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Monetary shocks with variable effort

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7 Abstract

8 In a model with rigid nominal wages, full information and competitive product markets, I
9 show that when an effort augmented production function is incorporated into an analysis of
10 supply and demand shocks, the outcomes are in line with traditional Keynesian analysis for a
11 wide range of parameter values. Monetary shocks can increase output and employment.
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15 1. Introduction

16 Traditional Keynesian analysis assumes nominal wage rigidity in the face of nom-
17 inal shocks. A problem with such analysis is that workers are assumed to be willing
18 to supply more labor even though real wages have fallen. Lucas (1972) introduces
19 imperfect information on the source of price changes to rationalize unanticipated
20 monetary shocks having real effects. Models such as Akerlof and Yellen (1985) or
21 Ball and Romer (1990) assume nominal rigidity of prices in models with imperfectly
22 competitive labor and product markets, showing that small adjustment costs can
23 rationalize nominal rigidities that can generate employment and output effects con-

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24 sistent with the Keynesian model. The model developed below has similar results but
25 with a perfectly competitive product market and no uncertainty.

26 Waller (1989) incorporates effort (as a function of the wage) into the production
27 function. In this model firms are price takers, firms and workers are fully informed
28 about all prices, and efficiency units of labor are the product of effort and employ-
29 ment as in Solow (1979). Waller shows that monetary shocks leave output un-
30 changed in the presence of nominal wage rigidity. This result arises because
31 workers' labor supply is determined by a combination of wages and effort. While
32 a rise in the price level reduces the real wage, which induces the firm to increase
33 employment, the reduction in the real wage also induces a reduction in effort leaving
34 output unchanged. Waller also shows that, unlike models without effort, indexing
35 wages will not have a destabilizing effect on output in the face of supply shocks.
36 In this paper I generalize Waller's (1989) model, replacing the Solow (1979)
37 Cobb–Douglas model of efficiency units with a constant elasticity of substitution
38 function. Accordingly, the output effect of monetary shocks will only be zero if
39 the elasticity of substitution is unity (the Cobb–Douglas case). For a wide range
40 of elasticities of substitution the results support the Traditional Keynesian story, that
41 is, a monetary shock with nominal wage rigidity causes higher output and employ-
42 ment in the short run and wage indexation increases the variability of output in re-
43 sponse to supply side shocks.

44 2. Background to the model

45 This section discusses some of the basic assumptions of the model and some
46 empirical regularities. Specifically I discuss the assumption that efficiency units of la-
47 bor should not be restricted to the product of effort and employment, the assumption
48 of nominal wage rigidity, and the observed regularity that productivity is pro-cyclical
49 in contrast with the predictions of the model.

50 Akerlof and Yellen (1986, pp. 14–16) question the appropriateness of the assump-
51 tion that efficiency units of labor are the product of employment and effort.^{1,2} Ra-
52 mana and Rowthorn (1991) formalise Akerlof and Yellen's argument in a general
53 model where effort and hours enter as separate inputs. It is argued, for example, that
54 with technologies where workers can do a large amount of damage by reducing effort
55 (assembly lines or airline pilots are examples given by Ramana and Rowthorn) it will
56 be more difficult to substitute between effort and employment. One can also think of
57 many possibly menial or low skill tasks where the ease of substitution between effort
58 and hours would possibly be greater than implied by the Cobb–Douglas assumption

¹ Akerlof and Yellen (1986) argue that the elasticity of effort with respect to the wage will be less than unity in contrast with Solow's (1979) model. They argue that workers exerting less effort will damage the firm via the effect on the return to other inputs in a model where labour is not the only input. Faria (2000) develops an efficiency wage model where the Solow condition cannot hold in equilibrium.

² Holmes and Hutton (2000) get a positive output effect by introducing Monopsony power into the efficiency wage model.

59 (workers picking fruit for example). An additional feature of the Solow model is that
 60 effort and hours work have the same weight in producing efficiency units of labor. If
 61 effort has less weight than employment in the production of efficiency units of labor,
 62 then monetary shocks will increase output and employment even in the Cobb–Doug-
 63 las case. Finally, with regard to the appropriateness of the Solow model, it is worth
 64 noting that introducing labor taxes into the wage effort model is enough to ensure
 65 that the Solow condition will not hold.

66 Another feature of the model developed below is the assumption of nominal wage
 67 rigidity. In Romer (1996) Section 6.1.1 it is illustrated in a model with nominal price
 68 rigidity, imperfectly competitive firms, and a competitive labor market that the cost
 69 of adjusting prices needed to justify nominal rigidity would be unreasonably large
 70 unless the labour supply elasticity is also unreasonably large. Romer (1996) as well
 71 as Akerlof and Yellen (1985) show that small costs in adjusting prices can rationalize
 72 nominal price rigidity and generate relatively large changes in output and employ-
 73 ment. In Akerlof and Yellen's model product markets are imperfectly competitive
 74 while the labor market is characterised by Solow's (1979) efficiency wage model.
 75 Walsh (2002) shows that the decrease in profits from failing to adjust nominal wages
 76 are of the first order and argues that small menu costs can justify nominal wage rigid-
 77 ity in the model developed below. The possibility that wage indexation can increase
 78 output variability also gives credence to the nominal wage rigidity assumption. A
 79 standard argument is that indexing wages to the inflation rate is a cheap mechanism
 80 for adjusting wages, making the existence of menu costs implausible (see Romer
 81 (1996, p. 280) for example). The results below show that such a strategy may in fact
 82 be costly because adjusting the nominal wage in line with price changes resulting
 83 from supply shocks would be inefficient.

84 At first glance the model is at variance with the empirical regularity that labour
 85 productivity is pro-cyclical. See Bernanke and Parkinson (1991) for a discussion
 86 and some evidence of different models that can explain pro-cyclical productivity.
 87 In Walsh (2002) I show that when one focuses on particular groups of workers where
 88 one surmises that alternative reasons for pro-cyclical productivity such as labor
 89 hoarding would not be important, the pro-cyclical productivity pattern following
 90 an unexpected monetary shock is less clear.

91 3. The model

92 In this Section I outline the model and conduct some comparative static analysis.
 93 It is shown for a wide range of elasticity's of substitution that monetary shocks have
 94 positive output and employment effects and that indexing wages raises the output
 95 variability associated with supply side shocks.

96 Competitive firms have the following production function:

$$y = \beta f \left\{ \left[A e \left(\frac{W}{P} \right)^\alpha + B n^\alpha \right]^{\frac{1}{\alpha}} \right\}, \quad (1)$$

99 where y is output, W the nominal wage, P the price level, e effort, n employment and
 100 there is a technology parameter $\beta = 1 + \mu$ where $\mu \sim G(0, \sigma_\mu^2)$. $G(\cdot)$ is a distribution
 101 function that allows for either positive or negative supply side shocks. There is no
 102 uncertainty so all agents know the realization of the shock when we solve for equi-
 103 librium. Efficiency units of labor $x(e, n)$ are generated with a constant elasticity of
 104 substitution function:

$$x = \left[Ae \left(\frac{W}{P} \right)^\alpha + Bn^\alpha \right]^{\frac{1}{\alpha}}. \quad (2)$$

107 The elasticity of substitution between effort and employment in producing efficiency
 108 units is

$$\sigma = \frac{1}{1 - \alpha}. \quad (3)$$

111 The relative importance of effort and hours work in producing efficiency units of la-
 112 bor is determined by A and B . The model is identical to Waller (1989), except that
 113 Waller assumed that $\alpha = 0$ and $A = B$. That is, Waller used Solow's model where
 114 $x = (en)$. As α increases towards unity it gets easier to substitute between effort
 115 and workers, while larger negative values imply it is more difficult to substitute.
 116 The profit function divided by price is

$$\pi = \beta f \left\{ \left[Ae \left(\frac{W}{P} \right)^\alpha + Bn^\alpha \right]^{\frac{1}{\alpha}} \right\} - \frac{W}{P} n. \quad (4)$$

119 Profit maximization yields the following first order conditions for W and n , respec-
 120 tively (where for notational convenience $[\cdot] = [Ae(\frac{W}{P})^\alpha + Bn^\alpha]$):

$$\beta f_W(x) = A \frac{\beta f[x]_x e^{\alpha-1} e_w \left(\frac{W}{P} \right) [\cdot]^{\frac{1-\alpha}{\alpha}}}{P} = \frac{n}{P}, \quad (5)$$

$$\beta f_n(x) = B \beta f[x]_x n^{\alpha-1} [\cdot]^{\frac{1-\alpha}{\alpha}} = \frac{W}{P}. \quad (6)$$

125 The first order conditions imply:

$$e_w \frac{W}{Pe} = \left(\frac{n}{e} \right)^\alpha \frac{B}{A}. \quad (7)$$

128 The demand and supply for money are given, respectively, as

$$M^D = kPy, \quad (8)$$

$$M^S = \delta \bar{M}, \quad (9)$$

133 where $\delta = 1 + \varphi$ and $\varphi \sim H(0, \sigma_\varphi^2)$. The distribution function $H(\cdot)$ allows for random
 134 shocks to the money stock. As with the supply shock, the realization of the money
 135 supply is known to all agents when we solve for equilibrium. We do not make any
 136 assumptions on the shape of these distributions. In equilibrium one finds that:

$$kPy = \delta \bar{M}. \quad (10)$$

139 Totally differentiating Eq. (1) one gets:

$$dy - \beta f_n dn - \beta f_w dW - \beta f_p dp - f d\beta = 0. \quad (11)$$

142 Using Eqs. (5) and (6) this can be rewritten as

$$dy - \frac{W}{P} dn - \frac{n}{P} dW + \frac{nW}{P^2} dp - f d\beta = 0. \quad (12)$$

145 Totally differentiating Eqs. (6) and (10) one gets the following equations:

$$\beta f_{nn} dn + \left(\beta f_{nw} - \frac{1}{P} \right) dW + \left(\beta f_{np} + \frac{W}{P^2} \right) dp + f_n d\beta = 0, \quad (13)$$

$$\bar{M} d\delta = kP dy + ky dP. \quad (14)$$

150 The money stock is assumed to be constant apart from the random shock.

151 Eqs. (12)–(14) can be used to analyze the impact of various shocks on equilibrium.

152 The first comparative static exercise is to analyze the output effect of a monetary
153 shock when nominal wages are rigid. The details of the analysis are in Appendix A.1
154 where it is shown that:

$$\frac{dy}{d\delta} = \frac{\bar{M}}{Pk} \left(\frac{\alpha \frac{W}{P^2}}{\alpha \frac{W}{P^2} - f_{nn} \frac{y}{W}} \right). \quad (15)$$

157 It is only if $\alpha = 0$ (the Cobb–Douglas case) that the output effect of a monetary shock
158 is zero. If the elasticity of substitution between effort and employment (3) is greater
159 than unity ($0 < \alpha < 1$), then (15) is unambiguously positive. For the case where $\alpha < 0$.
160 I show in the appendix that the sign of the output effect is more likely to be positive if
161 the elasticity of substitution is small, if the elasticity of effort with respect to the real
162 wage is large, the smaller are fixed costs and the less curvature there is in the produc-
163 tion function. It is easy to construct examples where the firm's problem is well be-
164 haved and the output effect can be positive or negative for different values of α .
165 Overall though, for a wide range of parameter values the output effect is positive.

166 The next comparative static exercise is to examine the employment effects of a
167 monetary shock. In this case once again $dW = 0$ and $\beta = 1$. Solving Eqs. (11) and
168 (12) and using Eq. (A.2) from the appendix one gets:

$$\frac{dn}{d\delta} = \frac{\bar{M}}{Pkw} \left(\frac{\alpha \frac{W}{P^2} - f_{nn} \frac{n}{P}}{\alpha \frac{W}{P^2} - f_{nn} \frac{y}{W}} \right). \quad (16)$$

171 A sufficient condition for the employment effects to be positive is that the elasticity of
172 substitution between employment and effort is greater than or equal to unity ($\alpha \geq 0$).
173 For negative values of α where it is more difficult to substitute between effort and
174 hours the employment effect will be positive unless the following condition holds:
175 $-f_{nn} \frac{n}{P} < -\alpha \frac{W}{P^2} < -f_{nn} \frac{y}{W}$. The condition for a positive output effect (15) is sufficient
176 for a positive employment effect.

177 Having analyzed the impact of monetary shocks I continue by contrasting the im-
 178 pact of a supply side shock under nominal wage rigidity with the outcome when
 179 wages are indexed. Waller (1989) shows that the output effects are the same. A neg-
 180 ative supply shock with rigid nominal wages increases the price level and lowers the
 181 real wage. Both effort and labor demand fall. On the other hand if wages are indexed,
 182 effort is constant and employment falls by more than in the sticky wages case. Thus
 183 Waller (1989) shows that a full indexation of wages does not increase the variation in
 184 output associated with supply shocks. This result depends on the Solow model as is
 185 shown below.³ Given that in reality it may be difficult to separate the parts of infla-
 186 tion that come from real and monetary factors, the results imply that indexation is
 187 not a simple way of maintaining the optimal real wage.

188 In this case $dW = 0$ as before and also $d\delta = 0$ and $\delta = 1$ as shown in Appendix
 189 A.2.

$$\frac{dy}{d\beta} = \frac{\beta f_{nn} f - f_n \frac{W}{P}}{\beta f_{nn} - \alpha \frac{W^2}{P^2 y}}. \quad (17)$$

192 If $\alpha > 0$ then (17) is unambiguously positive. The possibility of a negative output ef-
 193 fect arises because nominal wages are rigid in the face of falling output prices, lead-
 194 ing to the possibility that real wages will be too high. Firms may find it profitable to
 195 produce less output in a more effort intensive fashion.

196 If wages are fully indexed then $d\delta = 0$ and $\delta = 1$. Because real wages are constant
 197 one finds that:

$$dW = \frac{W}{P} dP. \quad (18)$$

200 Appendix A.2 shows that:

$$\frac{dy}{d\beta} = \frac{\beta f_{nn} f - f_n \frac{W}{P}}{\beta f_{nn}}. \quad (19)$$

203 It can be seen that it is only when $\alpha = 0$ (the Cobb–Douglas case) that the output
 204 effect of a supply shock is the same under nominal wage rigidity and wage indexation
 205 (Eqs. (17) and (19) are the same). If $\alpha > 0$ the supply shock will have a bigger effect
 206 on output with wage indexation as in more traditional models such as Gray (1976).

207 4. Conclusion

208 The addition of effort into the production function provides a means for monetary
 209 shocks to have real effects without appealing to asymmetric information on prices or
 210 wages and where firms are price takers in the output market.

³ Solow (1979) showed that it is only in the Cobb–Douglas case that the real wage will be invariant to the firms output. The implication is that in any non-Cobb–Douglas case a supply shock will change the optimal real wage, so that wage indexation will not adjust to the “optimal” real wage.

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213 ory group and the referees for helpful comments. Any errors are mine.

214 **Appendix A**

215 *A.1. The output effects of a monetary shock*

216 In this case I assume that there is no supply shock and there is a random money
217 shock. This means $\beta = 1$ and $d\beta = 0$. Nominal wages are sticky so $dW = 0$. Solving
218 from Eqs. (11)–(14) gives

$$\frac{dy}{d\delta} = \frac{\bar{M}}{Pk} \left[\frac{f_{nP} + \frac{W}{p^2} + \frac{n}{p} f_{nn}}{f_{nP} + \frac{W}{p^2} + \frac{n}{p} f_{nn} - \frac{y}{W} f_{nn}} \right]. \quad (\text{A.1})$$

221 By substitution using (7) these equations imply:

$$\beta f_{nP} + \beta \frac{n}{p} f_{nn} = (\alpha - 1) \frac{W}{p^2}. \quad (\text{A.2})$$

224 Using this in Eq. (A.1) results in Eq. (15) in the text

225 In the case where $\alpha < 0$ one can see from (15) that there will be a positive output
226 effect if

$$\alpha \frac{W}{p^2} - f_{nn} \frac{y}{W} < 0. \quad (\text{A.3})$$

229 Given Eqs. (1) and (2) one notes the following derivatives:

$$f_n(x[n, w, p]) = f_x(x[n, w, p])x_n(w, n, p), \quad (\text{A.4})$$

$$f_{nn} = f_{xx}x_nx_n + x_{nn}f_x, \quad (\text{A.5})$$

$$f_{np} = f_{xx}x_px_n + x_{np}f_x, \quad (\text{A.6})$$

236 where

$$x_n = Bn^{\alpha-1} \left[Ae \left(\frac{w}{p} \right)^\alpha + Bn^\alpha \right]^{\frac{1-\alpha}{\alpha}}, \quad (\text{A.7})$$

$$x_p = -\frac{Ae^{\alpha-1}e_w w}{p^2} \left[Ae \left(\frac{w}{p} \right)^\alpha + Bn^\alpha \right]^{\frac{1-\alpha}{\alpha}}, \quad (\text{A.8})$$

$$x_{nn} = (\alpha - 1)Bn^{\alpha-2} \left[Ae \left(\frac{w}{p} \right)^\alpha + Bn^\alpha \right]^{\frac{1-\alpha}{\alpha}} + (1 - \alpha)B^2n^{2(\alpha-1)} \left[Ae \left(\frac{w}{p} \right)^\alpha + Bn^\alpha \right]^{\frac{1-2\alpha}{\alpha}} \quad (\text{A.9})$$

243 and

$$x_{np} = -(1 - \alpha)ABn^{\alpha-1}e^{\alpha-1}e_w \frac{w}{p^2} \left[Ae \left(\frac{w}{p} \right)^\alpha + Bn^\alpha \right]^{\frac{1-\alpha}{\alpha}}. \quad (\text{A.10})$$

246 Using (A.5) condition (A.3) is written as

$$\alpha \frac{W}{p^2} - (f_{xx}x_n^2 - x_{nn}f_x) \frac{y}{W} < 0. \quad (\text{A.11})$$

249 Using (A.7) and the first order condition on n note that

$$x_{nn}f_x = \frac{W}{p^2} [\alpha - 1] \frac{py}{wn} \left(\frac{Ae^\alpha}{Ae^\alpha + Bn^\alpha} \right). \quad (\text{A.12})$$

$$f_{xx}x_n^2 \frac{y}{w} = \frac{f_{xx}y}{f_x^2} \frac{W}{p^2}. \quad (\text{A.13})$$

254 Using Eqs. (A.12) and (A.13) in (A.11) one gets:

$$\left[\frac{(z - 1) - \varepsilon_{ew}}{1 + \varepsilon_{ew}} \right] \frac{1}{\sigma} + \left[1 - \frac{\varepsilon_{xx}}{\varepsilon_x} \right] < 0, \quad (\text{A.14})$$

257 where $z = \frac{pw}{wn} \geq 1$ is a parameter exogenous to the firm and determined by fixed entry
 258 costs. The elasticity of effort with respect to the wage is $\varepsilon_{ew} = e_w \frac{w}{pe}$, the elasticity of
 259 output with respect to efficiency units of labor is $\varepsilon_x = f_x \frac{x}{y}$ and the elasticity of the
 260 marginal product of efficiency units of labor with respect to efficiency units is
 261 $\varepsilon_{xx} = f_{xx} \frac{x}{f_x}$.

262 A.2. The output effect of a supply shock

263 From Eq. (14)

$$-Pdy = ydP. \quad (\text{A.15})$$

266 Using this in (13) one gets:

$$dn = \frac{\left(\beta f_{nP} + \frac{W}{p^2} \right) \frac{p}{y}}{\beta f_{nn}} dy - \frac{f_n}{\beta f_{nn}} d\beta. \quad (\text{A.16})$$

269 Using these equations in (11) gives:

$$dy = \frac{\left(\beta f_{nP} + \frac{W}{p^2} \right) \frac{W}{y}}{\beta f_{nn}} dy - \frac{W}{P} \frac{f_n}{\beta f_{nn}} d\beta + \frac{nw}{Py} dy + f d\beta. \quad (\text{A.17})$$

272 This implies that:

$$\frac{dy}{d\beta} = \frac{\beta f_{nn}f - f_n \frac{W}{P}}{\beta f_{nn} - \frac{W}{y} \left(\beta f_{nP} + \frac{W}{p^2} + \frac{n}{P} \beta f_{nn} \right)}. \quad (\text{A.18})$$

275 Using (A.2) in the denominator gives Eq. (17) in the text.

276 For indexed nominal wages using (18) in Eq. (11) one gets:

$$dy = \frac{W}{P} dn + f d\beta. \quad (\text{A.19})$$

279 Also recognizing that $\beta f_{nW} = -\beta f_{nP} \frac{P}{W}$ and using (A.17) in (13) one finds that:

$$dn = -\frac{f_n}{\beta f_{nn}} d\beta. \quad (\text{A.20})$$

282 This gives the employment effect of a supply shock. This is unambiguously positive
 283 with indexed wages, while substituting (A.20) into (A.16) gives (19), the output effect,
 284 which is also positive.

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