Output Taxation, Productive Investment, and Cost Pass-Through under Cournot Competition

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Abstract

This paper examines the interaction between output taxation, productivity-enhancing investment, and tax pass-through under Cournot competition. A two-stage n-firm model is developed in which firms first choose cost-reducing investment and subsequently compete in quantities under a specific output tax. Investment reduces marginal production costs and involves a convex investment cost, while firms take the strategic effects of investment on subsequent market competition into account. The model derives the symmetric subgame-perfect equilibrium and characterizes the effects of taxation, investment productivity, and market structure on investment, output, effective marginal cost, and equilibrium prices. The results show that an increase in the output tax reduces both equilibrium output and productivity-enhancing investment. The investment response arises indirectly because taxation reduces the equilibrium production scale and therefore lowers the private return to cost reduction. Lower investment subsequently increases firms' effective marginal production costs. The analysis further shows that greater investment productivity increases both investment and output, while greater competition reduces investment per firm but can increase aggregate industry investment under the maintained parameter conditions. Finally, endogenous investment can amplify tax pass-through and generate tax over-shifting when investment productivity is sufficiently high relative to its cost. These results highlight an investment-mediated channel through which output taxation affects productive efficiency and tax incidence under imperfect competition.

Keywords: output taxation; productive investment; cost-reducing investment; Cournot competition; tax pass-through; tax over-shifting; industrial organization

1. Introduction

Taxation can affect firms not only through its direct effect on production costs but also through firms' incentives to invest in productivity-enhancing technologies. This interaction is particularly relevant in imperfectly competitive markets, where firms make strategic production decisions, and the anticipated scale of output affects the private return to cost-reducing investment. The relationship between market structure and investment has long been examined in the industrial-organization literature. Brander and Spencer (1983) show how cost-reducing R&D can have strategic effects in oligopoly, while Fershtman and Judd (1987) emphasize strategic incentives in imperfectly competitive markets. More recent studies examine process R&D and cost-reducing investment under alternative competitive environments. López and Vives

(2019), for example, analyze cost-reducing R&D in an n-firm Cournot setting with ownership structures and R&D spillovers, while Hinloopen and Vandekerckhove (2009) examine process R&D under Cournot andBertrand competition.

A related literature considers government policy jointly with endogenous cost-reducing investment. Kujal and Ruiz (2007) study strategic trade policy when firms undertake cost-reducing R&D before competing in an oligopolistic market. The present paper differs in both the policy instrument and the transmission mechanism. Rather than examining export policy and strategic trade effects, it considers a specific output tax and asks how taxation affects productivity-enhancing investment through equilibrium production. The framework is also related to environmental-economics models of taxation and innovation. Lambertini, Poyago-Theotoky, and Tampieri (2017) analyze environmental taxation and green R&D in an n-firm Cournot model, while Aoyama and Silva (2022) compare emission and output tax incentives for abatement innovation. Unlike these studies, the present analysis focuses on investment that directly reduces ordinary production costs rather than pollution or environmental damage.

The paper also contributes to the literature on tax incidence under imperfect competition. Seade (1985) examines tax shifting in oligopoly, Delipalla and Keen (1992) compare specific and ad valorem taxation under imperfect competition, and Weyl and Fabinger (2013) provide a general framework for pass-through. The present model connects this literature with endogenous productive investment. A specific output tax directly increases the effective cost of production, but it also reduces equilibrium output and thereby lowers the return to cost-reducing investment. Lower investment subsequently raises effective marginal production costs. Thus, taxation can affect prices through both a direct tax channel and an indirect investment-mediated cost channel.

The paper develops a two-stage n-firm Cournot model in which firms first choose productivity-enhancing investment and subsequently compete in quantities. Investment reduces marginal production costs and has a convex cost. The analysis derives the symmetric subgame-perfect equilibrium and examines the effects of output taxation, investment productivity, and market structure on investment, output, effective marginal cost, and tax pass-through.

The model yields four main results. First, higher output taxation reduces equilibrium output. Second, it reduces productivity-enhancing investment even though investment is not directly taxed, because the tax lowers the equilibrium production scale and therefore the return to cost reduction. Third, greater investment productivity increases both investment and output, while greater competition reduces investment per firm but increases aggregate industry investment under the maintained parameter restrictions. Finally, endogenous investment can amplify tax pass-through and generate tax over-shifting when investment is sufficiently productive relative to its cost. The contribution is therefore to identify a specific investment-mediated transmission mechanism through which output taxation affects productive efficiency and tax incidence within a tractable Cournot framework.

2. Literature Review

The relationship between strategic investment and product-market competition is well established in industrial organization. In oligopolistic markets, cost-reducing investment can influence not only a firm's production cost but also its subsequent strategic position. Brander and Spencer (1983) show that R&D investment can serve as a strategic commitment in oligopoly, demonstrating that investment decisions may affect competitive outcomes beyond their direct cost-reduction effect. Subsequent research has examined how process innovation and cost-reducing investment interact with different forms of market competition. Hinloopen and Vandekerckhove (2009), for example, compare process R&D incentives under Cournot and Bertrand competition, while López and Vives (2019) analyze cost-reducing R&D in an n-firm Cournot environment with ownership structures and R&D spillovers. This literature establishes the importance of the production scale and competitive environment for firms' incentives to undertake productivity-enhancing investment.

A closely related strand combines government policy with endogenous cost-reducing investment. Kujal and Ruiz (2007) examine strategic trade policy in a framework where firms undertake cost-reducing R&D before competing in an oligopolistic market. Their analysis is particularly relevant because it demonstrates that government policy and firms' investment decisions can interact strategically. The present paper shares the sequential structure in which investment precedes product-market competition but differs in its policy instrument and economic mechanism. Rather than studying export taxation or subsidization and strategic trade incentives, the present model considers a specific output tax imposed on production. The focus is therefore on how taxation changes the scale of production, how that change affects the return to productive investment, and how the resulting investment response feeds back into firms' marginal costs.

The interaction between taxation and innovation has also received substantial attention in environmental economics. Lambertini, Poyago-Theotoky, and Tampieri (2017) examine green innovation in an n-firm Cournot model with environmental taxation and identify an interaction between competition and firms' incentives to innovate. Aoyama and Silva (2022) compare emission and output tax incentives for abatement innovation in a Cournot oligopoly. These contributions demonstrate that tax policy can affect firms' innovation decisions in addition to its direct regulatory effect. However, their primary concern is environmental innovation and pollution abatement. The present model instead considers productivity-enhancing investment that directly lowers the marginal cost of ordinary production. Consequently, the investment channel in this paper operates through the firm's productive scale rather than through an environmental externality, emissions target, or abatement requirement.

A further literature examines taxation and price pass-through under imperfect competition. Seade (1985) analyzes the shifting of cost increases and taxation in oligopolistic markets, showing that strategic market behavior can affect the extent to which taxes are reflected in prices. Delipalla and Keen (1992) compare specific and ad valorem taxation under imperfect competition and demonstrate that the incidence of alternative tax instruments depends on market structure. More generally, Weyl and Fabinger (2013) develop a framework for analyzing pass-through under imperfect competition and emphasize the role of firms' strategic responses to changes in marginal costs. This literature provides the basis for understanding why the relationship between a statutory per-unit tax and the resulting market price need not be one-to-one and why tax over-shifting can arise under certain market conditions.

The present paper connects these strands through an endogenous productive-investment mechanism. In the standard tax-incidence literature, a tax changes firms' effective marginal costs directly. In the present framework, the tax generates an additional indirect effect. A higher output tax reduces equilibrium production; the lower production scale reduces the private return to cost-reducing investment; and lower investment subsequently raises the firm's effective marginal production cost. The equilibrium price therefore reflects both the direct effect of taxation and the endogenous adjustment of productive efficiency. When investment is sufficiently productive relative to its cost, this additional channel can amplify tax pass-through and generate over-shifting.

The contribution should therefore be understood as a specific extension of existing theoretical mechanisms rather than as a claim that taxation, Cournot competition, or cost-reducing investment has not previously been studied. Existing research has separately established the strategic importance of cost-reducing investment, the interaction between government policy and investment, and the determinants of tax pass-through under imperfect competition. The present paper brings these elements together in a tractable two-stage n-firm Cournot model and isolates the transmission from output taxation to productive investment and subsequently to effective marginal cost and price. In addition, the model distinguishes between firm-level and aggregate investment responses to competition, showing that greater competition can reduce investment per firm while increasing total industry investment. This provides a focused theoretical contribution to the literature on taxation, productive investment, and imperfect competition.

3. Theoretical Model

Consider an industry with $n \geq 2$ identical firms competing in quantities. The model follows the standard Cournot framework, in which firms choose output strategically while taking the quantities of their rivals as given (Cournot, 1838). Firm i chooses output $q_i \geq 0$, while aggregate industry output is

$$Q = \sum_{i=1}^{n} q_i. \quad (1)$$

Market demand is represented by the linear inverse demand function

$$p = A - BQ. \quad (2)$$

where $A>0$ is the demand intercept and $B>0$ measures the sensitivity of price to aggregate output.

Each firm has a constant baseline marginal production cost $c>0$. Before competing in quantities, firms undertake productivity-enhancing investment. Let $I_i \geq 0$ denote the investment of firm i. Investment reduces marginal production cost according to

$$MC_i = c - \alpha I_i, \quad (3)$$

where $\alpha>0$ measures the effectiveness of investment in reducing marginal cost.

Investment has a convex cost

$$C(I_i) = \gamma I_i^2/2, \quad (4)$$

where $\gamma>0$ measures the marginal cost of investment.

The government imposes a specific output tax $\tau \geq 0$ on each unit produced. Firm i's profit is therefore

$$\pi_i = [p - c + \alpha I_i - \tau]q_i - \gamma I_i^2/2. \quad (5)$$

Substituting equation (2) into equation (5) gives

$$\pi_i = [A - BQ - c + \alpha I_i - \tau]q_i - \gamma I_i^2/2. \quad (6)$$

The model focuses on productivity-enhancing investment rather than environmental or pollution-abatement investment. The investment decision is made before product-market competition, so firms take into account the effect of investment on subsequent Cournot outcomes.

3.1 Timing of the Game

The model consists of two stages. In the first stage, firms simultaneously choose their productivity-enhancing investment I_i. In the second stage, after investment decisions have been made, firms simultaneously choose output quantities under Cournot competition. The market price is subsequently determined by aggregate output.

The equilibrium concept is a subgame-perfect Nash equilibrium. The output tax τ is treated as an exogenous policy parameter.

3.2 Cournot Competition

Given the investment profile, firm i chooses q_i to maximize

$$\pi_i = [A - B(q_i + Q_{-i}) - c + \alpha I_i - \tau]q_i - \gamma I_i^2/2, \quad (7)$$

where

$$Q_{-i} = \sum_{j \neq i} q_j$$

is the aggregate output of firm i's rivals.

The first-order condition is

$$\partial \pi_i / \partial q_i = A - c - \tau + \alpha I_i - BQ_{-i} - 2Bq_i = 0. \quad (8)$$

Thus, the quantity best-response function is

$q_i = [A - c - \tau + \alpha I_i - BQ_{-i}]/(2B)$. (9)

Investment increases the firm's optimal output because it reduces effective marginal production cost. At the same time, quantities are strategic substitutes because higher rival output reduces the firm's optimal quantity.

For a given investment profile, solving the system of Cournot first-order conditions gives the second-stage equilibrium quantities. In the symmetric case, where $I_i = I$ and $q_i = q$ for all firms,
$Q = nq$

and

$Q_{-i} = (n - 1)q$.

Substitution into equation (8) yields

$A - c - \tau + \alpha I - B(n + 1)q = 0$.

Hence, conditional on symmetric investment, the second-stage equilibrium output per firm is

$q = [A - c - \tau + \alpha I]/[B(n + 1)]$. (10)

3.3 Productivity-Enhancing Investment

At the first stage, each firm chooses investment while anticipating the strategic consequences for the subsequent Cournot equilibrium.

At the Cournot equilibrium, equation (8) implies

$p - c + \alpha I_i - \tau = Bq_i$.

Consequently, operating profit before investment expenditure can be written as

$\pi_i^O = Bq_i^2$.

Firm i's first-stage problem is therefore

$\max I_i \geq 0\ V_i = B[q_i^*(I_i, I_{-i})]^2 - \gamma I_i^2/2$. (11)

Because investment changes the equilibrium output of both the investing firm and its rivals, the strategic effect of investment must be taken into account.

Differentiating the second-stage Cournot system with respect to I_i gives

$\partial q_i^*/\partial I_i = \alpha n/[B(n + 1)]$. (12)

Therefore, the first-order condition for an interior investment equilibrium is

$2Bq_i^*(\partial q_i^*/\partial I_i) - \gamma I_i = 0$.

Using equation (12),

$[2\alpha n/(n + 1)]q_i^* - \gamma I_i = 0$. (13)

Hence, the optimal investment condition is

$I_i^* = [2\alpha n/(\gamma(n + 1))]q_i^*$. (14)

Equation (14) shows that the incentive to invest depends positively on equilibrium production. Unlike a non-strategic investment problem, however, the return to investment incorporates the strategic effect of investment on the firm's position in the subsequent Cournot market.

The second derivative of the reduced-form investment problem is

$d^2V_i/dI_i^2 = 2\alpha^2n^2/[B(n + 1)^2] - \gamma$. (15)

Thus, the first-stage investment problem is strictly concave when

$2\alpha^2n^2<\gamma B(n + 1)^2$. (16)

This condition is maintained throughout the analysis.

3.4 Symmetric Subgame-Perfect Equilibrium

Under symmetry, equation (14) becomes

$I = [2\alpha n/(\gamma(n + 1))]q$. (17)

Substituting equation (17) into equation (10) gives

$q = [A - c - \tau + 2\alpha^2nq/(\gamma(n + 1))]/[B(n + 1)]$. (18)

Rearranging,

$[B(n + 1) - 2\alpha^2n/(\gamma(n + 1))]q = A - c - \tau$. (19)

Define

$H \equiv \gamma B(n + 1)^2 - 2\alpha^2n$. (20)

Under condition (16), $H>0$. The symmetric equilibrium output per firm is therefore

$q^* = \gamma(n + 1)(A - c - \tau)/H$. (21)

Equilibrium investment per firm is

$I^* = 2\alpha n(A - c - \tau)/H$. (22)

Aggregate industry output is

$Q^* = \gamma n(n + 1)(A - c - \tau)/H$. (23)

Aggregate investment is

$I_t^* = 2\alpha n^2(A - c - \tau)/H$. (24)

where I_t^* denotes total industry investment.

The equilibrium market price is

$p^* = A - BQ^*$. (25)

For an interior equilibrium with positive output and investment, it is sufficient to require

$A - c - \tau>0$ (26)

and

$2\alpha^2n^2<\gamma B(n + 1)^2$. (27)

Proposition 1. Existence and Uniqueness

Under conditions (26) and (27), the model possesses a unique symmetric interior subgame-perfect equilibrium characterized by equations (21)–(25).

Proof. The second-stage quantity problem is strictly concave because
$\partial^2\pi_i/\partial q_i^2 = -2B<0$.

The first-stage reduced-form investment problem is strictly concave under condition (27). Therefore, the first-order conditions characterize the unique symmetric interior equilibrium. Substitution of the investment condition into the second-stage Cournot equilibrium yields equations (21)–(25).

3.5 Taxation and Productive Investment

From equation (22),

$\partial I^*/\partial \tau = -2\alpha n/H < 0$. (28)

Proposition 2. Output Taxation Reduces Productive Investment

An increase in the output tax reduces equilibrium investment by each firm.

Proof. Since $\alpha > 0$, $n > 0$, and $H > 0$, equation (28) is strictly negative.

The mechanism is indirect. A higher output tax reduces equilibrium production and therefore reduces the private return to cost-reducing investment. Thus, productive investment can decline even though investment itself is not directly taxed.

3.6 Taxation and Output

From equation (21),

$\partial q^*/\partial \tau = -\gamma(n + 1)/H < 0$. (29)
Similarly, from equation (23),
$\partial Q^*/\partial \tau = -\gamma n(n + 1)/H < 0$. (30)

Proposition 3. Output Taxation Reduces Production

An increase in the output tax reduces both firm-level and aggregate industry output.

Proof. Equations (29) and (30) are strictly negative because $H > 0$.
The output tax therefore affects production through both its direct effect on firms' effective costs and its indirect effect through lower productivity-enhancing investment.

3.7 Investment Productivity

From equation (22),

$\partial I^*/\partial \alpha = 2n(A - c - \tau)[\gamma B(n + 1)^2 + 2\alpha^2 n]/H^2 > 0$. (31)

Proposition 4. Investment Productivity Increases Investment

An increase in the effectiveness of productivity-enhancing investment increases equilibrium investment.

Proof. Under the maintained interior-equilibrium conditions, all terms in equation (31) are positive. Therefore,
$\partial I^*/\partial \alpha > 0$.
Investment productivity also increases equilibrium output. From equation (21),
$\partial q^*/\partial \alpha = 4\alpha\gamma n(n + 1)(A - c - \tau)/H^2 > 0$. (32)
Thus, more effective productivity-enhancing investment increases both investment and equilibrium output.

3.7 Market Structure and Investment

The number of firms affects investment incentives at both the firm and industry levels. From equation (22),

$I^* = 2\alpha n(A - c - \tau)/[\gamma B(n + 1)^2 - 2\alpha^2 n]$. (33)
Treating n as a continuous measure of market structure, differentiation gives
$\partial I^*/\partial n = -2\alpha\gamma B(A - c - \tau)(n^2 - 1)/H^2 < 0$. (34)

Proposition 5. Competition Reduces Investment per Firm

An increase in the number of firms reduces investment by each individual firm.

Proof. For $n \geq 2$, $A - c - \tau > 0$, and $H > 0$, equation (34) is strictly negative.

The intuition is that additional firms reduce the strategic value of investment for an individual firm. As competition becomes more intense, each firm's equilibrium production scale is generally reduced, weakening the private incentive to undertake cost-reducing investment.

The effect on aggregate investment is different. From equation (24),
$I_t^* = 2\alpha n^2(A - c - \tau)/[\gamma B(n + 1)^2 - 2\alpha^2 n]$. (35)
Differentiating with respect to n gives
$\partial I_t^*/\partial n = 4\alpha n(A - c - \tau)[\gamma B(n + 1) - \alpha^2 n]/H^2$. (36)
Therefore,
$\partial I_t^*/\partial n > 0$
when
$\alpha^2 n < \gamma B(n + 1)$. (37)

Proposition 6. Competition Can Increase Aggregate Investment

An increase in the number of firms can reduce investment per firm while increasing aggregate industry investment when condition (37) holds.

The result reflects the distinction between the intensive and extensive margins of investment. More competition reduces investment by each firm, while the larger number of firms can nevertheless increase total investment across the industry.

3.8 Taxation and Effective Production Cost

The firm's equilibrium effective marginal production cost is

$MC^* = c - \alpha I^*$. (38)
Using equation (22),
$MC^* = c - 2\alpha^2 n(A - c - \tau)/H$. (39)
Differentiating with respect to taxation,
$\partial MC^*/\partial \tau = 2\alpha^2 n/H > 0$. (40)

Proposition 7. Taxation Increases Effective Production Costs through Investment

An increase in the output tax increases the firm's effective marginal production cost by reducing productivity-enhancing investment.

The result identifies the central indirect transmission mechanism of the model. Although the government does not directly tax investment, taxation reduces investment and thereby weakens the cost-reducing effect of productive expenditure.

3.9 Tax Pass-Through

Using equations (23) and (25), equilibrium price can be expressed as

$p^* = A - B\gamma n(n + 1)(A - c - \tau)/H$. (41)
Differentiating with respect to the output tax gives
$\partial p^*/\partial \tau = B\gamma n(n + 1)/H > 0$. (42)

Proposition 8. Output Taxation Increases the Market Price

An increase in the output tax raises the equilibrium market price.

Tax over-shifting occurs when the increase in the market price exceeds the statutory tax:
$\partial p^*/\partial \tau > 1$. (43)
Using equation (42), this condition requires
$B\gamma n(n + 1) > H$. (44)
Substituting equation (20),
$B\gamma n(n + 1) > \gamma B(n + 1)^2 - 2\alpha^2 n$.

Therefore,
$2\alpha^2 n > \gamma B(n+1)$, (45)
or equivalently,
$\alpha^2 > \gamma B(n+1)/(2n)$. (46)

Proposition 9. Endogenous Investment Can Amplify Tax Pass-Through

If

$\alpha^2 > \gamma B(n+1)/(2n)$,
the equilibrium market price increases by more than the statutory output tax.

Proof. From equation (42), tax over-shifting requires $B\gamma n(n+1) > H$. Substituting equation (20) and rearranging yields condition (46).

The economic interpretation is that taxation generates two related effects. The direct effect increases firms' effective per-unit costs, while the indirect effect reduces productivity-enhancing investment and consequently increases the underlying marginal production cost. When investment is sufficiently productive relative to its cost, this endogenous investment response amplifies the price effect of taxation.

3.10 Equilibrium Profit

At the Cournot equilibrium, the second-stage first-order condition implies

$p^* - c + \alpha I^* - \tau = Bq^*$. (47)
Operating profit before investment expenditure is therefore
$B(q^*)^2$.
Total equilibrium profit is
$\pi^* = B(q^*)^2 - \gamma(I^*)^2/2$. (48)
Using equation (17),
$\pi^* = [B - 2\alpha^2 n^2/(\gamma(n+1)^2)]q^{*2}$. (49)
Under condition (27),
$\pi^* > 0$.

3.11 Main Theoretical Implications

The model yields four principal results. First, an increase in the output tax reduces both firm-level and aggregate equilibrium output. Second, the output tax reduces productivity-enhancing investment even though investment itself is not directly taxed. This effect arises because taxation reduces the equilibrium scale of production, thereby lowering the private return to cost-reducing investment.

Third, greater competition reduces investment at the firm level but can increase aggregate industry investment under the parameter condition specified in equation (37). This result highlights the distinction between firm-level investment incentives and the overall investment response of the industry.

Fourth, endogenous investment can amplify tax pass-through. When investment is sufficiently productive relative to its cost, the reduction in investment induced by taxation raises firms' effective marginal production costs and can lead to tax over-shifting, whereby the increase in the market price exceeds the statutory tax.

These results identify an investment-mediated transmission mechanism linking taxation to market outcomes. Output taxation reduces production, the lower production scale weakens incentives for productivity-enhancing investment, and the resulting decline in investment increases effective marginal production costs. This endogenous cost response can, in turn, strengthen the effect of taxation on equilibrium prices.

4. Conclusion

This paper developed a two-stage n-firm Cournot model to examine the interaction between output taxation and productivity-enhancing investment. Firms first choose cost-reducing investment and subsequently compete in quantities under a specific output tax.

The results show that higher output taxation reduces both equilibrium output and productive investment. The key mechanism is indirect: taxation reduces the equilibrium scale of production, which lowers the private return to cost-reducing investment. Lower investment subsequently raises firms' effective marginal production costs. The model also shows that greater investment productivity increases both investment and output, while greater competition reduces investment per firm but increases aggregate industry investment under the maintained parameter restrictions.

The analysis further shows that endogenous investment can strengthen tax pass-through. When investment is sufficiently productive relative to its cost, the reduction in investment following taxation raises effective production costs and may generate tax over-shifting. Thus, the incidence of output taxation depends not only on its direct effect on firms' production decisions but also on the endogenous investment response of firms.

The model is deliberately simple and abstracts from firm heterogeneity, investment spillovers, and dynamic adjustment. These limitations provide natural directions for future research. Extensions incorporating heterogeneous firms, technological spillovers, or dynamic investment decisions could provide further insight into how taxation affects productive capacity and tax incidence in imperfectly competitive markets.

Author Contributions

The sole author is responsible for conceptualizing, collecting, and analyzing data, and writing and editing the manuscript

Conflict of Interest

The authors declare no conflicts of interest

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