Economics Letters 156 (2017) 129–132

Contents lists available at ScienceDirect

Economics Letters

journal homepage: www.elsevier.com/locate/ecolet

Decoupling nominal and real rigidities
A reexamination of the canonical model of price setting under menu costs

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ARTICLE INFO

Article history:
Received 29 November 2016
Accepted 18 April 2017
Available online 28 April 2017

JEL classification:
E31
C70
D82

Keywords:
Global games
Menu costs
Sticky prices

ABSTRACT

We revisit Ball and Romer's (1990) canonical model of price setting with menu costs that exhibits multiple equilibria. We show that changes to firms' markups move nominal and real rigidities in opposite directions. Using game-theoretic tools to derive a unique equilibrium, we find that accounting for agents' endogenous adjustment of price expectations further weakens the link between real and nominal rigidities.

A cornerstone of the New Keynesian literature is that real rigidities (reluctance to adjust relative prices)[3] move in concert with nominal rigidities (inability to adjust nominal prices). Blanchard and Kiyotaki's (1987) and Ball and Romer's (1990, 1991) (henceforth BR)[4] models of monopolistic competition originated this link. The models posit that firms are more inclined to incur menu costs and adjust their prices in response to shocks if others do too. This strategic complementarity in firms' pricing decisions is increasing in the real rigidities facing firms, delivering a positive relationship between real and nominal rigidities. Yet price setters' beliefs regarding others' price changes are indeterminate, giving rise to multiple self-fulfilling equilibria.

We address this shortcoming by applying the Laplacian belief heuristic from the global games literature that preserves strategic uncertainty.[5] This pins down a unique equilibrium and erodes the close link between nominal and real rigidities.

If real rigidities increase, price setters react less to monetary shocks and nominal rigidities increase. But this is only partial equilibrium from BR's arbitrarily fixed beliefs about other price setters' responses, i.e., the aggregate price level. Accounting for an adjustment of beliefs, we find a countervailing effect: higher real rigidities imply that agents tolerate others' price adjustment less, making them more inclined to adjust their own prices. Which effect dominates depends on the parameterization and equilibrium selection.

1. Multiple price setting equilibria

Consider a representative price setter à la Blanchard and Kiyotaki (1987) and BR with utility

$$U_i = W\left(M/P, P_i/P\right) - zD_i \tag{1}$$

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1 We are grateful to Kartik Anand, Christian Basteck, Tijmen Daniëls and Frank Heinemann for useful discussions. A. Meyer-Gohde is thankful for the research assistance provided by Tobias König and the DFG's SFB 649. Any and all errors are entirely our own.

3 See Gopinath and Itskhoki (2011) for an overview of real rigidities.

4 Golosov and Lucas (2007), Nakamura and Steinsson (2009) and Klenow and Willis (2016) provide recent examples of menu cost models.

5 König and Meyer-Gohde (2014) rationalize this rigorously as the noiseless limit with a standard global game information structure.

http://dx.doi.org/10.1016/j.econlet.2017.04.019
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where $M/P = Y$ equates real balances and aggregate expenditures from the quantity theory, $\frac{P_i}{P}$ is the agent's relative price and z is the menu cost—a small resource cost of changing a nominal price; D_i equals one if i changes its price and zero otherwise.

In a stable symmetric steady state:

$$\overline{P_i} = \overline{P} = \overline{M} \quad \text{and} \quad W_2(1,1) = 0, \qquad W_{22}(1,1) < 0, \quad W_{12}(1,1) > 0.$$

Outside the steady state, i's optimal price can be log-approximated from $W_2\,(M/P, P_i/P) = 0$ as

$$p_i^* = \pi m + (1-\pi)p \tag{2}$$

where m, p, and p_i are log deviations from their steady state values. Following BR, price decisions are assumed strategic complements, $\pi \in (0,1)$, and $\pi \equiv W_{21}(1,1)/-W_{22}(1,1)$ measures real rigidities: a low π implies high real rigidities and vice versa.

Whenever an agent changes her price, she does so optimally. Deciding *whether* to change her price, she compares the payoff difference between setting the optimal price, $p_i = p_i^*$, and maintaining her old price, $p_i = 0$, to the menu costs z. This difference to second order in log steady-state deviations is[6]

$$PC(m,p,p_i^*) \equiv W\left(e^{m-p}, e^{p_i^*-p}\right) - W\left(e^{m-p}, e^{-p}\right) \approx -\frac{1}{2}W_{22}(1,1)\left(p_i^*\right)^2. \tag{3}$$

Suppose that agent i believes that no other agents adjust prices, $p = 0$. She will nevertheless adjust if $PC(m, 0, \pi m) > z$. Conversely, if she believes that all others adjust, $p = m$, she will nonetheless not adjust if $PC(m, m, 0) < z$. These two conditions partition the range of monetary deviations m for which adjustment or not are Nash equilibrium.

Proposition 1 (*Ball and Romer: Multiple Equilibria*). *There exist thresholds*

$$x^* \equiv \frac{1}{\pi}\sqrt{\frac{2z}{-W_{22}(1,1)}} \quad \textit{and} \quad x^{**} \equiv \pi x^*. \tag{4}$$

For $x^* < |m|$, price adjustment is dominant. For $|m| < x^{**}$, nonadjustment is dominant. For intermediate shocks, $|m| \in (x^{**}, x^*)$ both adjustment and rigidity can be sustained as pure strategy Nash equilibria.

Proof. See Ball and Romer (1990). □

Multiple equilibria for intermediate shocks are sustained by self-fulfilling beliefs about other price setters' behavior. This is a consequence of agents' common knowledge perfectly coordinating their beliefs and price setting behavior in equilibrium. (Morris and Shin, 2001) To overcome equilibrium indeterminacy, the price-setting literature largely selects equilibria arbitrarily.[7]

2. Unique price setting equilibrium

Multiplicity prohibits the derivation of general comparative statics. Global games address this by abandoning common knowledge and endowing agents with noisy private signals about the economy's fundamentals. Even when the signal noise (fundamental uncertainty) vanishes, agents still face uncertainty about the behavior of others (strategic uncertainty). Strategic uncertainty helps pin down a unique threshold equilibrium which can often be derived by hypothesizing that agents optimally respond to a *Laplacian belief* about others' behavior. As they are unsure about the position of their signal in the distribution, they apply Laplace's principle of insufficient reason and believe that the share of others who take each action is uniformly distributed. (Morris and Shin, 2003)

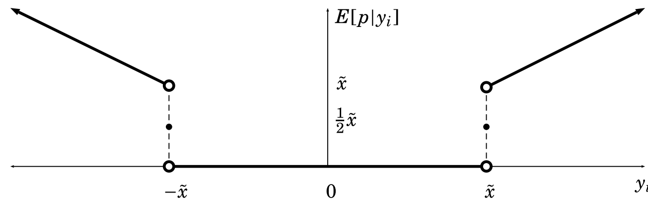

Fig. 1. Threshold equilibrium beliefs.

The possibility of both positive and negative shocks in our model induces a partition of the state space that deviates from standard global games. Nevertheless, we can apply similar techniques. Suppose that agents adjust their price if and only if $|m| > \tilde{x}$ and that the agent indifferent to adjusting holds a Laplacian belief—she expects only half of agents to adjust: $p = p_i^*/2$. Combining this belief with Eq. (2) yields

$$p_i^* = \frac{\pi m}{\frac{1}{2}(1+\pi)}.$$

The agent is indifferent at $m = \tilde{x}$

$$PC\left(\tilde{x}, \frac{\pi\tilde{x}}{(1+\pi)}, \frac{\pi\tilde{x}}{\frac{1}{2}(1+\pi)}\right) = z \quad \Rightarrow \quad \tilde{x} = \frac{x^* + x^{**}}{2}.$$

Proposition 2 (*Unique Threshold Equilibrium*). *There exists a unique threshold equilibrium with threshold $\tilde{x} = (x^* + x^{**})/2$. Agents adjust if and only if $\tilde{x} < |m|$.*

This follows more rigorously from a standard global game information structure where m follows a diffuse prior and agents observe signals $m_i = m + \sigma\epsilon_i$, $\epsilon_i \sim \mathcal{N}(0,1)$. Assuming agents use symmetric threshold strategies around $|k|$, for $\sigma \to 0$, the unique threshold becomes $k^* = \tilde{x}$.[8] Away from the threshold, agents expect $p \in \{0, m\}$ and adjust to $p_i^* = m$ or maintain $p_i^* = 0$. At $|m| = \tilde{x}$, the belief distribution collapses to a point mass divided evenly between rigidity and adjustment (Fig. 1), confirming the Laplacian belief above.

3. Decoupling real and nominal rigidities

BR's x^* and our $\tilde{x}$ measure nominal rigidities; e.g., a larger threshold implies a larger range of monetary shocks for which nominal prices remain unchanged. From Propositions 1 and 2, $\tilde{x} < x^*$ so that our measure predicts less nominal rigidity than BR's. Indeed, BR themselves point out that they examine the region with the largest possible nominal rigidities. BR (p. 184) further claim that "[t]he degree of nominal rigidity [...] is increasing in the degree of real rigidities". This conclusion, however, is not even fully correct in their model under x^*. Furthermore, once we endogenize

6 See König and Meyer-Gohde (2014) for a detailed derivation.

7 BR analyze only the x^* threshold, as it is associated with the most nominal rigidities. Others restrict parameters so equilibrium multiplicity does not arise; e.g., John and Wolman (2008) restrict agents' discount factors close to unity; similarly, Caballero and Engel (1993) and Nakamura and Steinsson (2009) assume idiosyncratic shocks of sufficient magnitude. Dotsey and King (2005) point out that multiplicity is intriguingly complex due to the discontinuity of the equilibrium correspondence.

8 For the full derivation, see König and Meyer-Gohde (2014).