsilon_\mu \mu(1-\alpha) + \frac{\alpha\delta(\alpha+\chi)}{\delta(1-\alpha)+\rho}}{\mu(1-\alpha)\left(\frac{\delta+\rho}{\delta(1-\alpha)+\rho} - \varepsilon_\mu\right) + \alpha + \chi} \widehat{X}_t. \tag{10}$$

Under perfect competition, $\mu = 1$, or constant markups, $\varepsilon_\mu = 0$, the coefficient on the right hand side of (10) is negative as in a standard RBC model, hence consumption and investment move in opposite direction at news' arrival. If the markup is countercyclical, the sufficient condition for positive comovement between investment

[8] See Christiano, Eichenbaum and Evans (2005). Our results are robust with respect to alternative adjustment cost specifications.

[9] See Appendix A.1 for further details.

and consumption is

$$\varepsilon_\mu < \varepsilon_\mu^* \equiv \frac{-\alpha\delta(\alpha+\chi)}{\mu(1-\alpha)[\delta(1-\alpha)+\rho]} < 0. \tag{11}$$

(11) implies that the wage-hours locus is upwardly sloping and steeper than the agent's labor supply curve (see Appendix A.1); it is essentially equivalent to the necessary condition for indeterminacy in a continuous time Benhabib and Farmer (1994) model.[10] Clearly, if both consumption and investment rise, then output must rise as well. Since capital is predetermined and news do not affect current TFP, hours worked must also rise, and hence positive comovement between consumption and investment also implies positive comovement between consumption and hours. Substituting in the lower limit of ε_μ from (4) yields the minimum steady state markup, $\mu_{\min}$, required for positive comovement:

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

If we calibrate standard parameters as $\chi = 0$, $\rho = 0.01$, $\alpha = 0.3$, and $\delta = 0.025$, then the minimum steady state markup required for comovement is $\mu_{\min} = 1.12$.[11] This value falls clearly in the empirically accepted zone.

Why does a time-varying markup solve the comovement puzzle? The markup drives an endogenous labor wedge between the marginal product of labor and the marginal rate of consumption-leisure substitution. Combining (1) and (7) leads to

$$\upsilon\mu_t H_t^{\alpha+\chi} C_t = (1-\alpha) z_t K_t^\alpha. \tag{12}$$

In a plain-vanilla RBC 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 12), consumption and hours (and therefore investment) cannot move in the same direction.[12] This is

[10] Positive comovement is not possible if $\varepsilon_\mu > 0$ (see Appendix A.2).

[11] Note that investment adjustment costs are completely absent from these expressions, although, as will be demonstrated in the next section, they influence the direction that the variables comove in.

[12] See Eusepi and Preston (2009).

also the case with a constant wedge ($\sigma = \eta$ in the current model). However, if the markup is sufficiently countercyclical then positive comovement becomes possible.

Finally, while we have shown that countercyclical markups address the comovement problem, the above conditions do not tell us whether they are sufficient for the artificial economy to boom in response to positive news about the future path of TFP. This will be discussed next.

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 TFP, z_t, 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 TFP that will occur in period $t = 4$ (or $l = 3$). The increase will be temporary and $\psi = 0.90$. We calibrate standard parameters as above and set the steady state markup at $\mu = 1.3$ and the markup elasticity to $\varepsilon_\mu = -0.1$, which satisfies the sufficient condition for comovement (11). 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 and 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 locus. Employment falls initially and this generates a recession in period $t = 1$.[13] 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 RBC 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. As in the standard RBC model, in order to make up for the depleted capital stock, both investment and hours rise even if the expected increase in TFP is not realized.[14]

In order for the income effect to dominate, we assume investment adjustment costs, i.e. an incentive to invest along the transition. In Figure 2 we assume $\Phi''(1) = 1.3$ (from Jaimovich and Rebelo, 2009). Consumption and hours rise on the arrival of news. This is the consequence of a wealth effect: when learning of technological improvements, agents are eager to consume at higher levels and to enjoy more leisure – the labor supply schedule shifts in. Yet, because of the upwardly sloping wage-hours locus, employment will rise and output increases.[15] Why is the substitution effect the relatively weaker one now? The reason is that adjusting investment became

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

[14] The responses are very similar because the rise in the investment share lowers the markup in both the realized and not realized case. This shifts out labor demand much like an increase in technology z_t.

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

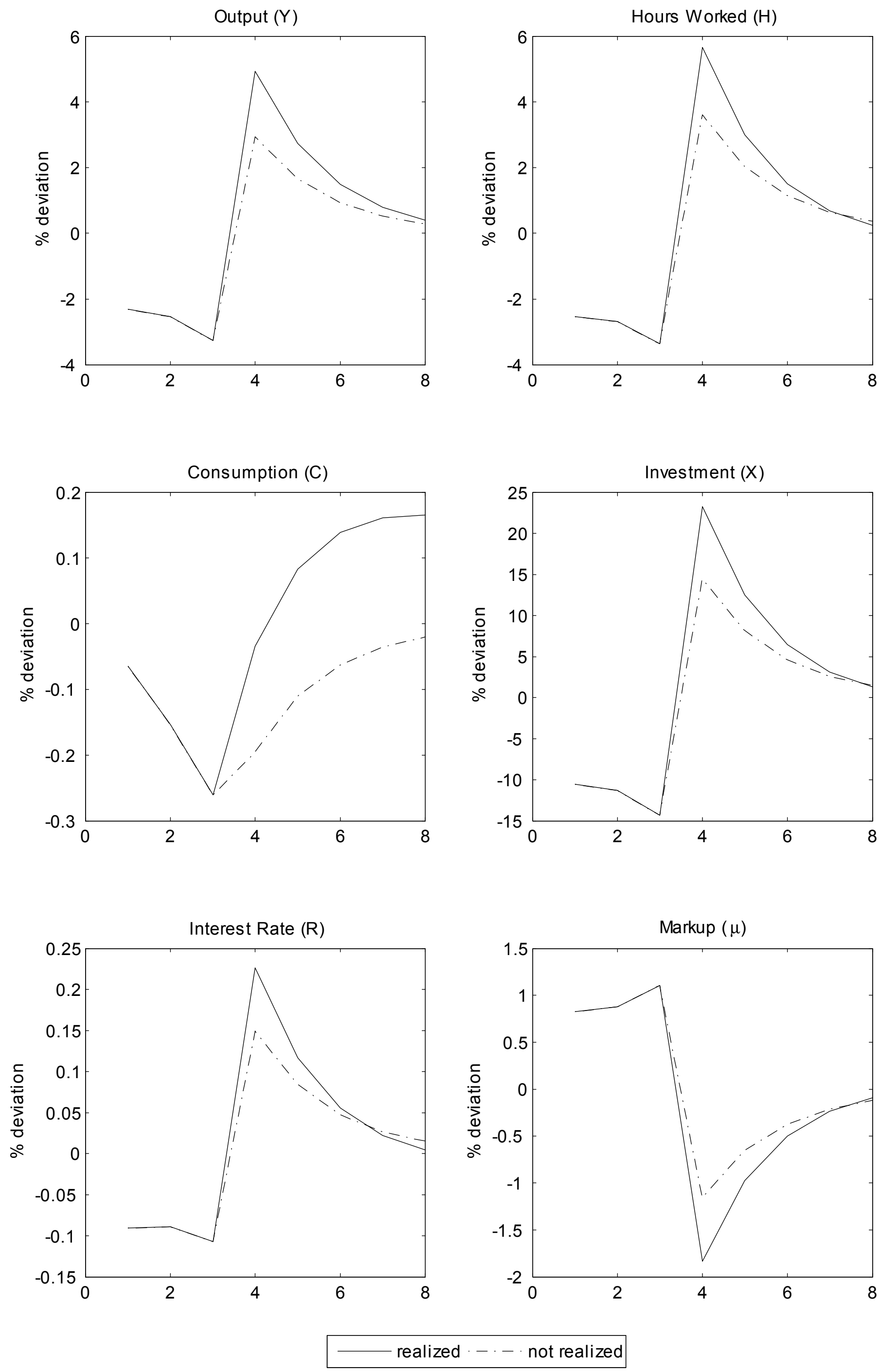

Figure 1: Response of the economy without investment adjustment costs to news arriving at $t = 1$ and a realization/non-realization at $t = 4$.

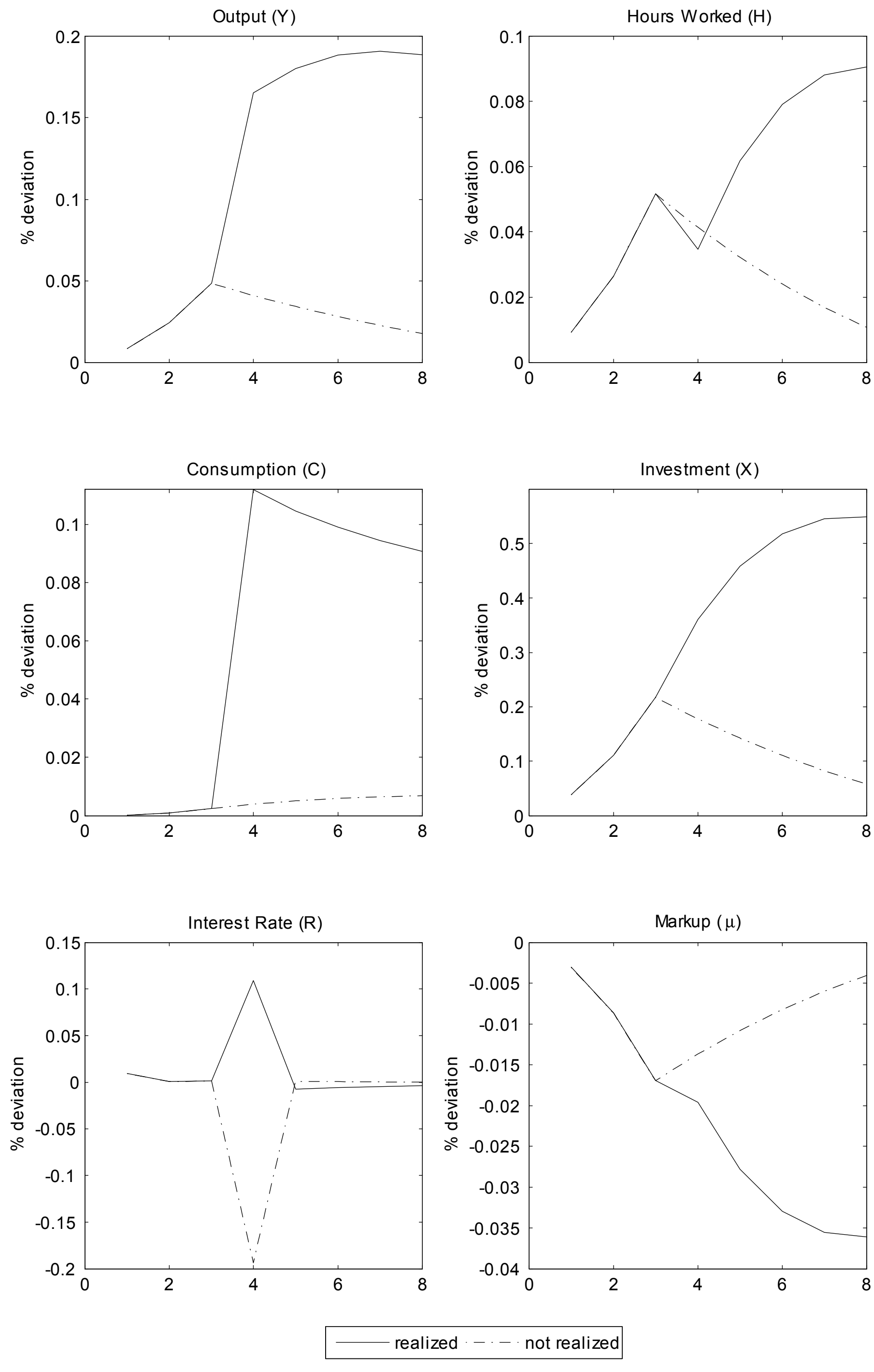

Figure 2: Response of the economy with investment adjustment costs to news arriving at $t = 1$ and a realization/non-realization at $t = 4$.

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, $\Phi''(1)$, 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 $\Phi''(1) = 0.1$, positive comovement can be achieved with a markup elasticity of $\varepsilon_{\mu} = -0.14$. Hence, the combination of endogenous countercyclical markups 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 makes it even easier to obtain expectations-driven business cycles. This is shown next.

5 Variable capital utilization

This section sets out to reduce the levels of market power and labor supply elasticity that are required to generate expectations driven business cycles. To accomplish this, we amend the model such that an intermediate good producer operates the production technology

$$y_{i,t} = z_t \left(U_t k_{i,t}\right)^{\alpha} h_{i,t}^{1-\alpha} - \phi$$

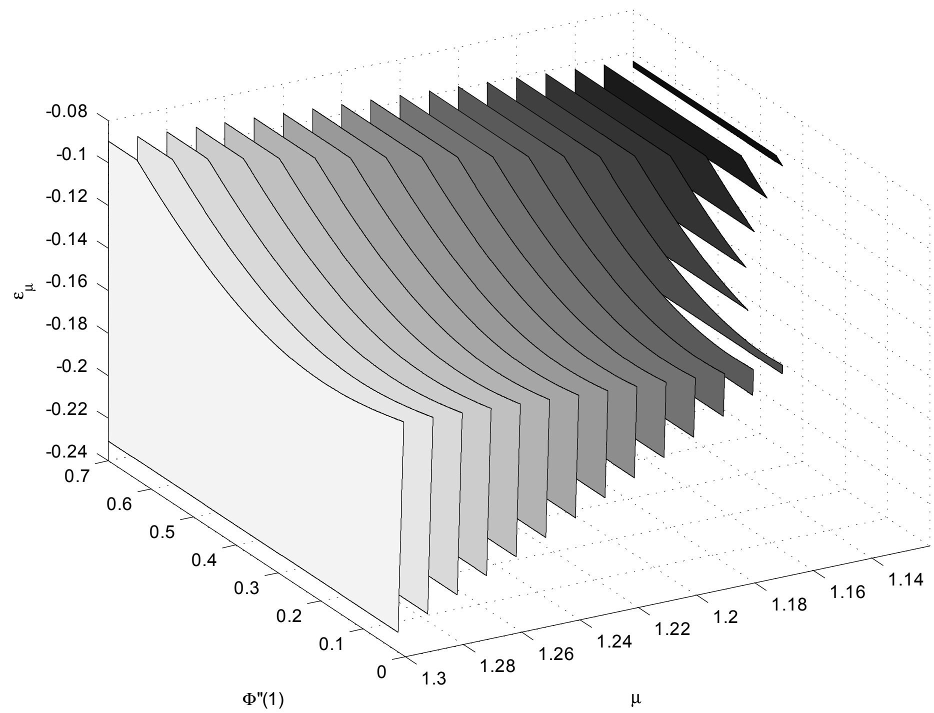

Figure 3: Markup elasticity, the steady-state markup, and adjustment costs to investment required for expectations-driven business cycles.

where U_t stands for the utilization rate of physical capital set by the capital stock's owner. Additionally, we assume that the rate of depreciation, δ_t, is an increasing function of the utilization rate

$$\delta_t = \frac{1}{\theta} U_t^{\theta} \qquad \text{with} \qquad \theta > 1.$$

Including these alterations yields an analog to (10)

$$\widehat{C}_t = -\frac{[\chi(\delta(1-\alpha)+\rho)+\alpha\rho]\frac{\alpha\delta}{\delta(1-\alpha)+\rho} + \varepsilon_\mu \mu\,[\delta(1+\alpha\chi)+\rho(1-\alpha)]}{\mu\left(\frac{(1-\alpha)(\delta+\rho)^2}{\delta(1-\alpha)+\rho} - \varepsilon_\mu[\delta(1+\alpha\chi)+\rho(1-\alpha)]\right) + \chi(\delta(1-\alpha)+\rho)+\alpha\rho}\widehat{X}_t$$

and a new sufficient condition for positive comovement between investment and consumption

$$\varepsilon_\mu < \varepsilon_\mu^* \equiv \frac{-\alpha\delta\,[\chi(\delta(1-\alpha)+\rho)+\alpha\rho]}{\mu\,[\delta(1+\alpha\chi)+\rho(1-\alpha)]\,(\delta(1-\alpha)+\rho)} < 0$$

which parallels (11). The new minimum steady state markup that is required for comovement is given by

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

Applying the same calibration as above yields $\mu_{\min} = 1.03$ if $\chi = 0$.[16] Phrased alternatively, our results require a mere slight departure from the plain-vanilla RBC model. Note that these analytical results were derived while keeping adjustment costs at zero to make our results consistent with Section 3's. Otherwise utilization and adjustment costs are intertwined, the relationship becomes complex and only numerical inspection provides insights. These then show that, unlike the case of constant utilization, adjustment costs bring down the minimum markup even further. For example, with the above calibration and $\Phi''(1) = 1.3$, a markup of 1.02 generates positive comovement along the adjustment path.[17] Moreover, our results no longer rest on a high Frisch elasticity. Kimball and Shapiro (2008) suggest a value for χ at around one. Then, variable utilization reduces the minimum markup to a reasonable value of $\mu_{\min} = 1.21$, down from 1.50 under constant utilization.

5.1 Simulations

What we have demonstrated so far is that a standard one-sector RBC model augmented by countercyclical markups is capable of producing positive comovement among the main macroeconomic aggregates in response to anticipated changes to future technology. This subsection evaluates whether the news shock driven model is able to replicate the cyclical regularities of the U.S. economy.

To begin with, the measure for TFP must be adjusted for market power and capital utilization. Hence, the Solow residual is estimated via

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

where Δ is the first difference operator.[18] The persistence parameter and the standard deviation of the technology shock are recovered as: $\psi = 0.97$, $\sigma_\zeta = \sqrt{\sigma_\xi^2 + \sigma_\epsilon^2} = 0.0057$. Since we are interested in the quantitative effect of news shocks we set $l = 3$

[16] The reason is similar to Wen's (1998) insight into how utilization amplifies increasing returns to scale.

[17] For this to occur, strictly positive adjustment costs are required. Moreover, the impulse responses mimic those shown in the previous section and are therefore not presented here.

[18] See Hornstein (1993).

and the volatilities to $\sigma_\zeta = \sigma_\epsilon$ and $\sigma_\xi = 0$, i.e. all shocks are anticipated three quarters in advance.

The calibration of all other key parameters remains as in the previous section. We set $\Phi''(1) = 1.3$ as in Jaimovich and Rebelo (2009), which is significantly lower than the estimate suggested by Christiano, Eichenbaum and Evans (2005) – it is selected to keep departures from the plain-vanilla model small. Estimates of the level of markups in the U.S. 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). We set $\chi = 1$, in line with Kimball and Shapiro (2008). Lastly, we consider two values of the markup elasticity parameter. First, $\varepsilon_\mu = -0.163 < \varepsilon_\mu^*$, which barely satisfies the sufficient condition for comovement. Second, we set $\varepsilon_\mu = -0.187$ to match the volatility of output in the U.S. data.

Table 1 presents the empirical and artificial moments from the Hodrick-Prescott filtered time series. The artificial economy echoes the empirical ordering of cyclical volatilities of the main macroeconomic aggregates, as well as their contemporaneous correlations with output. The last two columns report results for an alternative calibration that assumes indivisible labor, $\chi = 0$, and a low markup of $\mu = 1.1$. The business cycle statistics are very similar, although as expected, the higher labor supply elasticity allows the model to better match the volatility of hours worked.

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. This paper demonstrates that endogenous countercyclical markups can solve this comovement puzzle. Markups have to be sufficiently elastic in order to produce an upwardly sloping wage-hours locus that is steeper than the agents labor supply curve. A change in the markup on the arrival of news implies a shift to economic distortions via an endogenous labor wedge, and can allow for positive comovement between consumption, hours worked and

Table 1: Business Cycle Statistics

	Data	Model: $\mu = 1.3,\ \gamma = 1,$ $\varepsilon_\mu^* = -0.162$		Model: $\mu = 1.1,\ \gamma = 0,$ $\varepsilon_\mu^* = -0.023$	
		$\varepsilon_\mu = -0.163$ (η=0.92, σ=0.49)	$\varepsilon_\mu = -0.187$ (η=0.93, σ=0.39)	$\varepsilon_\mu = -0.024$ (η=0.95, σ=0.88)	$\varepsilon_\mu = -0.049$ (η=0.97, σ=0.82)
σ_Y	2.30 (1)	1.80 (1)	2.30 (1)	1.64 (1)	2.30 (1)
σ_X	6.03 (2.63)	5.86 (3.25)	8.01 (3.49)	5.22 (3.18)	8.10 (3.53)
σ_C	0.90 (0.39)	0.85 (0.47)	0.91 (0.40)	0.82 (0.50)	0.91 (0.39)
σ_H	1.91 (0.83)	0.71 (0.39)	1.08 (0.47)	0.95 (0.58)	1.69 (0.74)
σ_s	3.81 (1.66)	4.15 (2.30)	5.78 (2.52)	3.67 (2.23)	5.88 (2.56)
$\sigma_{Y/H}$	1.17 (0.51)	1.21 (0.67)	1.35 (0.59)	0.90 (0.55)	0.90 (0.39)
σ_μ	-	0.68 (0.37)	1.08 (0.47)	0.09 (0.05)	0.29 (0.13)
$\rho(X, Y)$	0.98	0.97	0.98	0.96	0.97
$\rho(C, Y)$	0.82	0.88	0.87	0.88	0.85
$\rho(H, Y)$	0.86	0.88	0.93	0.89	0.94
$\rho(s, Y)$	0.95	0.93	0.95	0.92	0.95
$\rho(Y/H, Y)$	0.56	0.96	0.96	0.88	0.78
$\rho(\mu, Y)$	-	-0.93	-0.95	-0.92	-0.95

See Appendix A.3 for the source of U.S. data. The model was simulated 1000 times for 276 periods (corresponding to the sample period plus 100 initial periods which were later purged). σ_x and $\rho(x, Y)$ denote the standard deviation of variable x and its contemporaneous correlation with Y. Relative standard deviations are in parentheses. Blank entries for μ are due to data unavailability.

investment. However, in order for positive news about the future to lead to an expansion, agents need an additional incentive to frontload investment, which we model through investment adjustment costs. We simulate the artificial economy driven by anticipated shocks and find that it is able to replicate the regular features of U.S. aggregate fluctuations.

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Appendix A

A.1 Derivation of the comovement condition and the wage-hours locus

We log-linearize the symmetric equilibrium version of the real wage (1), equations (2), (3), (7), the investment share $s_t = X_t/Y_t$, and the resource constraint $Y_t = C_t + X_t$ to obtain

$$\hat{w}_t = \hat{z}_t + \alpha \hat{K}_t - \alpha \hat{H}_t - \hat{\mu}_t$$

$$\hat{Y}_t = \mu \hat{z}_t + \mu \alpha \hat{K}_t + \mu(1-\alpha)\hat{H}_t$$

$$\hat{\mu}_t = \varepsilon_\mu \hat{s}_t$$

$$\chi \hat{H}_t + \hat{C}_t = \hat{w}_t$$

$$\hat{s}_t = \hat{X}_t - \hat{Y}_t$$

$$\hat{Y}_t = \frac{\rho + \delta(1-\alpha)}{\delta + \rho}\hat{C}_t + \frac{\alpha\delta}{\delta+\rho}\hat{X}_t$$

where we use $\mu = (Y + N\phi)/Y$. Then, we set $\hat{z}_t = \hat{K}_t = 0$ to reflect that current TFP is unaffected by news and that capital is predetermined. Finally, we use these equations to solve for the comovement condition (10). See also Eusepi (2009).

The sufficient condition for positive comovement (11) implies an upwardly sloping wage-hours locus that is steeper than the agent's labor supply curve. Using the same log-linearized equations we obtain

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

Substituting in ε_μ^* from (11) implies that the term in front of $\hat{H}_t$ is equal to χ, which is also the slope of the agent's labor supply curve. Therefore, if this term is greater than χ, which will be the case if $\varepsilon_\mu < \varepsilon_\mu^*$, then the wage-hours locus is steeper than the labor supply curve and comovement arises.

Section 5's results were derived in parallel fashion, incorporating the new production function and the optimal utilization rate:

$$\hat{w}_t = \hat{z}_t + \alpha\widehat{U}_t + \alpha\hat{K}_t - \alpha\hat{H}_t - \hat{\mu}_t$$

$$\hat{Y}_t = \mu\hat{z}_t + \mu\alpha\widehat{U}_t + \mu\alpha\hat{K}_t + \mu(1-\alpha)\hat{H}_t$$

$$(\theta-1)\,\widehat{U}_t = \widehat{r}_t = \hat{z}_t + (\alpha-1)\widehat{U}_t + (\alpha-1)\hat{K}_t + (1-\alpha)\hat{H}_t - \hat{\mu}_t$$

with the latter coming from $U_t^{\theta-1} = r_t$.

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

Positive comovement between consumption and investment is not possible if the markup is procyclical to the investment share.[19] To see this, first note that if $\varepsilon_\mu > 0$, the denominator in (10) must be negative for comovement and hence $\frac{\delta+\rho}{\delta(1-\alpha)+\rho} - \varepsilon_\mu < 0$. Yet, substituting in the upper limit of ε_μ from (4) would imply that $\frac{\delta+\rho\left(1-\alpha\frac{\mu-1}{\mu}\right)}{\delta(1-\alpha)+\rho} < 0$, which clearly can not be satisfied since $\alpha\frac{\mu-1}{\mu} < 1$.

A.3 Data sources

This Appendix details the source and construction of the U.S. data used in Section 5. All data is quarterly and for the period 1967: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.

[19] Yet, positive comovement with $\varepsilon_\mu > 0$ becomes a possibility if we depart from logarithmic utility in consumption.

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: 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, $Y_t/H_t = (12)/(13)$.

16. Capital Utilization, U_t, total index, percentage, seasonally adjusted. Source: Board of Governors of the Federal Reserve System, G17/CAPUTL/CAPUTL.B50001.S.Q.

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IV Markup Variations, Product Variety, and Expectations-Driven Business Cycles

While countercyclical markups enable the real business cycle model to produce expectations-driven fluctuations, Nekarda and Ramey (2010) suggest that markups in the U.S. are procyclical. Galí's (1994) composition of aggregate demand model is extended by endogenous entry and exit of firms, product variety effects, and investment adjustment costs. The news shock driven model generates quantitatively realistic business cycles with procyclical markups that are in the empirically plausible range.

1 Introduction

The idea that news about future fundamentals could be an important driver of aggregate fluctuations has seen much attention in recent years.[1] With empirical studies such as Beaudry and Portier (2006) and Schmitt-Grohé and Uribe (2012) suggesting that anticipated shocks explain about half of U.S. business cycles, the inability of standard models to generate expectations-driven fluctuations has led many researchers to address this shortcoming. One extension to the standard real business cycle (RBC) model that has been proposed as crucial to understanding the impact of these news shocks are endogenous countercyclical markups. Yet, empirical and theoretical work has not evolved to the point where there is a clear consensus on how aggregate markups vary. Despite Rotemberg and Woodford's (1999) claim that they are countercyclical, a recent study by Nekarda and Ramey (2010) finds the reverse: markups in the U.S. are procyclical or acyclical. Although not uncontroversial, it nevertheless questions the plausibility of theories that utilize countercyclical markups. The current paper tackles this issue by proposing a model that twists the

[1] See Lorenzoni (2011) for an overview of this growing literature.

economic effect of markups such that realistic news-driven business cycles can arise even if they are strongly procyclical.

The inability to re-produce the empirically supported positive comovement between consumption and investment in absence of changes to current fundamentals lies at the heart of the canonical model's failure to generate expectations-driven business cycles. Pavlov and Weder (2013) show that countercyclical markups driven by changes to the composition of demand are able to solve this comovement puzzle, while Mekhari (2010) and Wang (2012) demonstrate that deep habits achieve a parallel outcome.[2] That is, the models rely on the fall of markups to increase the demand for labor on the arrival of positive news. If markups are sufficiently elastic, then the outward shift of the labor demand curve increases hours worked (together with output and investment) despite the rise in consumption that shifts the labor supply schedule inward. If markups are instead procyclical, then labor demand falls and positive comovement cannot arise. Moreover, given their contractionary effect, the incorporation of procyclical markups into other artificial economies will likely reduce the possibility of news-driven fluctuations.[3]

I extend Galí's (1994) composition of aggregate demand model by endogenous entry and exit of firms, product variety effects, and investment adjustment costs. The variety effect (aka taste for variety) implies that the procyclical entry of firms brings aggregate efficiency gains through the introduction of new products. This mechanism therefore works much like countercyclical markups and I show formally that it alone can produce the required consumption-investment comovement. Due to the presence of taste for variety, procyclical markups that arise due to changes in the composition of demand have two effects. First, rising markups render the usual distortions that contract economic activity. Second, higher markups induce additional firm entry and through the variety effect lead to endogenous productivity gains.

[2]Likewise, Basu and Bundick (2012) rely on countercyclical markups to generate comovement in a sticky price model driven by shocks to fundamental uncertainty.

[3]Eusepi (2009) and Guo, Sirbu and Suen (2012) show than increasing returns to scale are able to produce positive comovement in a similar way as countercyclical markups. A procyclical markup in their models would then shift the required production externalities beyond the empirically plausible level.

This environment allows expectations-driven business cycles to arise with procyclical markups and variety effects that are in the empirically plausible range. In fact, if the second effect dominates, then in contrast to existing literature some parameter constellations imply that procyclical markups expand the efficiency wedge during an expansion and thus make the required comovement easier to obtain. As in Pavlov and Weder (2013) and others, investment adjustment costs help to produce a positive response upon good news by providing an incentive to invest immediately. Finally, I simulate the calibrated artificial economy by standard and anticipated shocks to total factor productivity (TFP) and show that it is able to produce quantitatively realistic business cycles.

The comovement issue described above is related to the necessary condition for local indeterminacy in the continuous time Benhabib and Farmer (1994) model. Like technological increasing returns and productive externalities in their paper, taste for variety and markup variations can also produce an upwardly sloping wage-hours locus. The empirically pleasing aspect of the current paper is that this occurs with marginal costs being independent of the scale of production.[4] While Pavlov and Weder (2012) show that variety effects together with markup variations are a strong source of sunspot equilibria, the models described in the present paper are characterized by a saddle path equilibrium and therefore only shocks to the economy's fundamentals can generate fluctuations.

To my knowledge, this is the first paper that studies variety effects in the context of news-driven fluctuations. Devereux et. al. (1996) examine the effect of contemporaneous technology shocks, while Chang et. al. (2011) consider local indeterminacy. Unlike those papers, the current paper follows Benassy (1996) by disentangling taste for variety from the elasticity of substitution parameters that determine the market power of monopolistic firms. The empirical evidence for variety effects can be found in economic growth and international trade literature. Funke and Ruhwedel (2001) find that product variety relative to the U.S. is significantly correlated with relative

[4] Countercyclical marginal costs do not receive empirical support. For example, see Basu and Fernald (1997).

per capita GDP levels. Feenstra and Kee (2008) find that growth in export variety leads to a rise in the productivity of exporters. Finally, Ardelean (2009) finds that the gains from variety exist regardless of whether the good is domestically produced or imported.

I employ the Simulated Method of Moments to estimate the key parameters and then obtain second moments from the calibrated economy. The model performs well at matching the main empirical aggregate regularities of U.S. cyclical fluctuations. In sum, this paper shows that with variety effects and procyclical markups, a one-sector real business cycle model is able to generate realistic business cycles driven by anticipated shocks to TFP.

The paper is organized as follows. Section 2 outlines the baseline model. Section 3 presents the conditions for positive comovement and explains how the model is able to generate expectations-driven business cycles. The economy is extended by capital utilization in Section 4 and is simulated in Section 5. Section 6 concludes.

2 Model

The economy is based on the model described by Galí (1994) and Schmitt-Grohé (1997) where the composition of aggregate demand influences the market power of monopolistically competitive intermediate good firms. It differs from these papers in three ways. First, free entry takes place until each period firms earn zero pure profits. Second, positive variety effects imply that final goods are produced more efficiently when there are more differentiated intermediate goods. Finally, adjustment costs to investment give an incentive to smooth investment intertemporally.

2.1 Agents

The representative agent chooses a sequence of consumption, C_t, and hours worked, H_t, to maximize lifetime utility:

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

where E_0 denotes the expectation conditional on period 0 information, ρ is the discount rate, and χ is the inverse of the Frisch labor supply elasticity. The agent receives the equilibrium wage, w_t, for labor services and rents the capital stock, K_t, for the equilibrium rate, r_t. He owns all firms and receives any profits, Π_t, that they potentially generate. The budget is thus constrained by

$$w_t H_t + r_t K_t + \Pi_t \geq X_t + C_t. \tag{1}$$

Here X_t is investment that adds to the capital stock, which follows the law of motion

$$K_{t+1} = (1-\delta)K_t + X_t \left[1 - \Phi\left(\frac{X_t}{X_{t-1}}\right)\right] \qquad 0 < \delta < 1 \tag{2}$$

where δ is the depreciation rate and the adjustment cost function follows $\Phi(1) = \Phi'(1) = 0, \Phi''(1) \geq 0$.[5] The first-order conditions from the agent's maximization problem are

$$\gamma H_t^{\chi} C_t = w_t \tag{3}$$

$$\varrho_t = \beta E_t \left[\lambda_{t+1} r_{t+1} + \varrho_{t+1}(1-\delta)\right] \tag{4}$$

$$\lambda_t = \varrho_t \left[1 - \Phi\left(\frac{X_t}{X_{t-1}}\right) - \frac{X_t}{X_{t-1}}\Phi'\left(\frac{X_t}{X_{t-1}}\right)\right] + \frac{1}{1+\rho} E_t \varrho_{t+1} \left(\frac{X_{t+1}}{X_t}\right)^2 \Phi'\left(\frac{X_{t+1}}{X_t}\right) \tag{5}$$

where λ_t and ϱ_t are the multipliers associated with (1) and (2), respectively. (3) is the usual labor supply equation, (4) is the intertemporal Euler equation and (5) governs optimal investment dynamics in the presence of adjustment costs.

2.2 Firms

The perfectly competitive final goods sector produces the final consumption good and the final investment good according to the production technologies

$$C_t = N_t^{1+\tau} \left(\frac{1}{N_t} \int_0^{N_t} y_{i,c,t}^{\sigma} di\right)^{1/\sigma} \qquad \tau \geq 0,\ \sigma \in (0,1)$$

and

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

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

where $y_{i,c,t}$ ($y_{i,x,t}$) is the amount of the unique intermediate good i used in the production of the final consumption (investment) good and N_t is the number of intermediate good firms. The functional form implies that the constant elasticities of substitution between intermediate goods are equal to $1/(1-\sigma)$ and $1/(1-\eta)$. The formulation of the variety effect, τ, follows Benassy (1996): taste for variety does not depend on the elasticities of substitution and is thus independent of the level of market power. An intermediate good producer i cannot price discriminate between consumption and investment demands and therefore charges the identical price $p_{i,t}$ for its good. From the profit maximization problem of the representative final consumption good firm, the conditional demand for intermediate good i is

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

with the price index

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

The monopolist faces a similar demand from the final investment good firm. Each firm i hires capital, $k_{i,t}$, and labor, $h_{i,t}$, via perfectly competitive factor markets and produces according to the production function

$$y_{i,t} = y_{i,c,t} + y_{i,x,t} = z_t k_{i,t}^{\alpha} h_{i,t}^{1-\alpha} - \phi \qquad 0 < \alpha < 1, \phi > 0 \tag{6}$$

where ϕ denotes fixed overhead costs. Aggregate total factor productivity, z_t, affects all firms equally and follows the process

$$\log z_t = \psi \log z_{t-1} + \zeta_t \qquad 0 \leq \psi < 1$$

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

where ξ_t is the standard contemporaneous shock and ϵ_{t-l} is a news shock observed and anticipated l periods in the past. Both are i.i.d. disturbances with variances satisfying $\sigma_\xi^2 + \sigma_\epsilon^2 = \sigma_\zeta^2$. Given the demand for its unique good, each monopolist sets the profit maximizing price such that the markup, $\mu_{i,t}$, equals

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

and the implicit demands for hours and capital satisfy

$$\frac{\mu_{i,t}}{p_{i,t}} w_t = (1-\alpha) \frac{y_{i,t} + \phi}{h_{i,t}} \tag{7}$$

and

$$\frac{\mu_{i,t}}{p_{i,t}} r_t = \alpha \frac{y_{i,t} + \phi}{k_{i,t}}. \tag{8}$$

I consider a symmetric equilibrium where all monopolists produce an identical amount and charge the same price, $p_{i,t} = p_t$. The functional form of the final good production functions implies that the prices of the final goods are equal and setting them as the numeraire results in

$$p_t = N_t^{\tau}.$$

Higher number of firms and varieties therefore reduce the prices of final goods relative to that of intermediate goods. Each period, free entry and exit into the intermediate goods sector proceeds until each active firm earns zero profit (net of fixed costs). Using (6), (7), and (8) with the zero profit condition leads to

$$y_t = \frac{\phi}{\mu_t - 1}$$

and to aggregate output

$$Y_t = \frac{z_t N_t^{\tau}}{\mu_t} K_t^{\alpha} H_t^{1-\alpha} \tag{9}$$

where aggregate capital and hours are $K_t = N_t k_t$ and $H_t = N_t h_t$. The efficiency wedge, $z_t N_t^{\tau} / \mu_t$, is a positive function of TFP and the number of firms and it is negatively related to the markup. The number of firms moves positively with aggregate output and the markup and it is inversely related to the fixed costs:

$$N_t = \left(Y_t \frac{\mu_t - 1}{\phi} \right)^{1/(1+\tau)}. \tag{10}$$

Finally, I define $s_t \equiv X_t / Y_t$ as the share of investment in aggregate output and rewrite the markup as

$$\mu_t = \frac{\frac{1}{1-\sigma}(1-s_t) + \frac{1}{1-\eta} s_t}{\frac{1}{1-\sigma}(1-s_t) + \frac{1}{1-\eta} s_t - 1}. \tag{11}$$

If $\sigma = \eta$ the markup is constant and completely irrelevant for local dynamics due to the instantaneous entry and exit (see Kim, 2004). If $\sigma > \eta$ the markup is procyclical to s_t. A higher demand for investment means that the monopolist confronts a less elastic demand curve and this permits it to charge a higher markup. Rather than calibrating σ and η directly, I instead calibrate the markup's steady state, μ, and its elasticity with respect to the investment share, $\varepsilon_\mu \equiv (\partial\mu/\partial s)(s/\mu)$.[6] Since $\mu > 1$ and $\sigma, \eta \in (0,1)$, some algebra restricts ε_μ to

$$\frac{1-\mu}{\mu} < \varepsilon_\mu < \frac{\mu-1}{\mu}\frac{s}{1-s} \tag{12}$$

where $s = \alpha\delta/(\delta+\rho)$ is the steady state investment share.

3 Expectations-driven business cycles

Expectations-driven business cycles are characterized by positive comovement between the main economic aggregates in response to information about future changes to fundamentals. Therefore, as a first-pass, it is important to establish whether the current model is able generate positive consumption-investment comovement in the absence of changes to current technology. To do this, I first log-linearize all the static equilibrium equations and solve for the following expression:[7]

$$\hat{C}_t = \frac{\tau(1-\alpha) - \alpha - \chi + \varepsilon_\mu \dfrac{(1+\tau-\mu)(\delta(1-\alpha)+\rho)(1+\chi)}{\alpha\delta(\mu-1)}}{(1-\alpha)(1+\tau) + \dfrac{\delta(1-\alpha)+\rho}{\alpha\delta}\left(1+\varepsilon_\mu \dfrac{1+\tau-\mu}{\mu-1}\right)}\hat{X}_t. \tag{13}$$

Here hatted variables denote percent deviations from the steady state. If $\tau = \varepsilon_\mu = 0$, the term in front of $\hat{X}_t$ is negative as in the standard RBC model and expectations-driven fluctuations cannot arise. If $\tau > 0$, the presence of taste for variety implies that firm entry leads to an endogenous rise in the efficiency wedge. The sufficient condition for positive comovement when $\varepsilon_\mu = 0$ is

$$\tau > \tau^* \equiv (\alpha+\chi)/(1-\alpha) > 0.$$

This condition also ensures positive consumption-hours comovement since an increase in output can only be achieved by higher employment (recall that capital is a

[6] See Schmitt-Grohé (1997) for more details.
[7] The procedure is explained in Appendix A.1.

predetermined variable and that news do not affect current technology). Calibrating the standard parameters as $\alpha = 0.3$, $\delta = 0.025$, $\rho = 0.01$, $\chi = 0$ (indivisible labor) implies that $\tau^* = 0.429$. While a variety effect of this magnitude is unlikely to be empirically plausible, variable markups bring the required value considerably lower.

Let us now consider the situation where markups are variable. The sufficient condition for positive consumption-investment comovement when $\tau = 0$ is

$$\varepsilon_\mu < \varepsilon_\mu^* \equiv -\frac{\alpha\delta(\alpha + \chi)}{(\delta(1-\alpha) + \rho)(1+\chi)} < 0.$$

Countercyclical markups in this case endogenously expand the efficiency wedge. Using the lower limit of ε_μ from (12) implies that the minimum steady state markup is $\mu_{\min} = 1/(1 + \varepsilon_\mu^*) = 1.09$. Under the same calibration in a model with a constant number of firms, Pavlov and Weder (2013) report a minimum markup of 1.12. Therefore, endogenous entry and exit reduces the required market power necessary for news-driven business cycles.

Another way to think about comovement is to derive the wage-hours locus:

$$\hat{w}_t = \left[\tau(1-\alpha) - \alpha + \varepsilon_\mu \frac{(1+\tau-\mu)(\delta(1-\alpha)+\rho)(1+\chi)}{\alpha\delta(\mu-1)}\right] \hat{H}_t. \tag{14}$$

The sufficient conditions for consumption-investment comovement described earlier ensure that this locus is upwardly sloping (the term in front of $\hat{H}_t$ is positive) and steeper than the agent's labor supply curve. If positive news about the future lead to a dominating wealth effect, the increase in consumption shifts the labor supply curve inward. Since the wage-hours locus is upwardly sloping, employment and investment also rise. It is equivalent to the necessary condition for local indeterminacy in a continuous time Benhabib and Farmer (1994) model and hence the possibility of sunspot equilibria and expectations-driven fluctuations are closely linked.

What happens if variety effects and variable markups are both relevant? As in Pavlov and Weder (2012), countercyclical and procyclical markups can expand or contract the efficiency wedge depending on the size of the taste for variety. From (14), if $\varepsilon_\mu(1+\tau-\mu) > 0$, then the required τ for positive comovement is lower. Therefore, a procyclical markup endogenously expands the efficiency wedge if $\tau > \mu - 1$. The variety effect is sufficiently large such that the higher efficiency due to the entry of firms dominates the contractionary effect of a higher markup. For example, under a very small markup of $\mu = 1.05$ and an elasticity (near its upper boundary) of $\varepsilon_\mu = 0.01$, the required τ drops to 0.235.

If $\tau < \mu - 1$, then a procyclical markup contracts the efficiency wedge. However, the higher markup still contributes to greater firm entry. This implies that under variable markups, variety effects work significantly differently to other forms of increasing returns. For example, let us assume that taste for variety does not exist (i.e. $\tau = 0$) and that the production function of each intermediate good firm is given by $y_{i,t} = k_{i,t}^{\alpha} h_{i,t}^{1-\alpha} K_t^{\alpha\kappa} H_t^{(1-\alpha)\kappa} - \phi$ where κ represents productive externalities. Under the same calibration but a constant markup, the minimum externality required for positive comovement is $\kappa = \tau^* = 0.429$. Now for the sake of argument, suppose that $\mu = 1.5$ and $\varepsilon_\mu = 0.09$, which is close to its upper boundary from (12). In this case, the minimum externality jumps considerably to $\kappa = 0.902$, while in the model with taste for variety the minimum τ only rises slightly to 0.464. In addition, unlike productive externalities, variety effects do not imply decreasing marginal costs with respect to output.

So far I have shown that taste for variety and variable markups are able to solve the comovement problem that is present in the standard RBC model. One noticeable aspect about the comovement conditions is that they are completely independent of investment adjustment costs. However, these prove to be important in generating the empirically supported direction of comovement. The absence of adjustment costs implies that the artificial economy plunges into a recession upon positive news even if the wage-hours locus is upwardly sloping. The intuition for this result follows Pavlov and Weder (2013). When agents learn about future improvements to technology they realize that their lifetime wealth will be higher. The positive wealth effect stimulates higher consumption and an inward shift of the labor supply curve. On the other hand, there is also an opposing intertemporal substitution effect that induces lower consumption due to higher expected future real interest rates. This substitution effect dominates when the wage-hours locus is upwardly sloping. As a result, the drop in current consumption shifts the labor supply curve outward and this leads to a fall in current hours and investment. Adjustment costs reverse this outcome through their negative impact on the return to investment, which allows the wealth effect to dominate.

4 The extended model

The previous section demonstrated that taste for variety can allow for positive comovement between consumption and investment in response to news about future technology. Yet, there seems to be no consensus regarding its size. This section illustrates that the required variety effect for expectations-driven business cycles does not need to be too large by a simple extension to the baseline model.

Each intermediate good firm i now operates the production technology

$$y_{i,t} = z_t \left(U_t k_{i,t}\right)^{\alpha} h_{i,t}^{1-\alpha} - \phi$$

where U_t stands for the utilization rate of capital set by its owners.[8] The aggregate production function in the symmetric equilibrium is thus

$$Y_t = \frac{z_t N_t^{\tau}}{\mu_t}(U_t K_t)^{\alpha} H_t^{1-\alpha}. \tag{15}$$

Capital accumulation follows

$$\begin{aligned} K_{t+1} &= (1-\delta_t)K_t + X_t\left[1-\Phi\left(\frac{X_t}{X_{t-1}}\right)\right] \\ \delta_t &= \frac{1}{\theta}U_t^{\theta} \qquad\qquad \theta > 1 \end{aligned}$$

and the optimal rate of capital utilization is

$$r_t \lambda_t = U_t^{\theta-1}\varrho_t. \tag{16}$$

In the presence of adjustment costs, the current rate of utilization depends on past and (expected) future investment. As a result, the corresponding comovement condition to (13) and the wage-hours locus can no longer be obtained from this version of

[8] The introduction of capital utilization increases the elasticity of output with respect to labor. See Wen (1998).

the model. The conditions for the case where adjustment costs are exactly zero can be found in Appendix A.2, and these show that for a constant markup, the minimum variety effect required for comovement is $\tau = 0.094$ (down from 0.429 under constant utilization). Otherwise, considering adjustment costs, comovement boundaries can only be uncovered numerically.

Figure 1 shows the three-way relationship between the markup elasticity, the steady-state markup, and the variety effect required for expectations-driven business cycles. Inside each region, consumption, investment and hours rise and positively comove along the adjustment path in response to news arriving in period $t = 1$ about a rise in TFP that will occur in $t = 4$. The standard parameters here are the same as in Section 3. Investment adjustment costs are set to $\Phi''(1) = 1.3$ as in Jaimovich and Rebelo (2009) and the persistence of the technology shock is $\psi = 0.9$. In general, higher values of the variety effect make news-driven business cycles easier to obtain. The figure also shows that higher (positive) markup elasticities require a larger taste for variety when $\mu = 1.1$ or higher. As in Pavlov and Weder (2012), there are two regions if $\mu = 1.05$ and for the upper region a procyclical markup (through its positive influence on firm entry) actually reduces the required variety effect. Another point of note is that under constant markups, the minimum taste for variety is $\tau = 0.083$, and thus adjustment costs (unlike in the baseline model) bring down the requirements for comovement even further.

5 Simulations

The previous sections have shown that a one-sector RBC model with procyclical markups, variety effects and investment adjustment costs is able to produce the positive comovement between consumption and investment in response to an anticipated disturbance to future technology. This section evaluates whether the news-driven fluctuations from the capital utilization model are quantitatively realistic. First, technology shocks are measured in a way that is consistent with the model's equilibrium conditions. Then, the Simulated Method of Moments is used to calibrate the

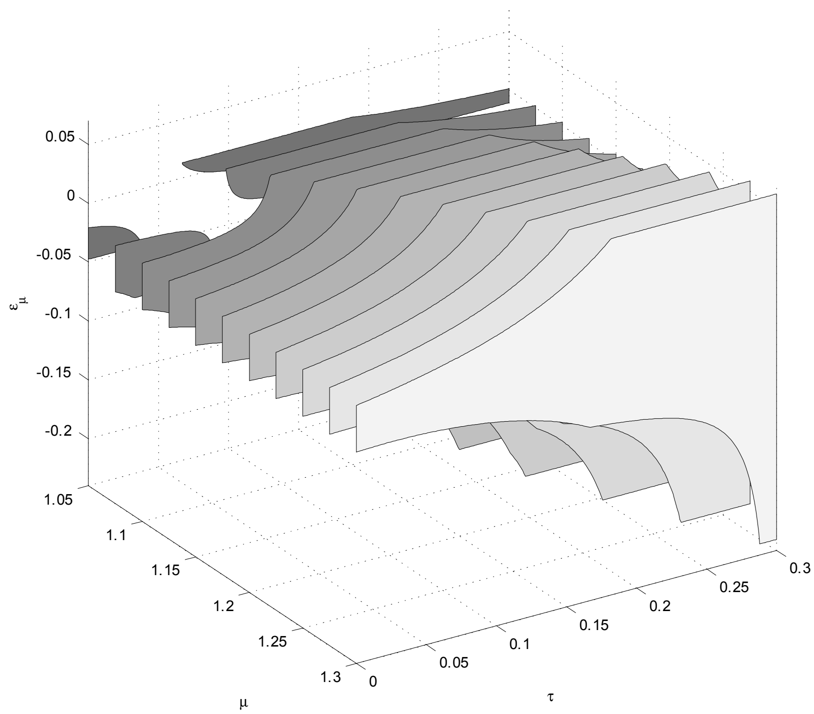

Figure 1: Markup elasticity, the variety effect, and the steady-state markup required for expectations-driven business cycles.

two parameters critical to positive comovement: the variety effect and the markup elasticity with respect to the investment share. Finally, the model's second moments are compared with its counterparts from the Hodrick-Prescott filtered U.S. quarterly time series for the period 1967:I-2010:IV.[9]

5.1 Measuring technology shocks

Due to the variation in the number of firms, the aggregate markup and capital utilization, technology shocks must be measured by the model's aggregate production function (15).[10] The conventional definition of the Solow residual, SR_t, would thus imply

$$SR_t = \hat{Y}_t - \alpha \hat{K}_t - (1 - \alpha) \hat{H}_t = \hat{z}_t + \hat{N}_t^{\tau} + \alpha \hat{U}_t - \hat{\mu}_t.$$

[9] See Appendix A.3 for the data sources.

[10] See Devereux et al. (1996) and Jaimovich and Floetotto (2008).

The procyclical movement of the number of firms and the rate of utilization would give an upward bias to SR_t as an estimator of z_t, while a procyclical markup would have the opposite effect. Since data for μ is not available, the model's log-linearized equilibrium equations can be used to obtain a measure of the true exogenous TFP process. Eliminating $\hat{\mu}_t$ and the $\hat{N}_t$ from the above equation yields

$$\hat{z}_t = \frac{1}{1+\tau}\hat{Y}_t - \alpha\hat{K}_t - \alpha\hat{U}_t - \left(1 - \alpha + \varepsilon_\mu \frac{(1+\tau-\mu)(\rho+\delta(1-\alpha))(1+\chi)}{\alpha\delta(\mu-1)(1+\tau)}\right)\hat{H}_t. \quad (17)$$

The model-consistent technology shocks can then be estimated after calibrating the parameters.

5.2 Calibration and estimation

As in Sections 3 and 4, the model's standard parameters are set as is common in the real business cycle literature: $\alpha = 0.3$, $\delta = 0.025$, $\rho = 0.01$ and $\chi = 0$. I set $\Phi''(1) = 1.3$ as in Jaimovich and Rebelo (2009), which is very close to the value estimated by Altig et al. (2011). Beaudry and Portier (2006) identify anticipated shocks to TFP via a vector autoregressive model and their variance decompositions indicate that news shocks explain roughly 50 percent of business cycle fluctuations. Schmitt-Grohé and Uribe (2012) use Bayesian and maximum likelihood methods to estimate the contribution of anticipated shocks and likewise find that these account for about half of the variance of the main macroeconomic aggregates. Guided by these results, I set the variances of the anticipated and standard innovations to TFP to $\sigma_\epsilon^2 = \sigma_\xi^2 = \frac{1}{2}\sigma_\zeta^2$ (i.e. 50 percent of the shocks are anticipated). The steady state markup is set to $\mu = 1.3$, which lies in the middle of the estimates of U.S. markups in value added data (see Floetotto and Jaimovich, 2008). I consider two calibrations of the markup elasticity parameter. First, I restrict the markup to be constant ($\varepsilon_\mu = 0$). Second, based on the results of Nekarda and Ramey (2010), I consider the possibility of procyclical markups ($\varepsilon_\mu \geq 0$).[11] Since there is no direct evidence on the size of this elasticity and also no straightforward way to pin down the magnitude of the variety

[11] News-driven fluctuations in a model with countercyclical markups has been investigated by Pavlov and Weder (2013).

effect, these are then estimated by the Simulated Method of Moments (SMM).[12]

The parameter vector to be estimated by SMM (for some value of anticipation periods l) is $\Theta \equiv [\tau, \varepsilon_\mu]$. The standard deviation of aggregate output and the correlation of consumption with investment provide information on these two parameters. Recall that τ and ε_μ determine whether positive comovement and thus expectations-driven business cycles are possible. In particular, under constant or procyclical markups, consumption moves in the opposite direction to investment in response to news if the variety effect is not sufficiently large. The vector of targeted moments is defined as $M^i \equiv [\sigma_Y, \rho(C, X)]$, $i = E, S$.

For each parameter constellation, after obtaining σ_ζ^2 and ψ via (17), the model is simulated $N^S = 20$ times for 276 periods (corresponding to the 1967:I-2010:IV period, $T = 176$, plus 100 initial periods which are later purged). This estimation procedure is replicated 500 times. Each of the replications generates a vector of parameter values

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

that minimizes the distance between the theoretical (simulated) moments, $M_t^S(\Theta)$, and empirical moments, M^E. Here Ω is the variance-covariance matrix of the empirical moments (see Appendix A.4). Finally, τ and ε_μ are calculated by taking the average across the replications.

Table 1 presents the estimated and implied parameters based on anticipation periods $l = 3$.[13] Note that only parameters in vector $\Theta = [\tau, \varepsilon_\mu]$ have been directly estimated by SMM and that those present in (17) ultimately determine σ_ζ^2 and ψ. The estimated variety effect, which is critical for the positive consumption-investment comovement, is not too large to be empirically implausible. When the markup is allowed to vary (last row of Table 1), SMM picks a procyclical markup that has a negative impact on the efficiency wedge and this leads to a higher estimate of the variety effect. Nevertheless, as mentioned in Section 3, this variety effect

[12] See Karnizova (2010) for a similar application of SMM.

[13] $l = 3$ provided a closer match to the empirical moments than $l = 4$.

Table 1: Estimated and Implied Parameters

Calibration	Estimated		Implied	
	ε_μ	τ	σ_ζ^2	ψ
$\varepsilon_\mu = 0$	-	0.1301 (0.0082)	0.4199	0.9638
$\varepsilon_\mu \geq 0$	0.0624 (0.0003)	0.2037 (0.0049)	0.3786	0.9605

ε_μ and τ are directly estimated by SMM and together with the rest of the parameters imply values for σ_ζ and ψ. Standard deviations are in parentheses. σ_ζ^2 is reported in percent terms.

is considerably smaller than the production externalities that would otherwise be required for positive comovement. Importantly, the estimates in both cases are consistent with realistic expectations-driven business cycles. This is illustrated next.

5.3 Business cycle dynamics

Figure 2 plots the impulse response functions of the variable markup economy (ε_μ, τ, and ψ from the last row of Table 1) to news arriving in period $t = 1$ about a rise in TFP that will occur in $t = 4$.[14] There are two situations: the expected rise in productivity is realized (news turn out to be correct) and unrealized (news turn out to be incorrect and there is no change to TFP). Positive news about the future lead to positive comovement among all the main aggregates. The intuition for this is as follows. Upon hearing about the rise in future TFP, adjustment costs give an incentive to invest today. Since $\varepsilon_\mu > 0$ ($\sigma > \eta$), higher demand for investment induces monopolistic firms to raise their markups. While higher markups reduce the demand for labor, higher potential profits stimulate greater firm entry, which through the variety effect leads to an overall increase in the efficiency wedge. The downwardly sloping labor demand curve thus shifts out and hours worked rise. This creates a positive wealth effect that raises consumption and shifts the labor supply curve inward. It is the relatively flat dynamics of the interest rate, R, that allow the

[14] The impulse response functions of the model with $\varepsilon_\mu = 0$ are qualitatively identical and are omitted to conserve space.

Table 2: Business Cycle Dynamics

	Data	Model, $\varepsilon_\mu = 0$	Model, $\varepsilon_\mu \geq 0$
σ_Y	2.30 (1)	2.13 (1)	2.14 (1)
σ_X	6.03 (2.63)	7.01 (3.29)	6.98 (3.27)
σ_C	0.90 (0.39)	1.06 (0.50)	1.07 (0.50)
σ_H	1.91 (0.83)	1.36 (0.64)	1.35 (0.63)
σ_s	3.81 (1.66)	5.01 (2.35)	4.98 (2.33)
$\sigma_{Y/H}$	1.17 (0.51)	1.06 (0.50)	1.07 (0.50)
σ_N	-	1.88 (0.88)	2.83 (1.32)
σ_μ	-	-	0.31 (0.15)
$\rho(C, X)$	0.70	0.65	0.65
$\rho(X, Y)$	0.98	0.95	0.95
$\rho(C, Y)$	0.82	0.85	0.85
$\rho(H, Y)$	0.86	0.91	0.90
$\rho(s, Y)$	0.95	0.91	0.90
$\rho(Y/H, Y)$	0.56	0.85	0.85
$\rho(N, Y)$	-	1.00	0.99
$\rho(\mu, Y)$	-	-	0.90

See Appendix A.3 for the source of U.S. data. σ_x and $\rho(x, Y)$ denote the standard deviation of variable x and its contemporaneous correlation with Y. Blank entries for μ and N are due to data unavailability.

wealth effect to dominate and this is due to the negative impact of adjustment costs on the return to investment. If TFP remains unchanged in $t = 4$, this bad news causes agents to realize that they have overinvested, the expansion comes to a halt and economic activity declines back to the steady state.

I simulate the model 1000 times for the two alternative calibrations and compare the second moments to those from the U.S. economy. Table 2 presents the empirical and artificial moments. Theory successfully mimics the ranking of cyclical volatilities in output, consumption, investment and hours. The contemporaneous correlations with output are also in line with their empirical counterparts. Altogether, the statistics are very similar for the two calibrations. As expected from (10), a procyclical markup raises the volatility of the number of firms and product varieties.

Tables 3 and 4 check the robustness of these results by considering full anticipation of shocks ($\sigma_\epsilon^2 = \sigma_\zeta^2$), higher adjustment costs (from Christiano, Eiechenbaum

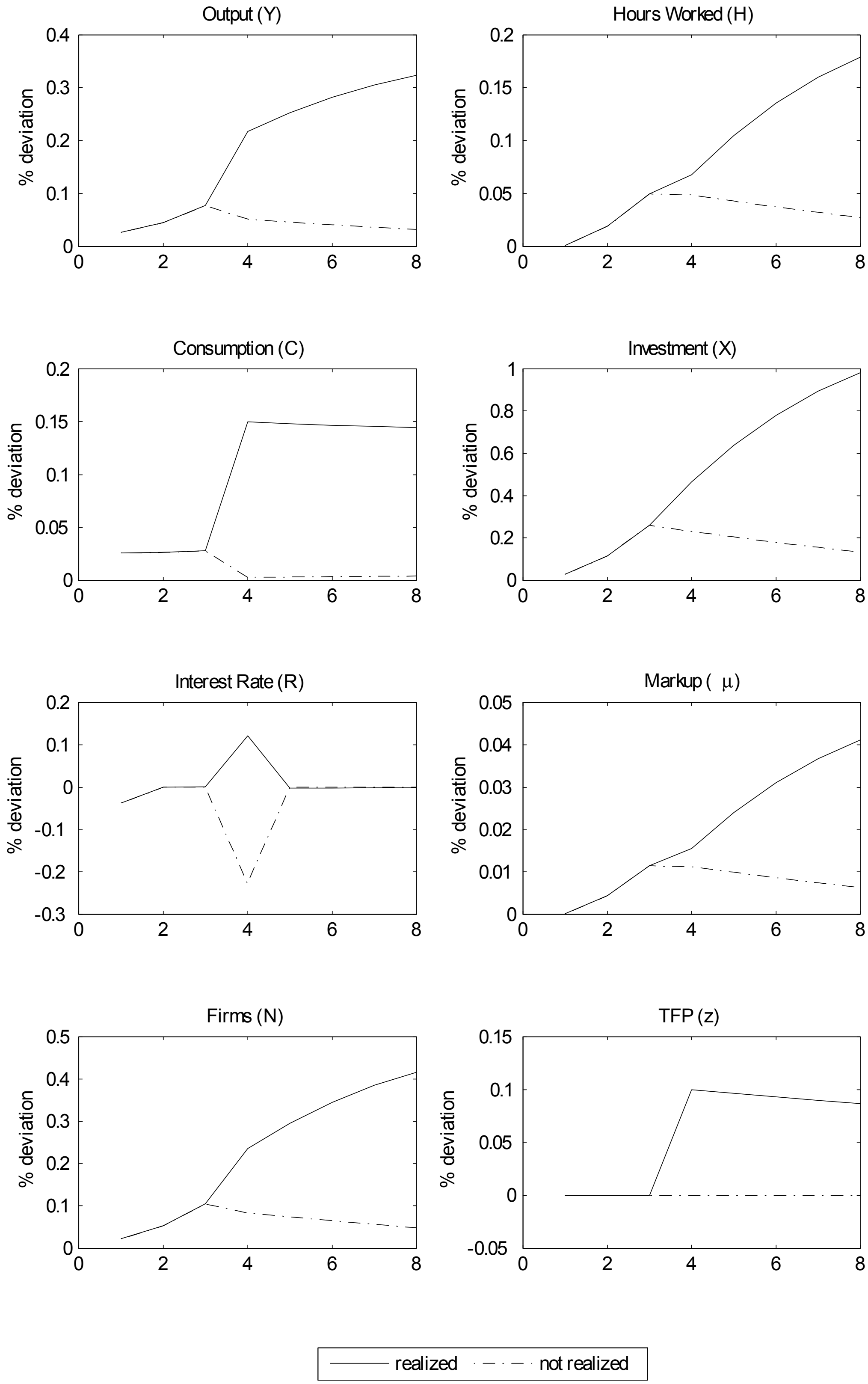

Figure 2: Response of the economy to news arriving at $t = 1$ and a realization/non-realization at $t = 4$.

Table 3: Robustness: Estimated and Implied Parameters

Calibration	Estimated		Implied	
	ε_μ	τ	σ_ζ^2	ψ
$\sigma_\epsilon^2 = \sigma_\zeta^2$	0.0375 (0.0299)	0.1936 (0.0350)	0.3930	0.9624
$\Phi''(1) = 2.5$	0.0627 (0.0000)	0.2433 (0.0043)	0.4020	0.9651
$\mu = 1.2$	0.0446 (0.0006)	0.1615 (0.0046)	0.4012	0.9624

Baseline calibration: $\mu = 1.3$, $\Phi''(1) = 1.3$, $\sigma_\epsilon^2 = \sigma_\zeta^2/2$.

and Evans, 2005), and a lower steady state markup. Expectations-driven business cycles exist under all three calibrations. When all shocks to TFP are anticipated, the parameters are less precisely estimated but the model is able to match the targeted moments more accurately. This suggests that fluctuations arising from anticipated future movements in TFP are quantitatively important. As expected, higher adjustment costs allow the model to better match the volatility of investment and its share in output, yet, the model performs slightly weaker in most other statistics. In the case of the lower steady state markup, the moments are almost identical to those from the last column of Table 2. The only notable difference being a slightly higher volatility of firms.

6 Conclusion

Countercyclical markups have been shown to solve many economic enigmas, and more recently, their presence has allowed the standard one-sector real business cycle model to generate expectations-driven fluctuations in response to news about future fundamentals. Yet, latest research suggests that aggregate markups are procyclical or acyclical. Although this finding is contentious, it puts doubt on models that rely on countercyclical markups. Moreover, with procyclical markups, the possibility of news-driven fluctuations in many other models falls significantly. This paper presents an artificial economy where such business cycles occur easily even if

Table 4: Robustness: Business Cycle Dynamics

	Data	Model		
		$\sigma_\epsilon^2 = \sigma_\zeta^2$	$\Phi''(1) = 2.5$	$\mu = 1.2$
σ_Y	2.30 (1)	2.22 (1)	1.87 (1)	2.13 (1)
σ_X	6.03 (2.63)	7.31 (3.29)	5.49 (2.94)	6.99 (3.28)
σ_C	0.90 (0.39)	1.04 (0.47)	1.17 (0.63)	1.06 (0.50)
σ_H	1.91 (0.83)	1.41 (0.64)	1.05 (0.56)	1.36 (0.64)
σ_s	3.81 (1.66)	5.20 (2.34)	3.86 (2.07)	4.99 (2.34)
$\sigma_{Y/H}$	1.17 (0.51)	1.04 (0.47)	1.17 (0.63)	1.06 (0.50)
σ_N	-	2.53 (1.14)	2.25 (1.20)	2.92 (1.37)
σ_μ	-	0.19 (0.09)	0.24 (0.13)	0.22 (0.10)
$\rho(C, X)$	0.70	0.71	0.58	0.65
$\rho(X, Y)$	0.98	0.96	0.91	0.95
$\rho(C, Y)$	0.82	0.87	0.86	0.85
$\rho(H, Y)$	0.86	0.93	0.81	0.90
$\rho(s, Y)$	0.95	0.93	0.81	0.90
$\rho(Y/H, Y)$	0.56	0.87	0.86	0.85
$\rho(N, Y)$	-	0.99	0.98	0.99
$\rho(\mu, Y)$	-	0.93	0.81	0.90

markups are procyclical. The key to this result is the endogenous entry and exit of firms under the presence of taste for variety. Rising markups in such an environment induce greater firm entry, which leads to gains in endogenous productivity through higher product variety. In order for positive news to bring about an economic expansion, investment adjustment costs give an incentive to increase investment and production immediately. The simulated economy performs well at re-producing the main empirical regularities of U.S. business cycles. In comparison to many other studies that generate macroeconomic comovement by increasing returns to scale, product variety effects do not imply decreasing marginal costs. The size of the variety effect under procyclical markups is significantly smaller than the productive externalities that would otherwise be required, and hence, news-driven fluctuations occur for empirically plausible levels of market power.

Appendix A

A.1 Equations used to derive the comovement condition and the wage-hours locus

I first log-linearize (3), the symmetric equilibrium version of the real wage (7), equations (9), (10), (11), the investment share $s_t = X_t/Y_t$, and the resource constraint $Y_t = C_t + X_t$ to obtain

$$\chi \hat{H}_t + \hat{C}_t = \hat{w}_t$$

$$\hat{w}_t = \hat{Y}_t - \hat{H}_t$$

$$\hat{Y}_t = \hat{z}_t + \tau \hat{N}_t + \alpha \hat{K}_t + (1-\alpha)\hat{H}_t - \hat{\mu}_t$$

$$\hat{N}_t = \frac{1}{1+\tau}\hat{Y}_t + \frac{1}{1+\tau}\frac{\mu}{\mu-1}\hat{\mu}_t$$

$$\hat{\mu}_t = \varepsilon_\mu \hat{s}_t$$

$$\hat{s}_t = \hat{X}_t - \hat{Y}_t$$

$$\hat{Y}_t = \frac{\rho + \delta(1-\alpha)}{\delta+\rho}\hat{C}_t + \frac{\alpha\delta}{\delta+\rho}\hat{X}_t$$

I then set $\hat{z}_t = \hat{K}_t = 0$ (to reflect that news do not affect current technology and that capital is predetermined) and use these to solve for the comovement condition (13) and the wage-hours locus (14).

A.2 Extended model analytics

While investment adjustment costs have no effect on the condition for comovement (13), they are relevant for the model with variable capital utilization. Like in Pavlov and Weder (2013), adjustment costs make positive comovement a little easier to obtain because present utilization rates depend positively on expected future investment. Yet, since equation (16) is dynamic, the static condition for comovement can be derived only if $\Phi''(1) = 0$. The procedure for this is described in Appendix A.1 and the equations remain largely unchanged except for the production function and the optimal utilization rate:

$$\hat{Y}_t = \hat{z}_t + \tau \hat{N}_t + \alpha \hat{K}_t + \alpha \hat{U}_t + (1-\alpha)\hat{H}_t - \hat{\mu}_t$$

$$(\theta - 1)U_t = r_t = \hat{Y}_t - \hat{K}_t - \hat{U}_t$$

where the latter is from (16) when $\Phi''(1) = 0$ and hence $\lambda_t = \varrho_t$.

If the markup is constant, that is $\varepsilon_\mu = 0$, the analytical expression for comovement is

$$\hat{C}_t = \frac{\alpha\delta\{\tau[\rho(1-\alpha) + \delta(1+\chi\alpha)] - \chi(\delta(1-\alpha)+\rho) - \alpha\rho\}\hat{X}_t}{\rho^2(1+\chi) + \delta^2(1-\alpha)\{1+\chi[1-\alpha(1+\tau)]\} + \delta\rho\{2(1+\chi) - \alpha[1+\alpha+2\chi+(\alpha+\chi)\tau]\}}.$$

As long as τ is not large enough to sustain endogenous growth, the denominator is positive, and positive comovement therefore requires $\tau > [\alpha\rho + \chi(\delta(1-\alpha)+\rho)]/[\rho(1-\alpha) + \delta(1+\chi\alpha)]$.

The analytics are far less tractable when the markup is variable and for $\chi = 0$ this expression is

$$\hat{C}_t = \frac{\gamma + \alpha\delta(\mu-1)\{\tau[\rho(1-\alpha)+\delta] - \alpha\rho\}\hat{X}_t}{\gamma + (\mu-1)\{\delta[\rho(2-\alpha[1+\alpha(1+\tau)]) + \delta(1-a)] + \rho^2\}}.$$

where $\gamma = \varepsilon_\mu(1+\tau-\mu)\{\rho^2 + \delta[\delta(1-\alpha) + \rho(2-\alpha)]\}$.

A.3 Data sources

This Appendix details the source and construction of the U.S. data used in Section 5. All data is quarterly and for the period 1967: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: 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, $Y_t/H_t = (12)/(13)$.

16. Capital Utilization, U_t, total index, percentage, seasonally adjusted. Source: Board of Governors of the Federal Reserve System,
G17/CAPUTL/CAPUTL.B50001.S.Q.

A.4 Weighting matrix

I follow Karnizova (2010) in constructing the weighting matrix Ω. This matrix depends entirely on empirical data. First, the vector of empirical Hodrick-Prescott filtered moments is defined as

$$\hat{m}_T = [var(Y_t), var(C_t), var(X_t), cov(C_t, X_t)]'$$

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

$$m_t = [Y_t^2, C_t^2, X_t^2, C_t X_t]'.$$

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

$$x_1 \equiv var(Y_t), x_2 \equiv var(C_t), x_3 \equiv var(X_t), x_4 \equiv cov(C_t, X_t).$$

The two moments targeted in the simulation are functions of these variances and covariances:

$$\begin{aligned} g_1(x) &= \sigma_Y = \sqrt{x_1} \\ g_2(x) &= \rho(C, X) = x_4 / \left(\sqrt{x_2}\sqrt{x_3}\right) \end{aligned}$$

Then the weighting matrix is $\Omega = [\Delta G(x) * \hat{\omega} * \Delta G(x)']^{-1}$ where $\Delta G(x)$ is the gradient of the function $G(x) = [g_1(x), g_2(x)]'$.

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V Conclusion

This thesis contributes to our understanding of how news and beliefs about the future drive the business cycle by investigating primarily the role of imperfect competition in a dynamic stochastic general equilibrium model. The three self-contained papers show a number of new plausible channels by which the artificial economy can generate such expectations-driven fluctuations. As such, the thesis furthers our comprehension of the features of the economy that potentially shape the business cycle. Furthermore, I believe that the mechanisms driving my results are intuitively simpler and possibly more plausible than what has been discussed in the literature.

The first paper examines the role of variable markups and taste for variety in business cycles driven by self-fulfilling beliefs. It finds that under the free entry and exit of monopolistic firms, if taste for variety is sufficiently large, then the artificial economy's equilibrium is indeterminate and hence animal spirits can influence business cycles. Endogenous markup variations can reduce the required variety effects. Moreover, higher markups induce a greater number of firms to enter, and hence, procyclical markups can make the economy even more susceptible to such belief shocks. This result is particularly important given the recent research claiming that aggregate markups in the U.S. are in fact procyclical. In sum, realistic endogenous business cycles occur with variety effects that are significantly smaller than the externalities required by many other studies and with markups that are well within empirical estimates.

The second paper investigates whether markup variations allow the economy to produce the empirically supported comovement among the main macroeconomic aggregates in response to news about future fundamentals. Given the recent research suggesting that news shocks are a major source of business cycle fluctuations, it is unfortunate that standard models are unable to reproduce the positive comovement between consumption and investment in absence of changes to the economy's current fundamentals. The current paper addresses this shortcoming. It shows that the addition of endogenous countercyclical markups and modest investment adjustment costs enable the otherwise standard one-sector real business cycle model to generate such comovement in conjunction with an economic expansion in response to positive news about the future path of total factor productivity. Furthermore, when driven by news shocks, these minimal departures from standard theory allow the simulated model to replicate the regular features of U.S. economic fluctuations.

The final paper considers endogenous markups and product variety effects in news-driven business cycles. First, it demonstrates that the standard one-sector real business cycle model augmented by taste for variety and adjustment costs to investment can display expectations-driven fluctuations in response to information about future total factor productivity. Second, under procyclical markups, the required variety effects are substantially smaller than the productive externalities that would otherwise be necessary for generating positive macroeconomic comovement. Finally, the key parameters are estimated via the Simulated Method of Moments and the model performs well at matching the aggregate cyclical regularities of the U.S. economy.