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Monetary policy games, inflationary bias, and openness

Gikas A. Hardouvelis*

Rutgers University, New Brunswick, NJ 08903, USA

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When a country's central bank has higher output objectives than those of wage-setters, the noncooperative Nash equilibrium contains an inflationary bias, which is higher, the flatter the economy's aggregate supply curve. An economy's openness from the input side is an exogenous observable characteristic that provides a direct way of testing the theory. When the imported intermediate goods displace capital (labor) in production, a higher degree of openness flattens (steepens) the economy's aggregate supply curve and increases (decreases) the inflationary bias.

1. Introduction

The paper analyzes the effects of an economy's degree of openness on the size of the central bank's inflationary bias. Kydland and Prescott (1977), Barro and Gordon (1983), Canzoneri (1985), Rogoff (1985), and others have shown that if the central bank has higher output objectives than those of wage-setters, the noncooperative (Nash) solution of the resulting game contains an extra inflation component which is not present in the cooperative (ideal) solution.[1]

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[1]However, the cooperative solution is time-inconsistent [see Kydland and Prescott (1977) or Calvo (1978)]. Most of the subsequent academic work has examined methods that can enforce the Pareto superior cooperative solution through, say, reputation or legislation.

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Three key parameters determine a central bank's temptation to inflate: the amount of extra output it desires to achieve, a measure of its dislike for inflation, and the slope of the economy's aggregate supply function (or the slope of the Phillips curve). The first two parameters are exogenous but unobservable. The third parameter is observable but endogenous and thus of special interest. In general, the flatter the economy's aggregate supply curve, the higher the central bank's temptation to inflate because it can achieve its higher output objectives at a lower inflation cost. In the Nash equilibrium the higher temptation to inflate leads to a higher rate of inflation because wage-setters understand the central bank's objective.

Openness is an exogenous observable characteristic of an economy that may affect the slope of the aggregate supply function and thus the size of the central bank's inflationary bias. The paper examines openness from the input side, as measured by the importance of imported intermediate goods in production. In an economy with no wage indexation, the slope of the aggregate supply curve depends only on the nature of its production function. In such an economy, openness from the input side matters because it affects the relative importance of the flexible factors of production. When imported intermediate goods displace capital in the production function, the flexible factors of production gain importance, thus the aggregate supply curve becomes more elastic and the temptation to inflate increases. But when imported intermediate goods displace labor in the production function, the flexible factors of production lose importance, thus the aggregate supply curve becomes less elastic and the temptation to inflate decreases.

In an economy with partial wage indexation to the price level, the slope of the aggregate supply curve depends both on the parameters of the production function and on the size of the wage indexation parameter. A larger indexation parameter implies a steeper aggregate supply curve and a lower temptation to inflate. In our framework, the choice of the wage indexation parameter is part of the overall optimization problem and will, therefore, depend on exogenous characteristics of the economy such as the degree of openness. We find that a higher degree of openness from the input side decreases the optimal wage indexation and flattens the slope of the aggregate supply curve. However, the effect is weak and is dominated by the direct effect of openness on the nature of the production function.

Section 2 describes the basic model, which has one final good that is internationally traded. The supply side of the model is characterized by a Cobb–Douglas production function, with labor and an imported intermediate good as variable inputs, and by a wage contracting framework as in Gray (1976). The demand side of the model is driven by the monetary sector. Section 3 describes the wage indexation contract and the optimization problem of wage-setters and the central bank. Section 4 derives the optimal wage indexation contract. Section 5 measures the size of the inflationary bias in the noncooperative solution of the model and analyzes the effect of openness on the size of that inflationary bias. Section 6 discusses some empirical implications of the analysis, and section 7 summarizes the principal conclusions.

2. The model

The model assumes risk neutrality and incomplete information. At the beginning of the period workers sign a labor contract and the central bank determines the supply of money. Later, during the period, the output and money markets clear and agents are able to observe market prices but not real quantities. Monetary policy can affect real output in the model by generating a surprise inflation, thus influencing the real wage rate.[2]

The analysis is conducted with the variables expressed in logarithmic form. Typically, a lower case letter, say x, will denote the logarithm of the corresponding level variable X, $x = \ln(X)$. To simplify the algebraic expressions we suppress all constant terms as well as the subscript t that denotes the contemporaneous time period of analysis.

2.1. Supply side

Final output, Y, is produced using labor, L, imported raw materials, N, and capital, $\bar{K}$, with a Cobb–Douglas production function:

$$Y = BL^{\alpha}N^{\beta}\bar{K}^{\rho}e^{u}, \qquad u \sim \mathrm{N}(0, \sigma_u^2), \quad \alpha + \beta + \rho = 1, \tag{1'}$$

where B is a constant and u is an *unobservable* productivity disturbance, which is assumed to be distributed normally with a mean value of zero and a standard deviation of σ_u.[3] Capital, $\bar{K}$, is a fixed factor in the short run. Without any loss of generality we can suppress the constant terms and rewrite the above production function in logarithmic form as follows:

$$y = \alpha l + \beta n + u. \tag{1}$$

Throughout the paper the elasticity (scale) parameter β of the imported

[2] Private information on money demand by the central bank does not affect the results of the model.

[3] Hardouvelis (1987) – in analyzing the effects of openness on optimal wage indexation – and Marston and Turnovsky (1985) utilize a CES production function with imported raw materials and domestic value added as the two inputs. Domestic value added is then a Cobb–Douglas in labor and capital. The present framework is slightly more general because it allows direct substitutability between the different factors of production.

intermediate good is our measure of the economy's openness from the input side.

Expected profit maximization leads to the following demands for labor, l^{d}, and materials, n^{d}:[4]

$$l^{\mathrm{d}}=-\frac{1-\beta}{1-\alpha-\beta}(w-p)-\frac{\beta}{1-\alpha-\beta}(p_n-p)+\frac{1}{1-\alpha-\beta}\mathrm{E}u, \tag{2}$$

$$n^{\mathrm{d}}=-\frac{\alpha}{1-\alpha-\beta}(w-p)-\frac{1-\alpha}{1-\alpha-\beta}(p_n-p)+\frac{1}{1-\alpha-\beta}\mathrm{E}u, \tag{3}$$

where w is the (logarithm of the) wage rate, p is the (logarithm of the) price of final output, and p_n is the (logarithm of the) price of raw materials. Note that since the productivity shock is unobservable, decisions are based on its conditional expectation, Eu. Later we derive this conditional expectation in terms of observable information. Eqs. (2) and (3) show that the demands for inputs are negatively related to their two relative input prices and positively related to the expected productivity shock. Notice also that the size of the responses of l^{d} and n^{d} to the two input prices and the expected productivity shock increases with a higher β (a more open economy) and a higher α.

Next, we assume that domestic producers are international price takers in materials. This implies that they can satisfy their demand n^{d} at the going price p_n, and thus $n=n^{\mathrm{d}}$. We also adopt a wage contracting framework similar to Gray (1976): Due to costs of continuous renegotiations producers and workers have agreed on a wage indexation rule. They have also agreed that producers can hire as much labor as they need at the wage rate which comes out of the wage indexation rule. Thus $l=l^{\mathrm{d}}$. Substituting for n and l in (1), we may express the supply of output, y^{s}, as follows:

$$y^{\mathrm{s}}=-\frac{\alpha}{1-\alpha-\beta}(w-p)-\frac{\beta}{1-\alpha-\beta}(p_n-p)+\frac{\alpha+\beta}{1-\alpha-\beta}\mathrm{E}u+u. \tag{4}$$

[4]The maximization problem is as follows: Maximize $\mathrm{E}\{PY-WL-P_nL-P_kK\}$ with respect to L and N, solve for L^{d} and N^{d}, and then express all variables in logarithmic form.

2.2. Demand side

The domestic final good is traded internationally and, therefore,

$$y^{s} = y. \tag{5}$$

We also assume that the law of one price (purchasing power parity) holds for the country's final good:

$$p = e + p', \tag{6}$$

where e denotes the (logarithm of the) exchange rate and p' the (logarithm of the) price of the same good in the foreign country. We also assume that the law of one price holds for materials, so:

$$p_n = e + p'_n. \tag{7}$$

Since the final good is internationally traded, the demand side of the model is driven by the monetary sector. We postulate the following simplified money demand relation:

$$m^{d} = p + y + v, \qquad v \sim \mathrm{N}(0, \sigma_v^2), \tag{8}$$

where v is an *unobserved* shock to money demand.[5] Assuming equilibrium in the money market, i.e., that $m^d = m^s$, and substituting eqs. (4), (5), (6) and (7) into (8), we get

$$p = m^{s} + \frac{\alpha}{1-\alpha-\beta}(w-p) + \frac{\beta}{1-\alpha-\beta}(p'_n - p') - \frac{\alpha+\beta}{1-\alpha-\beta}\mathrm{E}u - (u+v). \tag{9}$$

As we see later, wage-setters are able to deduce the amount of money, m^s, which the central bank supplies. Since $w-p$ and $p'_n - p'$ are observable and since wage-setters know their own expectations of u, $\mathrm{E}u$, they can deduce from eq. (9) the sum of the unobservable productivity and monetary disturbances, $u+v$. $u+v$ captures all the available information on u and v.[6] Since $\mathrm{E}u$ is a rational forecast, it must, therefore, equal the regression fit when

[5]Eq. (7) could be expanded to include the negative influence of nominal interest rates on money demand. Excluding the nominal interest rate simplifies the algebraic expressions and does not affect the generality of the results.

[6]Assuming complete information during the period, i.e., that shocks u and v are individually observable, does not affect the results of the analysis. The present framework is more general.

regressing u on $u + v$:

$$\mathrm{E}u = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}(u + v) = g(u + v), \qquad g \equiv \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}. \tag{10}$$

3. Objective functions

The source of inflationary bias in the economy is the central bank's divergent objective function from the objective function of the private sector. In this section we describe the two objective functions, which lay the ground work for the model's solution. Our approach is similar to Rogoff (1985) and Canzoneri (1985).

3.1. Wage-setters' objective function

Wage-setters' objective is to attain the frictionless level of employment and output. Friction occurs when unanticipated shocks hit the economy and place workers off their labor supply schedule. This happens because workers are contracted to supply as much labor as firms demand. Labor supply behavior is described by the following equation:

$$l^{\mathrm{s}} = h(w - p), \qquad h \geq 0. \tag{11}$$

In labor market equilibrium $l^{\mathrm{s}} = l^{\mathrm{d}}$, thus by equating eqs. (2) and (11) we derive the labor market clearing real wage rate. We can then substitute the market clearing wage in eq. (4) and using the equality $p_n - p = p'_n - p'$ [see eqs. (6) and (7)], we can derive the optimal level of output, y^*, as

$$y^* = u + \frac{1}{1-\alpha-\beta}\left[\alpha + \beta - \frac{\alpha}{1-\beta+h(1-\alpha-\beta)}\right]\mathrm{E}u - \frac{\beta}{1-\alpha-\beta} \times\left[1 - \frac{\alpha}{1-\beta+h(1-\alpha-\beta)}\right](p'_n - p'). \tag{12}$$

Eq. (12) states that, in the presence of real shocks, the level of output consistent with labor market clearing is different from its original equilibrium level.

Wage setters would like to choose a wage indexation rule that minimizes the following loss function:[7]

$$LW \equiv \mathrm{E}_{-1}(y - y^*)^2. \tag{13}$$

[7]This is equivalent to minimizing $\mathrm{E}(l - l^*)^2$, where $l - l^*$ denotes the deviation of labor demand from its market clearing level. $l - l^* = [(1 - \beta)/\alpha](y - y^*)$.

E_{-1} denotes the wage-setters' expectations at the beginning of the period before the realization of output y, that is, during the time the wage contract is negotiated. To gain intuition on the components of LW, let us use eqs. (4), (5), and (12) to derive $y - y^*$ as follows:

$$y - y^* = -\frac{\alpha}{1-\alpha-\beta}\left[w - p + \frac{\beta(p_n' - p') - \mathrm{E}u}{1-\beta+h(1-\alpha-\beta)}\right]. \tag{14a}$$

Eq. (14a) shows that output would be at its frictionless level if real wages respond to the external relative price $p_n' - p'$ and the perceived size of the productivity shock $\mathrm{E}u$. Notice that $\mathrm{E}u$ denotes the wage-setters' conditional expectation of the unobserved productivity shock u during time t and is not the same as $\mathrm{E}_{-1}u$. $\mathrm{E}u$ is described by eq. (10) and is nonzero because during the period agents have information on $u + v$. $\mathrm{E}_{-1}u$ on the other hand is zero.

Throughout the analysis, we assume that wage-setters have negotiated an indexation rule that takes into account all available independent pieces of information. This is accomplished by the following indexation rule:

$$w = p^e + b_p(p - p^e) + b_n(p_n' - p'), \tag{15a}$$

where $p^e \equiv \mathrm{E}_{-1}p$ denotes workers' expectations of p at the beginning of the period. We use the notation p^e instead of $\mathrm{E}_{-1}p$ for simplicity and also because later we treat p^e as a parameter in the central bank's objective function. b_p and b_n are the parameters which will be chosen in order to minimize the loss function (13). The indexation parameter b_p is the typical wage indexation parameter in most countries. The optimal size of b_p is not unity because, as eq. (14) shows, real wages have to adjust in response to expected real productivity shocks. The term $b_n(p_n' - p')$ reflects the movement in real wages in response to movements in foreign relative prices.[8]

3.2. *The central bank's objective function*

The central bank uses its ability to affect the supply of money in order to minimize the following loss function:

$$LM = \mathrm{E}_{-1}\left[(y - y^* - y_0)^2 + \Phi(p - p_{-1})^2\right]. \tag{16}$$

$y^* + y_0$ is the desired level of output, with $y_0 > 0$. $p - p_{-1}$ denotes the rate of inflation from period $t-1$ to period t. The parameter Φ reflects the central bank's relative weights on its output and inflation objectives. The central bank believes that y^* is too low from a social point of view, perhaps

[8] Any additional terms in the wage indexation rule (15a) are redundant.

because taxes and subsidies (unemployment policy) distort the labor supply function (11) and lead to an inefficient equilibrium with low output. This is the preferred view of Barro and Gordon (1983).

At the beginning of the period, the central bank chooses the amount of money, m^s, that will minimize LM. The central bank's differing objective function implies that it would not necessarily act in accordance with wage-setters' wishes. Wage-setters understand that the central bank would like to increase output beyond y^* by expanding the money supply and, thus, choose a labor contracting rule that would nullify the 'harmful' effects of the central bank's expected behavior.[9]

4. The optimal wage contract

In this section we derive the optimal wage indexation rule. Substituting the wage indexation rule (15) and eq. (10) into the price eq. (9), we get

$$p = \left(\frac{1}{1+\delta}\right)\left\{m^s + \delta p^e + \frac{\alpha b_n + \beta}{1-\alpha-\beta}(p_n' - p') - \left(1 + \frac{\alpha+\beta}{1-\alpha-\beta}g\right)(u+v)\right\}. \tag{17a}$$

Taking the conditional expectation at $t-1$ of p, we can easily see that[10]

$$p^e = m^s, \tag{18}$$

and, hence, eq. (17a) simplifies to

$$p = p^e + \left(\frac{1}{1+\delta}\right)\left\{\frac{\alpha b_n + \beta}{1-\alpha-\beta}(p_n' - p') - \left(1 + \frac{\alpha+\beta}{1-\alpha-\beta}g\right)(u+v)\right\}. \tag{17b}$$

[9]Observe that unlike wage-setters, who index their nominal wages to the price level, p, and the foreign relative price, $p_n' - p'$, the central bank cannot change the money supply during the period. This assumption simplifies the later solution of the game and could be justified on the grounds of a cash-in-advance constraint or, alternatively, on the presumption that, unlike wage-setters, the central bank observes prices with a lag. Later, we discuss how a money supply policy rule similar to the indexation rule would affect our results.

[10]Throughout the analysis we assume that $E_{-1}(p_n' - p') = 0$ and, hence, $p_n' - p'$ represents an unanticipated change in foreign relative prices. The assumption is similar to suppressing all constant terms. It simplifies the calculations and does not affect the generality of the results.

Next, substituting (17b) into the wage indexation rule (15a), and then substituting into eq. (14a), we derive the deviation of output, y, from its equilibrium level, y^*, as follows:

$$y - y^* = \left\{ \frac{\alpha}{1-\alpha-\beta} \frac{1}{1-\beta-h(1-\alpha-\beta)} g - \frac{\delta}{1+\delta}\left(1 + \frac{\alpha+\beta}{1-\alpha-\beta} g\right)\right\}(u+v)$$
$$+ \left\{ \frac{\delta}{1+\delta} \frac{\alpha b_n + \beta}{1-\alpha-\beta} - \frac{\alpha}{1-\alpha-\beta} \times \left(b_n + \frac{\beta}{1-\beta+h(1-\alpha-\beta)} \right)\right\}(p_n' - p'). \qquad (14b)$$

Eq. (14b) shows that the deviation of output from its optimal level depends on two groups of variables: the sum of the unobserved productivity and money demand shocks, $u+v$, and the relative price of imported intermediate goods, $p_n' - p'$.

Wage-setters choose the indexation parameters b_p and b_n to minimize LW. In our setup, wage-setters are able to eliminate the loss LW completely. Setting the terms of the first set of braces in eq. (14b) to zero leads to the optimal wage indexation parameter with respect to the aggregate price level, b_p^*, as follows:

$$b_p^* = 1 - \frac{g}{1+h-(1-g)[\beta + h(\alpha+\beta)]}. \qquad (19a)$$

Setting the terms in the second set of braces in eq. (14b) to zero and utilizing eq. (19a) for the optimal b_p^* leads to the optimal wage indexation parameter with respect to the relative price shock, b_n^*, as follows:

$$b_n^* = -\frac{\beta(1-g)}{1+h-(1-g)[\beta + h(\alpha+\beta)]}. \qquad (19b)$$

From eqs. (15a), (19a), and (19b), we can now express the optimal wage indexation rule as follows:

$$w = p^{e} + \left\{1 - \frac{g}{1 + h - (1-g)[\beta + h(\alpha+\beta)]}\right\}(p - p^{e})$$

$$- \frac{\beta(1-g)}{1 + h - (1-g)[\beta + h(\alpha+\beta)]}(p_n' - p'). \qquad (15b)$$

Recall that, if expectations are formed rationally, p^{e} is described by eq. (18) and equals the money supply, m^{s}. Thus the above optimal indexation rule (15b) takes into account the unobserved – but inferred – policy response, m^{s}, of the monetary authority.[11]

5. Inflationary bias and openness

In this section we measure the size of the inflationary bias of the Nash solution to the game, and analyze the effect of openness from the input side on the size of that inflationary bias. We define the inflationary bias as the difference between the persistent rates of inflation under the noncooperative and cooperative solutions to the game, when the game is played repeatedly over time.

5.1. *Inflationary bias*

The Nash solution to the game is by now very familiar [see, for example, Canzoneri (1985)]. At the beginning of the period, the central bank chooses the supply of money $m^{s} = m^{s,*}$ to minimize its loss function, LM, taking wage-setters' indexation parameters and price expectations, p^{e}, as given. Wage-setters form their price expectations and choose the indexation parameters b_p and b_n, knowing the central bank's objective function, such that in

[11]Allowing the monetary authority to change the supply of money during the period does not affect the ability of wage-setters to eliminate their welfare loss. For example, let the money supply process be described by the following equation:

$$m^{s} = m_0 + m_p(p - p^{e}) + m_n(p_n' - p').$$

where m_0 describes the supply of money at the beginning of the period, as in the text. m_p and m_n are the counterparts of the wage indexation parameters b_p and b_n. In this case, the optimal wage indexation parameters are as follows:

$$b_p^{*} = 1 - \left[(1-m_p)g\right] / \{1 + h - (1-g)[\beta + h(\alpha+\beta)]\},$$

$$b_n^{*} = \left[m_n g - \beta(1-g)\right] / \{1 + h - (1-g)[\beta + h(\alpha+\beta)]\}.$$

These parameters eliminate the welfare loss function LW and take into account the central bank's attempt to change the money supply during the period in order to minimize LM instead of LW.

equilibrium their expectations are correct on average and their welfare loss, LW, is minimized. The wage indexation contract is then described by eq. (15b) with $m^s = m^{s,*}$.

Minimizing the central bank's loss function with respect to m^s, taking price expectations, p^e, and the wage indexation parameters as given, leads to the optimal money supply process:

$$m^{s,*} = \frac{\Phi(1+\delta)p_{-1} + \delta(1+\delta)y_0 + \delta(\Phi - \delta)p^e}{\delta^2 + \Phi}. \tag{20}$$

In the Nash solution, price expectations are formed rationally and p^e is governed by eq. (18). Thus, from eqs. (18) and (20), the expected output price is

$$p^{e,\mathrm{Nash}} = p_{-1} + \frac{\delta}{\Phi} y_0. \tag{21}$$

Eq. (21) states that in the Nash solution the expected rate of inflation is $(\delta/\Phi)y_0$. The actual rate of inflation can be found from eqs. (17b) and (21) as follows:

$$p^{\mathrm{Nash}} - p_{-1} = \frac{\delta}{\Phi} y_0 + \Delta p^u,$$

$$\Delta p^u \equiv \frac{1}{1+\delta}\left[\frac{\alpha b_n + \beta}{1-\alpha-\beta}(p_n' - p') - \left(1 + \frac{\alpha+\beta}{1-\alpha-\beta} g\right)(u+v)\right]. \tag{22a}$$

The actual rate of inflation equals the expected rate of inflation plus a surprise component that depends on shocks that will occur during the period.

When the game is repeated over time, the expected rate of inflation $(\delta/\Phi)y_0$ persists period after period, and the unexpected rate of inflation averages out to zero. Hence, $(\delta/\Phi)y_0$ forms a core inflation rate over time that represents the inflationary bias of the Nash solution. To see this point, observe that in the cooperative equilibrium the economy will reach the same level of output, y^*, but will have no persistent rate of inflation. The cooperative equilibrium can be attained when the central bank can credibly precommit itself to the money supply process $m^{s,\mathrm{Coop}} = p_{-1}$. Note that $m^{s,\mathrm{Coop}}$ is different from the optimal money supply rule (20). If such an announced money supply policy were credible, then the expected rate of inflation would be zero because from eq. (18), $p^e = p_{-1}$. The realized rate of inflation in the *cooperative* solution, $p^{\mathrm{Coop}} - p_{-1}$, can be derived from eq. (17b) and the condition that p^e equals p_{-1}:

$$p^{\mathrm{Coop}} - p_{-1} = \Delta p^u. \tag{22b}$$

Eqs. (22a) and (22b) show that the cooperative solution is free of the persistent rate of inflation $(\delta/\Phi)y_0$ that is present in the Nash solution. The cooperative solution is Pareto superior because wage-setters' loss function is the same as in the Nash solution, namely zero, and the loss function of the central bank is lower than in the Nash solution:

$$LW^{\mathrm{Coop}} = LW^{\mathrm{Nash}}, \qquad LM^{\mathrm{Coop}} = LM^{\mathrm{Nash}} - \frac{\delta^2}{\Phi} y_0^2. \tag{23}$$

Unfortunately, as previous authors have emphasized, although Pareto superior, the cooperative solution is time-inconsistent: When $p^e = p_{-1}$, the central bank has an incentive to cheat by expanding the money supply to attain a level of output higher than y^*. Eq. (20) shows that, when $p^e = p_{-1}$, the optimal money supply rule is

$$m^{\mathrm{s,Cheat}} = p_{-1} + \frac{\delta(1+\delta)}{\delta^2 + \Phi} y_0.$$

Using the above money supply rule we can derive the *cheating* solution of the model as follows:

$$p^{\mathrm{Cheat}} = p_{-1} + \frac{\delta}{\delta^2 + \Phi} y_0 + \Delta p^u,$$

$$y^{\mathrm{Cheat}} = y^* + \frac{\delta^2}{\delta^2 + \Phi} y_0. \tag{22c}$$

Eq. (22c) shows that the central bank is able to attain a level of output higher than y^* at the cost of generating an extra rate of inflation of $[\delta/(\delta^2 + \Phi)]y_0$. In the cheating solution, the loss function of the central bank is lower than in the cooperative solution, but the loss function of wage-setters is higher than in the cooperative (or the Nash) solution:

$$LW^{\text{Cheat}} = LW^{\text{Coop}} + \left(\frac{\delta^2}{\delta^2 + \Phi}\right)^2 y_0^2,$$

$$LM^{\text{Cheat}} = LM^{\text{Coop}} - \frac{\delta^2}{\delta^2 + \Phi} y_0^2. \tag{24}$$

Wage-setters understand the central bank's temptation to cheat, and since their welfare loss is higher in the cheating solution, they will never form price expectations according to the cooperative solution. The only viable solution is the Nash solution, which carries an inflationary bias.

5.2. *The effects of openness*

The inflationary bias $(\delta/\Phi)y_0$ is higher, the lower the direct cost of generating inflation (Φ), the higher the extra amount of output that the central bank desires to achieve beyond the frictionless level $y^*(y_0)$, and the flatter the economy's aggregate supply curve (the higher the parameter δ). A flatter aggregate supply curve (a higher δ) increases the incentive of the central bank to generate a surprise inflation in order to expand output because the inflation cost of such an expansionary policy is lower. Wage-setters understand this incentive and, hence, a flatter aggregate supply curve is associated with a higher inflationary bias.

Openness can affect the size of the inflationary bias by affecting the parameter δ, the inverse of the economy's aggregate supply curve. Recall that δ equals $(1 - b_p)[\alpha/(1 - \alpha - \beta)]$, where b_p is the wage indexation parameter to the aggregate price level, α is the labor share in production, and β is the share of imported intermediate goods and represents our measure of openness. To examine the effects of openness on δ, we first assume that α, the labor share in production, is constant. This assumption implies that under constant returns to scale an increased share of imported intermediate goods in the production function displaces the share of the fixed factor, capital.

If the wage indexation parameter b_p is constant, a higher degree of openness from the input side (a higher β) implies a higher δ and a larger inflationary bias. Put differently, a higher degree of openness from the input side increases the elasticity of factor demands, which results in a more elastic supply of the final good. However, b_p is not constant. It is determined endogenously in the model. In order to find out the total affect of openness on the inflationary bias of the Nash solution we have to incorporate the effects of β on the optimal level of the wage indexation parameter, b_p^*.

Substituting b_p^* from eq. (20a) into the definition of δ, we get the economy's inverse aggregate supply slope with optimal wage indexation:

$$\delta^* = \frac{\alpha}{1-\alpha-\beta} \frac{g}{1+h-(1-g)[\beta+h(\beta+\alpha)]}. \tag{25}$$

From eq. (25), it is clear that[12]

$$\left.\frac{\partial\delta^*}{\partial\beta}\right|_{\bar{\alpha}} > 0, \quad \left.\frac{\partial\delta^*}{\partial\alpha}\right|_{\bar{\beta}} > 0, \quad \frac{\partial\delta^*}{\partial g} > 0, \quad \frac{\partial\delta^*}{\partial h} < 0. \tag{26}$$

Both β (the degree of openness) and α affect δ^* through two channels. First, a higher β or α increases the elasticity of factor demands, which translates into a more elastic supply of the final good. Second, a higher β or α decreases the optimal indexation parameter b_p^* in order to allow for a required higher real wage rate flexibility [see the bracketed term of eq. (14)], which also increases the elasticity of aggregate supply. Thus a higher degree of openness would result in a larger inflationary bias.[13]

Parameters g and h affect δ^* through b_p^* only. The effects of g and h on b_p^* can be seen from the bracketed term of eq. (14). With real shocks gain more importance relative to nominal shocks, that is when g increases, the optimal wage indexation parameter decreases to allow more flexibility in real wage rate movements as $y-y^*$ becomes more sensitive to Eu. This decreases the slope of aggregate supply (δ^* increases). Similarly, when the elasticity of labor supply, h, increases, the sensitivity of $y-y^*$ to Eu decreases. This implies that a higher h requires a less flexible real wage rate, thus a higher b_p^* and a lower δ^*.

So far we have shown that changes in the degree of openness, β, and changes in the labor input scale parameter, α, have similar effects on δ^*, and

[12] The derivatives of δ^* with respect to g and h are unambiguous. The derivatives of δ^* with respect to α and β are unambiguously positive when δ^* itself is positive, that is, when the aggregate supply curve slopes upward. The following discussion is based on the presumption that aggregate supply curves slope upward.

[13] If the central bank has the ability to change the supply of money during the period, as described in footnote 11, then the optimal δ would be as follows:

$$\delta^* = [\alpha/(1-\alpha-\beta)]\big[(1-m_p)g\big]\big/\{1+h-(1-g)[\beta+h(\beta+\alpha)]\}.$$

The slope of the aggregate supply function would then depend on m_p, namely the sensitivity of the money supply to changes in the price level that are observed during the period. Hence, an increase in the degree of openness would continue to increase δ, only if the derivative of m_p with respect to β is less than k, where k is as follows:

$$k \equiv (1-m_p)\{1/(1-\alpha-\beta) + [(1-g)(1+h)]/[1+h-(1-g)(\beta+h(\alpha+\beta))]\}.$$

Since m_p is chosen optimally, it is a complicated function of the parameters of the model and the realizations of the various shocks. m_p and, hence, k will differ from period to period.

thus on the size of the inflationary bias. But does openness have a more special role? To answer this question let us now assume that intermediate goods displace labor in the production function. Thus assume that ρ, the scale parameter of capital, remains fixed and an increase in β is accompanied by an equal decrease in α. To see the effects of β on b_p^* let us express eq. (20a) for b_p^* in terms of β and ρ by setting $\alpha = 1 - \beta - \rho$:

$$b_p^* = 1 - \frac{g}{1+h-(1-g)[\beta+h(1-\rho)]}, \qquad \left.\frac{\partial b_p^*}{\partial \beta}\right|_{\bar{\rho}} < 0. \tag{27}$$

It can be readily seen from eq. (27) that an increase in β decreases the optimal wage indexation parameter b_p^*. Intuitively, a higher β requires a higher real wage flexibility and, hence, a lower indexation parameter. The reason for the lower real wage flexibility is as follows: Eq. (2) shows that labor demand becomes less sensitive to real wage rate movements when β is higher – the sensitivity equals $(1-\beta)/\rho$ – because labor loses importance in the production of output. The labor demand and supply eqs. (2) and (11) subsequently imply that the real wage rate has to adjust by more to bring the labor market into equilibrium when productivity shocks occur. A lower b_p^* achieves the required higher adjustment in real wages to expected productivity shocks. And a lower b_p^* implies a higher δ^*.

δ^*, however, depends not only on b_p^*, but also on the factor $\alpha/(1-\alpha-\beta) = (1-\beta-\rho)/\rho = -1 + (1-\beta)/\rho$. This factor decreases when ρ increases and leads to a lower δ^*. Hence, when β increases and the higher share of imported intermediate goods displaces labor in production, there are two opposing effects on the slope of the aggregate supply curve. The total effect can be found by differentiating δ^* with respect to β, keeping ρ constant:

$$\delta^* = \frac{(1-\beta-\rho)g}{\rho[1+h-(1-g)(\beta+h(1-\rho))]}, \qquad \left.\frac{\partial \delta^*}{\partial \beta}\right|_{\bar{\rho}} < 0. \tag{28}$$

The net effect is a lower δ^*, that is, a steeper aggregate supply curve and lower inflationary bias.

We conclude that openness from the input side increases the inflationary bias when imported intermediate goods are capital-displacing, but decreases the inflationary bias when imported intermediate goods are labor-displacing.

6. Empirical implications

The Kydland–Prescott or Barro–Gordon theory of the central bank's inflationary bias provides an elegant explanation for the persistent inflation component present in most countries. So far, however, the theory has not been tested empirically. The obvious way to proceed empirically is to associate cross-country trend rates of inflation with cross-country measures of the central bank's temptation to inflate. Recall that three key parameters determine the central bank's temptation to inflate: the amount of extra output it desires to achieve, its dislike for inflation, and the slope of the economy's aggregate supply curve. Unfortunately, the first two parameters are unobservable and the third presents special difficulties because it is an endogenous parameter. The endogeneity of the slope of the aggregate supply curve means that there may be a feedback running from the average rate of inflation to the slope of the short-run aggregate supply curve (or the slope of the short-run Phillips curve), which confounds the effects of the slope itself on the average rate on inflation. For example, an independent economic mechanism may exist through which high average rates of inflation cause the aggregate supply curve to steepen. In such case the two effects would cancel each other out and the investigator would find no connection between the slope of the aggregate supply curve and the economy's average rate of inflation. Conversely, an independent economic mechanism may exist through which high average rates of inflation cause the aggregate supply curve to flatten. In such case the investigator will find an association between average rates of inflation which is consistent with the theory but faces an observation equivalence problem. Thus for a test of the theory one needs to isolate a characteristic of the economy associated with the central bank's temptation to inflate, which is both exogenous and observable.

Recent Keynesian theories of the business cycle based on menu costs predict that periods of high rates of inflation cause the slope of the aggregate supply curve to steepen. Ball, Mankiw, and Romer (1988) argue that during periods of high rates of inflation menu costs become less important and producers change their prices more frequently. This increases the flexibility of output prices and steepens the aggregate supply curve. The authors present cross-country correlations between average rates of inflation with aggregate supply curve slopes but their empirical evidence is mixed. One explanation for the ambiguity of their results is that, according to the Barro–Gordon model, the slope of the aggregate supply curve itself affects both the central bank's temptation to inflate and the equilibrium inflation rate in a direction opposite from the menu cost theory's prediction.

The present analysis suggests a direct way of testing the Kydland–Prescott theory of inflationary bias because it associates an exogenous characteristic of an economy, namely openness from the input side, with the central bank's temptation to inflate. Specifically, our analysis predicts that countries in which imported intermediate goods displace capital in the production process have higher average rates of inflation while countries in which imported intermediate goods displace labor in the production process have lower rates of inflation.

7. Conclusion

The size of the central bank's inflationary bias depends on the slope of the economy's aggregate supply curve. The economy's openness from the input side has both a direct and an indirect effect on the slope of the aggregate supply curve because it affects both the nature of the production function and the flexibility of real wages.

The direct effect depends on whether intermediate goods displace capital or labor in production. When imported intermediate goods displace capital, the flexible factors of production gain importance over the fixed factors of production and, thus, the aggregate supply curve becomes flatter and the inflationary bias increases. When imported intermediate goods displace labor, the flexible factors of production lose importance, the aggregate supply curve becomes steeper, and the inflationary bias decreases.

The indirect effect of openness works through the optimal wage indexation parameter. A higher degree of openness from the input side increases the sensitivity of output to real productivity shocks, and this higher sensitivity requires higher real wage rate flexibility in order for the economy to attain its optimal frictionless level of real output. Higher real wage rate flexibility is accomplished by a lower optimal degree of wage indexation to the general price level, which flattens the aggregate supply curve and increases the inflationary bias.

Overall, when imported intermediate goods displace capital in production, both the direct and indirect channels of influence imply that a higher degree of openness would flatten the aggregate supply curve and increase the inflationary bias of the central bank. When imported intermediate goods displace labor, however, the influence of the direct effect dominates the opposing influence of the indirect effect, and a higher degree of openness leads to a steeper aggregate supply curve and a smaller inflationary bias.

Empirical work on the relevance of the Kydland–Prescott or Barro–Gordon theory of a central bank's inflationary bias in explaining persistent rates of inflation in different countries is absent from the literature. The lack of empirical work may be due to the fact that the theory associates a central bank's inflationary bias with parameters or variables that are either unobservable, such as the amount of extra output above the economy's frictionless level that a central bank wants to achieve or a central bank's dislike for inflation, or endogenous, such as the economy's slope of the aggregate supply curve. This article suggests that a simple and direct way of testing the theory of inflationary bias is to explore the association of openness from the input side, an exogenous observable characteristic of an economy, with realized rates of inflation. For example, our analysis predicts that, *ceteris paribus*, countries in which imported intermediate goods displace capital in the production process have higher average rates of inflation than countries in which imported intermediate goods displace labor in the production process. The full empirical implications of the theory, however, are left for future research.

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