OUTPUT EFFECTS OF INFLATION WITH FIXED PRICE- AND QUANTITY-ADJUSTMENT COSTS

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Abstract

With fixed costs of price and quantity adjustment, output effects of inflation depend on the elasticity of the firm's marginal real revenue. If the elasticity always exceeds minus unity, then output decreases with inflation, while if the elasticity is always less than minus unity, then output increases with inflation. In the special case that the elasticity always equals minus unity, then output is independent of inflation. This is the case if demand is derived from a log-quadratic utility function.

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1 Introduction

There is convincing evidence that fixed costs of price adjustment may be large. Thus, Levy et al. (1997) and Zbaracki et al. (2004) find the cost to be 0.7% and 1.22% of a firm's revenue, respectively. In the presence of fixed costs of price adjustment, a monopolistic firm does not adjust its nominal price continuously, with the result that the real price and output generally deviate from their static monopoly level. At low inflation rates, the average output is higher than the static monopoly output if there is positive discounting (Danziger, 1988), and depends on higher order derivatives of the profit and demand functions if there is no discounting (Benabou and Konieczny, 1994).[1]

Most of the literature assume that only price adjustments are costly, while output can be continuously adjusted. However, Bresnahan and Ramey (1994) document that there may be very large fixed costs of adjusting quantities, and many papers show that adjusting labor and capital inputs involves significant fixed costs.[2] Such costs may derive from the loss of organizational capital (Baily et al., 2001 and Jovanovic and Rousseau, 2001), as well as from job protection rules, severance pay, and legal and administrative complications.

In a framework with both price- and quantity-adjustment costs, Andersen (1995) and Andersen and Toulemonde (2004) demonstrate that only intermediate-size shocks – but not large or small shocks – may affect output. For a constant inflation rate, Danziger (2001) shows that a firm's permanent production decreases with inflation at low inflation rates if discounting is positive, and Danziger and Kreiner (2002) that output capacity decreases with inflation if the elasticity of demand is constant and there is no discounting.

The purpose of this paper is to provide a simple general characterization of the output effects of a constant inflation rate if both price and quantity adjustments involve fixed costs. It is assumed that quantity adjustments are at least as costly as price adjustments, which

[1] See also Rotemberg (1983), Kuran (1986), Naish (1986), Benabou (1988), and Konieczny (1990).

[2] For the cost of adjusting labor, see Davis and Haltiwanger (1992), Hamermesh (1989), Caballero et al. (1997), and Abowd and Kramarz (2003). For the cost of adjusting capital, see Doms and Dunne (1998), Cooper et al. (1999), and Nilsen and Schiantarelli (2003).

implies that production is kept constant at a permanent level.[3] The firm keeps its nominal price unchanged in periods of equal length, and adjusts the nominal price so that the initial real price is the same in each period. Thus, the firm's optimal strategy consists of the initial real price, the duration of the periods with unchanged nominal price, and the permanent level of production. It is proved that, in the absence of discounting, the effect of inflation on the permanent production is fully determined by the elasticity of the firm's marginal real revenue: output decreases with inflation if the elasticity is always greater than minus unity, increases with inflation if the elasticity is always less than minus unity, and is unaffected by inflation if the elasticity is always equal to minus unity. The latter occurs if demand is derived from a log-quadratic utility function.

The explanation for this is that the firm can only sell part of the permanent production at the beginning of a period when the real price is high, but all of it at the end of a period when the real price is low. A higher inflation rate is associated with a higher real price, and hence lower sales, at the beginning of a period, as well as with a lower real price at the end of the period, when the firm anyway sells all it produces. The smaller the marginal real revenue at the initial real price, the less pronounced is the negative effect on the real revenue of lower sales at the beginning of the period; accordingly, for a given inflation-induced increase in the real price at the beginning of a period, the smaller is the absolute value of the inflation-induced decrease in the real price at the end of a period, which tends to decrease the permanent production.

Additionally, a higher real price at the beginning of a period and a lower real price at the end of the period imply a smaller average marginal real revenue in the period. Hence, a smaller loss of average marginal real revenue from an increase in the initial real price relative to the loss of average marginal real revenue from a decrease in the terminal real price, also leads to a smaller absolute value of the decrease of the real price at the end of the period for a given increase in the real price at the beginning of a period, which further tends to

[3] See Danziger (2001). Production clearly reacts to shocks and may even vary more than prices over the business cycle. However, the present model does not include shocks, the focus being on a fully anticipated, constant rate of inflation.

decrease the permanent production.

The effect of inflation on output therefore depends on how fast the marginal real revenue decreases with demand. As shown in the paper, if the marginal real revenue is less than inversely proportional to demand, in which case the elasticity of the marginal real revenue always exceeds minus unity, then output decreases with inflation. Conversely, if the marginal real revenue is more than inversely proportional to demand, in which case the elasticity of the marginal real revenue is always less than minus unity, then output increases with inflation. If the marginal real revenue is inversely proportional to demand, so that the elasticity of the marginal real revenue always equals minus unity, then output is invariant to inflation.

Several recent studies have found that the co-movement between output and prices is typically negative in the long run (Kydland and Prescott, 1990; Cooley and Ohanian, 1991; Fiorito and Kollintzas, 1994; Den Haan, 2000; and Den Haan and Summer, 2004). Within the framework of the present model, this indicates that the empirically relevant case is that the elasticity of the marginal real revenue always exceeds minus unity.[4] This is satisfied, among others, by the important class of demand functions exhibiting a constant price elasticity less than minus unity.

2 The Model

Consider a monopolistic firm producing a single perishable. The stationary demand function is $D(z_t)$, where z_t denotes the real price at time t, and $z_t D'(z_t)/D(z_t) < -1$.

The inflation rate is a constant $\mu > 0$. The firm sets its output and nominal price, and adjusting either involves a fixed cost. Quantity adjustments are at least as expensive as price adjustments, so the firm keeps its output constant at a permanent level, while adjusting the

[4] While this paper analyzes the output behavior of a single firm, the empirical findings refer to the aggregate output of all firms. However, with similar assumptions as in Danziger (2001), the partial-equilibrium framework can be embedded in a general-equilibrium model with a continuum of firms producing differentiated goods and facing demand functions that depend on only the real price charged for the firm's good. The aggregate production in the economy will then depend on the inflation rate in the same way as the output of a single firm studied in this paper. See also Chari, Kehoe and McGrattan (2000) who study the output consequences of monetary shocks in a model with staggered price setting.

nominal price at equally spaced intervals. The initial real price is the same in all periods with unchanged nominal price.

Let Y denote the permanent production and $C(Y)$, $C'(Y) > 0$, the real cost of production. The real price at which demand equals production is $z_Y \equiv D^{-1}(Y)$. At higher real prices, the firm sells less than it produces, while at lower real prices, the firm could sell more than it produces. The firm's instantaneous real profit from production at time t is

$$\begin{cases} z_t D(z_t) - C(Y) & \text{if } \ z_t \geq z_Y, \\ z_t Y - C(Y) & \text{if } \ z_t < z_Y. \end{cases}$$

If S is the initial real price in a period with a constant nominal price, then $z_\tau = Se^{-\mu\tau}$ is the real price after τ of the period has elapsed, and $T_Y \equiv (1/\mu)\ln(S/z_Y)$ is the time taken for the real price to decrease z_Y. It is assumed that $0 < T_Y < T$, where T is the duration of the period. If c is the fixed real cost of a price adjustment incurred at the beginning of the period, the average real profit in a period is

$$V \equiv \frac{1}{T}\left[\int_0^{T_Y} Se^{-\mu\tau} D(Se^{-\mu\tau})d\tau + \int_{T_Y}^{T} Se^{-\mu\tau} Y d\tau - c\right] - C(Y).$$

The first integral is the total real revenue when the firm sells less than it produces, and the second integral is the total real revenue when the firm sells everything it produces.

There is no discounting, and the firm chooses S, T, and Y to maximize the average real profit. The first-order conditions are

$$\begin{aligned} \frac{\partial V}{\partial S} &= \frac{1}{T}\left[\int_0^{T_Y} e^{-\mu\tau} D(Se^{-\mu\tau})d\tau + \int_0^{T_Y} Se^{-2\mu\tau} D'(Se^{-\mu\tau})d\tau + \int_{T_Y}^{T} e^{-\mu\tau} Y d\tau\right] = 0, \\ \frac{\partial V}{\partial T} &= \frac{1}{T}\left[sY - C(Y) - V\right] = 0, \\ \frac{\partial V}{\partial Y} &= \frac{1}{T}\int_{T_Y}^{T} Se^{-\mu\tau} d\tau - C'(Y) = 0, \end{aligned}$$

where $s \equiv Se^{-\mu T}$ is the terminal real price.

These can be rewritten as[5]

$$SD(S) - sY = 0, \tag{1}$$

$$sY - C(Y) - V = 0, \tag{2}$$

$$\frac{1}{T}\int_{T_Y}^{T} Se^{-\mu\tau}d\tau - C'(Y) = 0. \tag{3}$$

Condition (1) shows that the initial and terminal real revenues are equal, or equivalently, that the initial and terminal real profits from production are equal. Condition (2) shows that the terminal real profit from production equals the average real profit (which takes the fixed cost of price adjustment into account). Condition (3) shows that the average marginal real revenue equals the marginal real cost. It is assumed that conditions (1)-(3) yield a unique maximum and that the average real profit is positive.

3 Inflation and Permanent Production

To determine how the permanent production varies with the inflation rate, conditions (1)-(3) are totally differentiated with respect to μ, which yields

$$\frac{dY}{d\mu} = \frac{[\phi D(S) - C'(Y)Y]cS}{\{\phi s\left[Y/D'(z_Y) + s - 2C'(Y) + YC''(Y)\mu T\right] + SC'(Y)^2)\}Y\mu T},$$

where

$$\phi \equiv \frac{D(S)}{D'(S)} + S$$

[5] Partially integrating $\int_0^{T_Y} Se^{-2\mu\tau}D'(Se^{-\mu\tau})d\tau$ yields

$$\int_0^{T_Y} Se^{-2\mu\tau}D'(Se^{-\mu\tau})d\tau = -\int_0^{T_Y} e^{-\mu\tau}D(Se^{-\mu\tau})d\tau + \frac{1}{\mu}\left[D(S) - e^{-\mu T_Y}D(z_Y)\right].$$

Hence,

$$\begin{aligned}\frac{\partial V}{\partial S} &= \frac{1}{T}\left\{\frac{1}{\mu}\left[D(S) - e^{-\mu T_Y}D(z_Y)\right] + \int_{T_Y}^{T} e^{-\mu\tau}Yd\tau\right\} \\ &= \frac{1}{\mu T}\left[D(S) - e^{-\mu T}Y\right] \\ &= \frac{1}{\mu TS}[SD(S) - sY].\end{aligned}$$

is the marginal real revenue at the initial real price.

Since the denominator of $dY/d\mu$ is positive from the second-order condition, $dY/d\mu$ has the same sign as

$$\phi D(S) - C'(Y)Y. \tag{4}$$

To understand this result, note that as the inflation rate increases, the initial real price increases and the terminal real price decreases. The firm sells less than it produces when real prices are high, but all it produces when real prices are low, so a higher S reduces output, while a lower s increases output. Hence, the overall effect of inflation on the permanent production depends on whether the output response of the higher S or the lower s dominates.

The smaller the marginal real revenue at the initial real price, the less the real revenue at the beginning of a period with a constant nominal price increases in $D(S)$; the lower is therefore the loss of initial real revenue from an increase in S relative to the loss of terminal real revenue from a decrease in s. Accordingly, the smaller the marginal real revenue at the initial real price, the less s decreases for a given increase in S, which tends to make Y a decreasing function of inflation.

The increase in S and the decrease in s reduce not only the initial and terminal real revenues, however, but also the average marginal revenue in a period. Since a smaller loss of average marginal real revenue from an increase in S relative to the loss from a decrease in s also causes a smaller decrease in s for a given increase in S, this too tends to make Y an decreasing function of inflation.

Specifically, expression (4) shows that Y decreases with inflation if the marginal real revenue decreases sufficiently slowly with demand that $\phi D(S)$ is an increasing function of $D(S)$. Put differently, Y decreases with inflation if the marginal real revenue always changes less than inversely proportional with demand, or equivalently, if the elasticity of the marginal real revenue always exceeds minus unity. Conversely, Y increases with inflation if the marginal real revenue decreases sufficiently fast with demand that $\phi D(S)$ is a decreasing function of $D(S)$; that is, if the marginal real revenue always changes more than inversely proportional with demand, or equivalently, if the elasticity of the real revenue is always

less than minus unity. Finally, Y is constant and equal to the static monopoly output for all inflation rates if the marginal real revenue is inversely proportional to demand, making $\phi D(S)$ constant; this occurs if the elasticity of the real revenue always equals minus unity.

4 An Example

In this example, depending on the value of a constant, the permanent production either decreases with inflation, increases with inflation, or is independent of inflation.

Let the inverse demand function be

$$z_t = \frac{\alpha \ln D(z_t) + \beta}{D(z_t)} + \gamma,$$

where $\alpha > 0$ and $\gamma < C'(0)$, β any real number, and $z_t \leq \alpha e^{\beta/\alpha - 1}$.[6] The marginal real revenue is $\alpha/D(z_t) + \gamma$, and its elasticity $-1/[1 + \gamma D(z_t)/\alpha]$. Thus, the marginal real revenue is inversely proportional to demand if $\gamma = 0$. Furthermore, since the demand curve moves up with γ without changing its slope, the marginal real revenue, and hence also its elasticity, for a given real price increases with γ.

If $\gamma > 0$, the elasticity of the marginal real revenue always exceeds minus unity: the permanent production decreases with inflation and is always less than the static monopoly output.[7] If $\gamma < 0$, the opposite is the case. If $\gamma = 0$, in which case the inverse demand function reflects a log-quadratic utility function, the elasticity of the marginal real revenue is always minus unity: the permanent production is independent of inflation and always equals the static monopoly output.

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[6] A quasilinear utility function of good y and numeraire good m underlying this inverse demand function is

$$\tfrac{1}{2}\alpha(\ln y)^2 + \beta \ln y + \gamma y + m,$$

which is log-quadratic in y if $\gamma = 0$. The utility is increasing and concave in y for $(\alpha \ln y + \beta)/y + \gamma > 0$ and $y \geq e^{1-\beta/\alpha}$.

[7] As mentioned in the introduction, the condition that the elasticity of the marginal real revenue always exceeds minus unity is also satisfied by all demand functions that have a constant price elasticity less than minus unity.

5 Conclusion

This paper examines how the permanent production varies with inflation when there are fixed price- and quantity-adjustment costs, showing that it is determined by the elasticity of the marginal real revenue. If the elasticity always exceeds minus unity, then output decreases with inflation, whereas if the elasticity is always less than minus unity, then output increases with inflation. In the special case that the elasticity always equals minus unity, then output is independent of inflation. This is the case if demand is derived from a log-quadratic utility function.

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