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Privatization and efficiency: a mixed oligopoly approach

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Abstract While models of mixed oligopoly have been analyzed within a rapidly growing literature, little is known about the mechanism of efficiency improvement relating to partial privatization. In this paper, we endogenize efficiency improvement in relation to the level of privatization. We show that in the short run, an improvement in efficiency associated with a state-owned firm reduces the output substitution among firms, and that the reduction in output substitution effect is proportional to the strength of the improvement in efficiency. Specifically, if the effect of efficiency improvement is sufficiently small, the magnitude of the improvement of social welfare is reduced. In the literature, the optimal policy in the long run is full nationalization. However, we argue that the optimal policy for a state-owned firm is partial privatization. Moreover, efficiency improvement provides the impetus for indirect entry regulation of private entrants.

Keywords Cost differentials · Efficiency-enhancing effect · Mixed oligopoly · Privatization

JEL Classification H42 · L13 · L32 · L51

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1 Introduction

Privatization is a common theme in studies of transition economies and fledgling markets. Within transition economies such as those in Eastern Europe, Latin America, and the BRIC countries, namely Brazil, Russia, India, and China, governments implement privatization initiatives to improve market efficiency.[1] Evidently, competition between public and private firms existed, or still exists, across a range of industries.[2]

In recent years, an increasing number of studies have focused on mixed markets in which a state-owned enterprise competes against private firms. The concept of a mixed oligopoly dates back several decades, at least according to Merrill and Schneider (1966). These authors showed that if public and private firms have symmetric and constant marginal production costs, a public monopoly is the best option for achieving welfare maximization. They further argued that the most efficient outcome is achieved through the nationalization of all firms in cases where X-inefficiency does not exist in a public firm. However, in reality, a state-owned enterprise usually incurs production inefficiency resulting from many factors, including formalism, inefficient governance, goal displacement, unresponsiveness, and redundant administrative staffs.[3] As a result, privatization of a public firm can often enhance its performance by reducing its inefficiency-related costs, which then leads to an improvement of social welfare. Sappington and Stiglitz (1987) described a privatization procedure entailing efficient allocation and increases in social welfare with a public firm's (partial) privatization.[4] To elaborate further, privatization induces a reduction in the output of a public firm and increases the output of a private firm, thus reducing the production inefficiency created by the cost asymmetry of the respective firms.[5]

[1] Many empirical observations have demonstrated that public firms in many developing countries are more inefficient than private firms. For relevant discussions and surveys, see, for example, Megginson and Netter (2001) and Bai et al. (2009).

[2] For instance, since 1978, China has adopted a policy of privatization to reform its state-owned enterprises (e.g., Bai et al. 2009). Furthermore, the worldwide trend of airport reform is one of the most notable examples of the reform of public firms (e.g., Gillen 2011).

[3] The absence of an ability to organize economic activities efficiently is in line with the observations in India. See, for example, Gupta (2005).

[4] The presence of state-owned enterprises can serve to discipline the behavior of private firms with market power, because these public enterprises generally pursue welfare maximization. Such an objective often results in the expansion of market outputs and subsequently raises consumer welfare. See, also, Garvie and Ware (1996) and Brandão and Castro (2007).

[5] Willner (1999) showed that welfare maximization will make a public firm appear less cost efficient than its private competitors in cases where state-owned firms are constrained by rules that require higher or lower wages than those that prevail within private firms. Maw (2002) examined the reasons for privatization. He showed that an important objective must be efficient allocation, entailing the transfer of control rights of capital to the most productive available entrepreneurs. As a result, the ownership structure needs to be sufficiently concentrated to allow for effective control and to ensure the correct choice of management. Konings et al. (2005) use representative panel data on 1701 Bulgarian and 2047 Romanian manufacturing firms. They have shown that privatized firms reduce costs for efficiency improvement rather than increasing costs. Furthermore, Cavaliere and Scabrosetti (2008) have investigated the theoretical literature relating to privatization and efficiency by tracing its evolution from applications of agency theory to more recent contributions in the field of the political economy.

In the literature of a quantity-setting mixed oligopoly associated with a state-owned welfare-maximizing enterprise and profit-maximizing private firms, there are essentially two lines of discussion regarding the cost differentials between public and private firms. The first relates to diseconomies of scale. When public and private firms have the same quadratic production costs, the outputs of welfare-maximizing public firms exceed those of private firms. The diseconomies of scale induce higher marginal costs for public firms compared with private firms. Privatization reduces the outputs of public firms and offsets diseconomies of scale, thereby reducing the cost differentials between firms (De Fraja and Delbono 1989, 1990; White 1996; Fjell and Heywood 2004; Pal and White 1998; Fjell and Pal 1996; Brandão and Castro 2007; Wang and Chen 2011; Lin and Matsumura 2012; Colombo 2016).

The second line of discussion relating to cost differentials considers cost functions and efficiency gaps as heterogeneous costs. Matsumura (1998) showed that fully nationalized firms are engaged with the issues of welfare maximizing and extensive market competition. Conversely, if a firm wants to make profits, there will naturally be a strong incentive for it to transform itself from being one that is welfare-oriented to one that is profit-oriented. This implies a change in the firm's objectives. When privatization occurs, the inefficiency (in terms of costs) of a state-owned enterprise is somewhat improved.[6] Matsumura's findings have been empirically verified by Gupta (2005), who reported that when minority shares of a public firm are released to private investors, the performance of Indian public firms is significantly improved.

Within the literature, the gap in efficiency between the public and private sectors is given exogenously in origin. Once privatization is initiated, the total output decreases and economies of scale remain the primary influence on privatization. An issue relating to asymmetric costs that is worth investigating is the "endogenous cost differentials" between public and private enterprises. One way of creating cost differentials is by introducing cost-reducing R&D investment. Matsumura and Matsushima (2004) have demonstrated that the privatization of a public firm would improve welfare since this would mitigate the loss arising from excessive cost-reducing investments.[7] On the other hand, some economists have endogenized cost differentials between firms by distinguishing wage settings within a model of unionized mixed duopoly (see, Willner 2001; Ishida and Matsushima 2009).

Although the literature considered endogenous cost differentials differently from the norm within a mixed duopoly, they did not endogenize the efficiency improvement connected with the level of privatization. To our knowledge, the efficiency-enhancing effect is empirically supported by Gupta (2005). However, the relationship between partial privatization and the efficiency improvement of public firms has not been sufficiently analyzed within the theoretical literature. In this paper, we present the findings of an in depth analysis of efficiency improvement related to privatization by envisaging a quantity-setting mixed oligopoly associated with endogenous cost differentials

[6] See also Bennett and Maw (2003), Chang (2005), Ohori (2006), Long and Stähler (2009), Mukherjee and Suetrong (2009), Wang and Chen (2010), Bjorvatn and Eckel (2011), Cato and Matsumura (2012), Beladi et al. (2013), Matsumura and Tomaru (2013), Matsumura and Okamura (2015), and Chang and Ryu (2015).

[7] Gil-Moltó et al. (2011) further considered R&D subsidies and spillover effects within a mixed duopoly.

between private firms[8] and a state-owned enterprise. Privatization can reduce the production costs of the privatized firm through the reduction of a public firm's output as well as the improvement of its production efficiency. Nonetheless, privatization has to maintain a desirable level of social welfare in relation to the government. When privatization occurs, three major effects can be observed within this mixed oligopoly: a *welfare-reducing effect*, an *output substitution effect,* and an *efficiency-enhancing effect*. Matsumura (1998) has argued that the *welfare-reducing effect* is a reduction of social surplus as a result of privatization, and the *output substitution effect* from an inefficient firm to an efficient one causes a welfare-improving situation. In addition to Matsumura's arguments, this paper contributes to a better understanding of the potential *efficiency-enhancing effect* that results from privatizing a state-owned firm in a mixed oligopoly.

In the short run, we show that a strong/weak efficiency-enhancing effect highly/slightly reduces the output substitution effect from an inefficient firm to an efficient firm. Specifically, if the efficiency-enhancing effect is sufficiently small, the magnitude of welfare-improving is reduced. Furthermore, we show that if the partial privatization of a state-owned enterprise (SOE) results in its production efficiency exceeding that of private entrants, the total output and consumer surplus will be higher compared to cases in which the SOE is not the most efficient among firms.

In the long run, which is assumed to have zero-profit conditions for private firms, Matsumura and Kanda (2005) have shown that the optimal level of privatization is full nationalization while the equilibrium price is equal to the marginal cost of SOE. Marginal cost pricing removes wasteful entry by private firms. Consequently, it improves welfare.[9] In this study, we show that through privatization, the efficiency-enhancing effect reduces the marginal cost of the state-owned enterprise, consequently improving producer surplus as well as social welfare. As a result, the optimal policy for a state-owned enterprise is partial privatization instead of full nationalization, which is totally different from the conventional outcome. Furthermore, the efficiency-enhancing effect resulting from privatization of a state-owned enterprise can be an indirect entry regulation for determining the optimal number of private entrants.

The remainder of this paper is organized as follows. In Sect. 2, we depict the model frameworks and assumptions. In Sect. 3, we present an in depth analysis of efficiency improvement related to privatization and examine optimal outcomes and welfare implications in the short and long run, respectively. In Sect. 4, we present a discussion on socially desirable and excessive entries. In the final section of the paper, we offer concluding remarks on our findings.

[8] In this paper, we consider private firms having the same production efficiency in the market. Hence, the endogenous cost differentials between a private firm and a state-owned enterprise is considered to be equivalent to the differentials between private firms and a state-owned enterprise.

[9] See also Wang and Chen (2010).

2 Model frameworks

We envisage a mixed-oligopoly economy in which an incumbent SOE indexed by 0 and private competitors indexed by $1, 2, \ldots, n$, respectively, produced a homogenous good.

Assumption 1 Suppose the representative utility, U, is an increasing concave and smooth function whose Hessian matrix is negative definite.

Given the utility, the inverse demand function, $P(Q) : (0, \infty) \to [0, \infty) \forall Q \in \Re_+$, is continuous, twice differentiable, and downward sloping, $P' < 0$, where $P(Q)$ denotes the market price and $Q(= q_0 + \sum_{i=1}^{n} q_i)$ denotes bounded total output.[10] The curvature of inverse demand for a convex (concave) demand function is defined as:

$$\eta(Q) = -P''Q/P' = -d \log P'/d \log Q \geq (\leq) 0.^{11} \tag{1}$$

In economic terms, the ratio of the slope of industry marginal revenue to the slope of demand is held constant for all quantities.[11] For tractability, we posit Assumption 2 relating to the property of η:

Assumption 2 All of these inverse demand functions have an *iso-elastic* slope, i.e. $\eta'(Q) = 0$.

Assumption 2 can be regarded as a smoothness condition for constant relative risk aversion within utility theory. When this assumption holds, we subsequently have $\eta(Q) = \eta$. Accordingly, depending on the sign of η, the second-order derivative of inverse demand, P'', could be larger than, equal to, or less than zero. Thus, $P'' > 0$ if $\eta > 0$; $P'' = 0$ if $\eta = 0$; $P'' < 0$ if $\eta < 0$.[12]

Assumption 3 Let $\eta \in (-\infty, 1)$ ensure the uniqueness of a Cournot equilibrium.

For a unique Cournot equilibrium, with twice continuously differentiable cost and inverse demand function (we will subsequently express the cost setting), Kolstad and Mathiesen (1987) explored that the sign of the determinant of the Jacobian matrix of the marginal profit must be positive[13] with $P' + qP''$ always being negative, where q denotes a firm's output. In our notation, we can, therefore, express the condition of uniqueness as $1 - \eta s > 0$, where s is the market share of each firm.

[10] $\forall Q \in [0, \bar{Q})$, where $0 \leq \bar{Q} < \infty, \exists \bar{Q}$, and thus $P(Q) > 0$; on the other hand, $\forall Q \in [\bar{Q}, \infty)$, $P(Q) = 0$.

[11] See also, Aguirre et al. (2010)

[12] When Assumption 2 holds, an inverse demand function can be set as (see, e.g., Anderson and Engers 1992; Ritz 2008):

$$P(Q) = \alpha - \frac{\kappa Q^{1-\eta}}{1-\eta},$$

where $\alpha \geq 0$ and $\kappa > 0$. This form includes, among others, linear, constant-elastic, log-linear, and quadratic demands. Evidently, $P' = -\kappa Q^{-\eta} < 0$, and $P'' = \eta\kappa Q^{-1-\eta}$. $P'' > 0$ if $\eta > 0$; $P'' = 0$ if $\eta = 0$; $P'' < 0$ if $\eta < 0$.

[13] Kolstad and Mathiesen (1987) stated: "$B(z) = \{i \in \bar{N} \,|z_i > 0\}$, $J_B(f, z)$ to the principal minor of the Jacobian matrix of f corresponding to the indices of $B(z)$, and $|J_B(f, z)|$ its determinant." See Mathiesen (1987, p. 684) for further details.

Assumption 4 For $q > 0$, the cost functions for SOE and private firms are $C(q_0) = F + g_0 q_0$ and $C(q_i) = F + g_e q_i$, respectively, where $i \in \{1, 2, \ldots, n\}$.[14] For $q = 0$, $C(0) = 0$.

$g_0, g_e \geq 0$ denote the heterogeneous technology level between SOE and private firms.

Given the inverse demand and cost functions, the profits of the public firm and of n private firms are: $\pi_0 = Pq_0 - F - g_0 q_0$ and $\pi_i = Pq_i - F - g_e q_i$, $i \in \{1, 2, \ldots, n\}$, respectively. Consumer surplus is given by $CS = \int_0^Q P(z)dz - PQ$, and the producer surplus is the difference between the total revenue and the total variable cost; i.e., $\pi_0 + \sum_{i=1}^n \pi_i + (n+1)F \equiv PS$. The welfare function is thus $W = \int_0^Q P(z)dz - PQ + \pi_0 + \sum_{i=1}^n \pi_i + (n+1)F$. Supposing the government plans to release some of state-owned shares of the SOE for the purpose of improving social welfare, the objective function of the SOE is expressed as: (see, Bös 1991; Matsumura 1998)

$$O_0 = (1-\theta)\pi_0 + \theta W; \quad \theta \in [0, 1], \tag{2}$$

where θ denotes the level of privatization. As explained in Matsumura (1998, pp. 475–476), the government can indirectly control θ through the changes of its shareholding. The manager of a fully privatized firm maximizes the firm's profit (i.e. $\theta = 0$), while the manager of a fully nationalized firm maximizes social welfare (i.e. $\theta = 1$). If the share owned by the government increases, then θ increases. Once the SOE is privatized, its efficiency is improved. We thereby assume that $g_0(\theta) = \underline{g}_0 + \Gamma(\theta) \geq 0$, where $g_e > g_0 \geq 0, \Gamma(0) = 0, \Gamma'(\theta) > 0$and $\Gamma''(\theta) = 0$. Furthermore, $g_0(1) \equiv \underline{g}_0 + \Gamma(1) = \bar{g}_0 > g_e$. We regard $\Gamma'(\theta) > 0$ as the *efficiency-enhancing effect* if θ declines from 1 to 0. If the value of Γ' is large, then the efficiency-enhancing effect will be weak and the marginal cost will remain high. Conversely, if the value of Γ' is small, then the efficiency-enhancing effect will be strong, and the marginal cost will consequently be low.

Specifically, we consider social welfare to be a concave function of θ. We subsequently adopt the following assumption to satisfy the concavity of social welfare with respect to θ.

Assumption 5 (i) $P' + \Gamma' < 0$; (ii) $d^2 q_0/d\theta^2 = 0$, and $d^2 q_i/d\theta^2 = 0$, $i = 1, \ldots, n$.

Without losing generalization, the first part of the fifth assumption restricts the magnitude of $\Gamma'(\theta)$, and the second part relates to the monotonic influence of the level of privatization on the firms' outputs.

A two-stage decision-making game is developed. In the first stage, the government maximizes social welfare to select the optimal level of privatization, θ. In the second stage, firms simultaneously maximize their objective functions, $\Omega : \Re_+^2 \to \Re_+$ where $\Omega(O_0(\pi_0, W, \theta; \eta), O_i(\pi_i; \eta))$, $i = 1, \ldots, n$, and determine each output. O_0, as in Eq. (2), is the SOE's objective function, and $O_i = \pi_i$ is the private firm's objective function. We use the backward induction method to obtain the equilibrium outcomes.

[14] In line with the empirical literature, marginal costs are usually constant (e.g., see Martin 2004).

3 Privatization in mixed oligopoly

3.1 The impact of privatization level on outputs

Commencing at the second stage of this game, given its rivals' outputs, each firm maximizes its objective function with respect to q_i, $i = 0, 1, 2, \ldots, n$. The first-order conditions for SOE and private firms, respectively, are:

$$\frac{\partial O_0}{\partial q_0} = \frac{\partial \pi_0}{\partial q_0} + \theta\left(\frac{\partial CS}{\partial q_0} + \sum_i \frac{\partial \pi_i}{\partial q_0}\right) = (1-\theta)P'q_0 + P - g_0(\theta) = 0; \text{ and} \quad (3)$$

$$\frac{\partial O_i}{\partial q_i} = \frac{\partial \pi_i}{\partial q_i} = P'q_i + P - g_e = 0, \ i = 1, \ldots, n. \quad (4)$$

The condition implicitly defines a firm's best response in the production market. We can determine output levels in terms of the level of privatization, the efficiency gap, and the curvature property of demand; that is, $q(\theta; \eta, g)$, where $g \in \{g_0, g_e\}$. Let x be the sum of the private firms' total outputs; i.e. $x = \sum_{i=1}^{n} q_i$. To characterize the effect of privatization, as well as the demand property on the outputs, we further totally differentiate first-order conditions with respect to q_0, x, and θ to obtain the following:

$$A_{11}dq_0 + A_{12}dx = (P'q_0 + \Gamma')d\theta; \text{ and} \quad (5)$$

$$A_{21}dq_0 + A_{22}dx = 0, \quad (6)$$

where $A_{11} \equiv (1-\theta)P'(1-\eta s_0) + P'$, $A_{12} \equiv P'[1-(1-\theta)\eta s_0]$, $A_{21} \equiv P'(n-\eta s_x)$, and $A_{22} \equiv P'(n+1-\eta s_x)$, and $s_0 = q_0/Q$ and $s_x = x/Q = \sum_{i=1}^{n} q_i/Q$.

Applying Cremer's rule, we can obtain

$$\frac{dq_0}{d\theta} = \frac{(P'q_0 + \Gamma')A_{22}}{\Delta} > 0, \text{ and } \frac{dx}{d\theta} = \frac{-(P'q_0 + \Gamma')A_{21}}{\Delta} < 0; \quad (7)$$

where $P'q_0 + \Gamma' < 0$ and $\Delta = A_{11}A_{22} - A_{12}A_{21} > 0$ because $|A_{11}| > |A_{12}|$ and $|A_{22}| > |A_{21}|$.

We subsequently obtain the following lemma:

Lemma 1 *In the short-run, both the SOE's output and total output in the market increase as θ increases.*

It should be noted that an increase in θ denotes a lower level of privatization of the SOE. It should also be noted that Assumption 3 is applicable, and $1 - \eta s > 0$. From Eq. (7) and Assumption 5, we find that an increase in θ increases the total output; that is, $\frac{dQ}{d\theta} = \frac{dq_0}{d\theta} + \frac{dx}{d\theta} > 0$. This implies that complete nationalization of the SOE results in the largest amount of total outputs in the market. Because we restrict the extent of the value of Γ', the efficiency-enhancing effect does not affect the sign of the comparative statics. Rather, it has an impact on the size of the change of outputs. From Eq. (7), it can be observed that if the value of Γ' is large, a change in θ will lead to less change of the outputs. In other words, when the value of Γ' is much closer to $|P'q_0|$,

θ has less influence on the outputs. Recall that $\left|P'\right| > \Gamma'$, based on Assumption 5. Furthermore, Matsumura (1998) has argued that there are two major effects in a mixed oligopoly. One is a *welfare-reducing effect*, which means that privatization reduces the total production level and, therefore, the consumer surplus. The other is an *output substitution effect*, which means that when privatization occurs, the output substitution effect from an inefficient firm to an efficient firm creates a welfare-improving situation.

Thanks to symmetric objective functions among private firms, from Eqs. (3) and (4) we can obtain, in equilibrium, $q_1 = q_2 = \cdots = q_n$. In the long run, postulating that the profits of all private firms are driven to zero, we can explore the long-run equilibrium wherein free entry and exit prevail. Accordingly, the number of private firms n is endogenously determined. To determine the outcomes, we consider first-order conditions, Eqs. (3) and (4), together with the zero-profit condition:

$$\pi_i = Pq_i - g_e q_i - F = 0; \quad i = 1, 2, \ldots, n. \tag{8}$$

In equilibrium, we can solve $q_0^L, q_i^L, Q^L = q_0^L + \sum_{i=1}^n q_i^L$ and n^L. The superscript L denotes the equilibrium variables at free entry. Turning back to the total differentiation of first-order conditions and zero-profit condition with respect to q_0^L, q_n^L, n^L and θ^L,[15] we then have,

$$p'q_n^L \begin{bmatrix} B_{11} & n^L[1-(1-\theta^L)\eta s_0 & [1-(1-\theta^L)\eta s_0 \\ P'(1-\eta s_n) & n^L P'(1-\eta s_n) + P' & (1-\eta s_n) \\ P'q_n^L & n^L P' q_n^L + P - g_e & q_n^L \end{bmatrix} \begin{bmatrix} dq_0^L \\ dq_n^L \\ dn_L \end{bmatrix}$$
$$= \begin{bmatrix} P'q_0^L + \Gamma' \\ 0 \\ 0 \end{bmatrix} d\theta^L$$

where $B_{11} = (1-\theta^L)P'(1-\eta s_0) + P'$ and $s_n = q_n/Q$.

Applying Cremer's rule, the comparative statics are derived as follows:

$$\frac{dq_0^L}{d\theta^L} = \frac{(P'q_0^L + \Gamma')P'q_n^L[q_n^L P' - (P-g_e)(1-\eta s_n)]}{\Delta^L} > 0, \tag{9}$$

$$\frac{dq_n^L}{d\theta^L} = 0, \tag{10}$$

$$\frac{dn^L}{d\theta^L} = \frac{-(P'q_0^L + \Gamma')q_n^L P' P'[q_n^L P' - (P-g_e)(1-\eta s_n)]}{\Delta^L} < 0, \tag{11}$$

where $\Delta^L = P'q_n^L \underset{(+)}{\left\{(1-\theta^L)P'q_n^L P' - P'(1-\eta s_n)(1-\theta^L)(P-g_e)\right\}} < 0.$

[15] Similarly, in equilibrium, $q_1^L = q_2^L = \cdots = q_n^L$ results from symmetric objective functions within private firms. To avoid complicated and messy calculations, we have only used a private firm's equation for our analysis. The sign of the impact of the level of privatization is the same as the matrix associated with n+2 linear equations.

Table 1 The impact of a change in θ

	$\frac{dq_0}{d\theta}$	$\frac{dq_i}{d\theta}$	$\frac{dQ}{d\theta}$
Short run	+	−	+
Long run	+	0	0

Solving Eqs. (4) and (8), the long-run output of a private firm in equilibrium is expressed as:

$$q_i^L = \sqrt{\frac{F}{P'}}, \quad i = 1, 2, \ldots, n. \tag{12}$$

Incorporating (9), (10), (11) and (12), we obtain the following *lemma*:

Lemma 2 *In the long-run,* (i) $sign(\frac{dq_0^L}{d\theta^L}) = (-1) \times sign(\frac{dn^L}{d\theta^L})$ *;* (ii) $\frac{dq_0^L}{d\theta^L} = -q_i^L \frac{dn^L}{d\theta^L}$*;* (iii) $\frac{dQ^L}{d\theta^L} = \frac{d(q_0^L + n^L q_i^L)}{d\theta^L} = \frac{dq_0^L}{d\theta^L} + q_i^L \frac{dn^L}{d\theta^L} + n^L \frac{dq_i^L}{d\theta^L} = 0.$

Table 1 presents a summary of the main results obtained in the short and long run to enable them to be easily comprehended.

The following proposition characterizes the role of efficiency-enhancing parameter on the comparative statics in either the short-run or long-run:

Proposition 1 *The efficiency-enhancing effect has no influence on the sign of the comparative statics but it does influence the extent of the change of outputs. If the value of* Γ' *is very close to* $\left|P'q_0\right|$ *, then the change in the level of privatization will have a weak influence on the output. If the value of* Γ' *is very far from* $\left|P'q_0\right|$ *then the change in the level of privatization will have a strong influence on the output.*

In a market in which free entry and exit prevail, the level of privatization has no impact on private firms' outputs because of the zero-profit condition. Together with an increase in the number of private firms, the government releases shares in the SOE to the market. Wang and Mukherjee (2012) have shown that equilibrium welfare under free entry market is higher than that which occurs in a situation wherein an SOE produces duopoly outputs. Hence, compared with a mixed duopoly, free entry increases welfare, and that this improvement in welfare is developed at the expense of consumers.

3.2 The government's decision in the first stage

Turning to the first stage of this two-stage game in the short run, $\max_{\theta} W(\theta)$, we obtain:

$$\begin{aligned} \frac{\partial W(\theta)}{\partial \theta} &= \frac{\partial CS(\theta)}{\partial \theta} + \frac{\partial \pi_0(\theta)}{\partial \theta} + \sum\nolimits_{i=1}^{n} \frac{\partial \pi_i(\theta)}{\partial \theta} \\ &= -(1-\theta)P'q_0 \frac{\partial q_0}{\partial \theta} - P'x\frac{\partial x}{\partial \theta} - q_0\Gamma' = 0, \end{aligned} \tag{13}$$

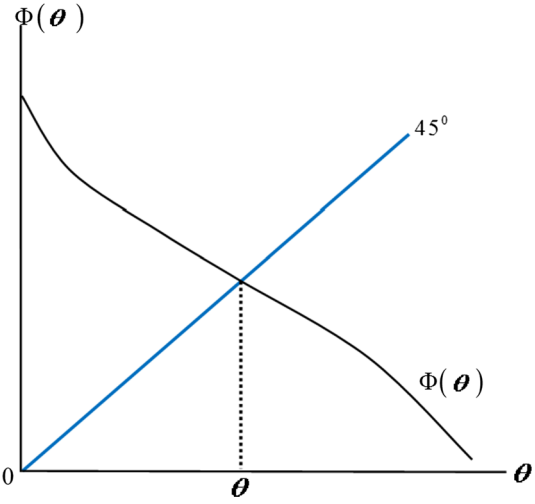

Fig. 1 Determining an optimal θ

where W, CS, q_0, x, and P in the first stage are functions of θ along with parameters (g_0, g_e).[16]

From (13), we can obtain the level of privatization as follows:

$$\theta = 1 - \underset{(+)}{\frac{x}{q_0}\frac{A_{21}}{A_{22}}} + \underset{(-)}{\frac{\Gamma'\Delta}{P'(P'q_0 + \Gamma')A_{22}}}. \tag{14}$$

Using Eqs. (3) and (4), the θ in the short-run is derived as follows:

$$\theta = 1 + \underset{(-)}{\frac{\Gamma'}{P'}} \underset{(+)}{\frac{(P - g_0)}{P(\partial Q/\partial\theta) - g_0(\partial q_0/\partial\theta) - g_e(\partial x/\partial\theta)}} \equiv \Phi(\theta). \tag{15}$$

Recall that $g_0'(\theta) > 0$ and $g_0''(\theta) = 0$. The optimal θ is seen to be the fixed point of $\Phi(\theta)$ in Eq. (15), as shown in Fig. 1. The $\Phi(\theta)$ curve decreases monotonically, because $\Phi'(\theta) < 0$ and $\Phi''(\theta) = 0$.[17] Furthermore, $g_0(0) \neq 0$ confirms the existence of a positive θ.

Let optimal θ in the short-run be θ^S. It follows that $g_0 \gtreqless g_e$. That is, after privatization, the SOE may become more efficient than private firms in the production line. We derive optimal outputs from (3) and (4):

[16] Along with Assumption 5, the second order condition is satisfied as a concavity, and $\partial W^2(\theta)/\partial\theta^2 = (P'q_0 - \Gamma')(\partial q_0/\partial\theta) - (1-\theta)P'q_0(\partial^2 q_0/\partial\theta^2) - P'x(\partial^2 x/\partial\theta^2) < 0$.

[17] Applying Assumption 5, it is evident that $d^2q_0/d\theta^2 = 0$ and $d^2q_i/d\theta^2 = 0$, $i = 1, \ldots, n$. To derive $\Phi'(\theta) < 0$, we have ignored several negligible terms associated with square numbers of first , because $\partial Q/\partial\theta$, $\partial q_0/\partial\theta$ and $\partial x/\partial\theta$ are all less than 1.

$$q_0^S\Big|_{\theta=\theta^S} = \left(\frac{1}{1-\theta^S}\right) q_i^S\Big|_{\theta=\theta^S} + \frac{g_0(\theta^S)-g_e}{(1-\theta^S)P'}$$
$$\equiv \left(\frac{1}{1-\theta^S}\right) q_i^S\Big|_{\theta=\theta^S} + G, \quad i = 1, 2, \ldots, n$$

We further define the following: $G|_{g_0(\theta^S)<g_e} \equiv G_1 > 0$, $G|_{g_0(\theta^S)=g_e} \equiv G_2 = 0$ and $G|_{g_0(\theta^S)>g_e} \equiv G_3 < 0$. It follows that $Q^S|_{g_0(\theta^S)<g_e} > Q^S|_{g_0(\theta^S)=g_e} > Q^S|_{g_0(\theta^S)>g_e}$, where Q^S denotes the optimal total output in the short run. Hence, if partial privatization results in the production efficiency of the SOE being substantially higher than that of private firms, then the consumer surplus will be the highest. In Sect. 3.3., we apply a linear demand function for numerical equilibrium configurations to confirm this finding. The following proposition characterizes this result:

Proposition 2 *Compared to the case of an inefficient SOE in the short run, if partial privatization of an SOE results in its production efficiency exceeding that of private entrants, the total output will be higher, leading to a higher consumer surplus.*

Proposition 2 shows that if partial privatization results in $g_0(\theta^*) < g_e$, then one can obtain higher output and CS than the case in which partial privatization results in $g_0(\theta^*) = g_e$ or $g_0(\theta^*) > g_e$. The intuitions on which this proposition is based relate to Eq. (7). A decrease in θ reduces q_0 but increases x. Considering the following assumptions: $\Gamma'(\theta) > 0$and $\Gamma''(\theta) = 0$, if partial privatization of an SOE results in its production efficiency exceeding that of private entrants, then an efficiency-enhancing parameter will reduce the output substitution effect from an inefficient firm to an efficient one. As a result, the total output is higher than it is in the case of an inefficient SOE.

In the long run, in association with private entrants' zero-profit conditions, $\max_{\theta^L} W^L(\theta^L)$, we obtain:

$$\frac{\partial W^L(\theta^L)}{\partial \theta^L} = \frac{\partial CS^L(\theta^L)}{\partial \theta^L} + \frac{\partial \pi_0^L(\theta^L)}{\partial \theta^L}$$
$$= 0 + [-(1-\theta^L)P' q_0^L]\frac{\partial q_0^L}{\partial \theta^L} - \Gamma' q_0^L = 0. \tag{16}$$

Together with Lemma 2, we can show that the optimal policy for an SOE is as follows:

$$\theta^L = 1 + \underset{(-)}{\frac{\Gamma'}{P'(\partial q_0^L/\partial \theta^L)}} = \Omega(\theta^L).$$

Analogously, $q_0^L|_{\theta^L=0} \neq 0$, $\Omega'(\theta^L) < 0$, and $\Omega''(\theta^L) = 0$ confirm the existence of a positive θ^L. As a result, the optimal policy for an SOE is partial privatization instead of full nationalization in a free entry market, and $g_0(\theta^L) \gtreqless g_e$. This is quite different from Matsumura and Kanda (2005)'s proposition 2. They showed that the optimal level of

privatization is achieved when the marginal cost of an SOE is equal to the equilibrium price. Marginal cost pricing removes wasteful entry by private firms, thus improving welfare.[18] The difference is derived from the *efficiency-enhancing effect*. From Eq. (16), we can see that in the absence of Γ', the magnitude of $(\partial q_0^L/\partial\theta^L)$ evidently affects the magnitude of $(\partial\pi_0^L/\partial\theta^L)$, and, consequently, that of $(\partial W^L/\partial\theta^L)$. When $\theta^L = 1$, $(\partial q_0^L/\partial\theta^L)$ is at the maximum value, leading to maximal social welfare. This supports the findings of the existing literature. However, the presence of Γ' reduces the magnitude of $(\partial q_0^L/\partial\theta^L)$in Eq. (9). In other words, when privatization occurs, the magnitude of the reduction of q_0^L is relatively small compared with cases entailing an absence of Γ'. Furthermore, a decrease in θ^L increases an SOE's marginal revenue $(\partial(P'q_0^L + P)/\partial\theta^L = P'\partial q_0^L/\partial\theta^L < 0)$ and decreases its marginal cost $(\partial g_0/\partial\theta^L = \Gamma' > 0)$. The *efficiency-enhancing effect* strengthens the reduction of the marginal cost when privatization occurs. Therefore, an increase in the producer surplus improves social welfare, and the optimal price is higher than the SOE's marginal cost. Thus, $P = g_0 - (1-\theta^L)P'q_0^L$.

Moreover, after privatization, the SOE may become more efficient than private firms in the production line. From Lemma 2, we have $dQ^L/d\theta^L = 0$. Unlike the analysis relating to the short run, in the long run, a change in the level of privatization has no impact on the total output or consumer surplus.

The following proposition relates to the findings in the long run:

Proposition 3 *In the long-run, through privatization, the efficiency-enhancing effect reduces the marginal cost of an SOE, and subsequently improves the producer surplus as well as social welfare. As a result, the optimal policy for an SOE is partial privatization rather than full nationalization.*

It should be noted that Matsumura and Kanda's (2005) study of a nationalized SOE in the long run is closely related to the "excess entry theorem," which states that the number of firms at free-entry equilibrium is excessive from the viewpoint of social welfare. Brandão and Castro (2007) have also examined how a public firm plays an indirect regulatory role in relation to the entry of private entrants, regardless of whether the public firm is less efficient than the private ones. However, in the presence of an *efficiency-enhancing effect*, partial privatization is conducive to the maximization of social welfare, and as Eq. (11) shows, the number of private firms is allowed to increase. To elaborate further, if $\theta^L \to 0^+$, then we have $g_0(\theta^L) \to \underline{g}_0$. A subsequent decrease in $g_0(\theta^L)$ reduces the amount of the increase of n^L which results from partial privatization in Eq. (11). The literature shows that pricing set at the marginal cost of the SOE indirectly controls the number of private entrants. Our findings using the present model indicate that the efficiency-enhancing effect is a drive for controlling private firms' excessive entry. In Sect. 4, we further elaborate excessive entry in a mixed oligopoly.

Together with Proposition 3, we have the following corollary:

[18] See Fujiwara (2007) for a study of a differentiated market with free entry and Wang and Chen (2010) for a study of an open market with free entry.

Corollary 1 *The efficiency-enhancing effect resulting from privatizing a state-owned enterprise can function as an indirect entry regulation for determining the optimal number of private entrants.*

3.3 Welfare implications and equilibrium configurations

Given a general function of $g_0(\theta)$, there are three possible outcomes relating to a government's implementation of privatization in the short-run. They are: (i) privatization results in an efficient SOE ($g_0(\theta^S) < g_e$); (ii) privatization results in identical production efficiency of firms within the market ($g_0(\theta^S) = g_e$); and (iii) privatization improves an SOE's efficiency. However, it remains inefficient compared with other firms ($g_0(\theta^S) > g_e$).

We already know that in the short run, $CS^S|_{g_0(\theta^S)<g_e} > CS^S|_{g_0(\theta^S)=g_e} > CS^S|_{g_0(\theta^S)>g_e}$. To examine the *efficiency-enhancing effect*, we need to analyze Eq. (13) in detail and reframe it as follows:

$$\begin{aligned}\frac{\partial W(\theta)}{\partial \theta} &= \frac{\partial CS(\theta)}{\partial \theta} + \frac{\partial PS(\theta)}{\partial \theta} \\ &= \underbrace{\left[-P'Q\frac{\partial Q}{\partial \theta}\right]}_{(+)} + \left[\underbrace{(\theta P'q_0 + P'x)\frac{\partial q_0}{\partial \theta} + P'q_0\frac{\partial x}{\partial \theta}}_{(+/-)} - \underbrace{\Gamma' q_0}_{(efficiency-enhancing\ effect)}\right].\end{aligned} \tag{17}$$

From Eq. (17), it is evident that privatization in the short run improves consumer welfare. However, its effect on producer surplus is ambiguous. When privatization occurs, total output decreases. A large/small value of Γ' highly/slightly reduces the *output substitution effect* from an inefficient firm to an efficient one. Also, privatization could transform an SOE from an inefficient firm to an efficient one. In theory, within an asymmetric oligopoly, private firms incur losses of profits. Consequently, the producer surplus could decrease and reduce the magnitude of welfare improvement. Furthermore, from Eq. (17), it is evident that if Γ' is sufficiently large, the producer surplus decreases, and the magnitude of welfare improvement is, therefore, reduced.

It has been shown that the extent of Γ' has an influence on the magnitude of welfare improvement. Naturally, in equilibrium, the social welfare associated with a highly efficiency-enhancing SOE may not be the highest among the three possible outcomes. To address this problem, we present below an example of a linear demand for an equilibrium configuration that demonstrates whether or not a level of privatization that significantly improves an SOE's production efficiency above that of private firms presents a "win-win" situation for both the government and consumers.

Suppose that $P(Q)$ is expressed by $P = a - Q$, where $Q = q_0 + \sum_{i=1}^{n} q_i$. Notice that η=0 according to Assumption 2, and $\Gamma' < -P'$ according to Assumption 5. From Eqs. (3) and (4), we obtain the following:

$$q_0 = \frac{a - (n+1)g_0 + ng_e}{n + 2 - (n+1)\theta} \quad \text{and} \quad q_i = \frac{(1-\theta)\,a - (2-\theta)g_e + g_0}{n + 2 - (n+1)\theta},\ i = 1, \ldots, n.$$

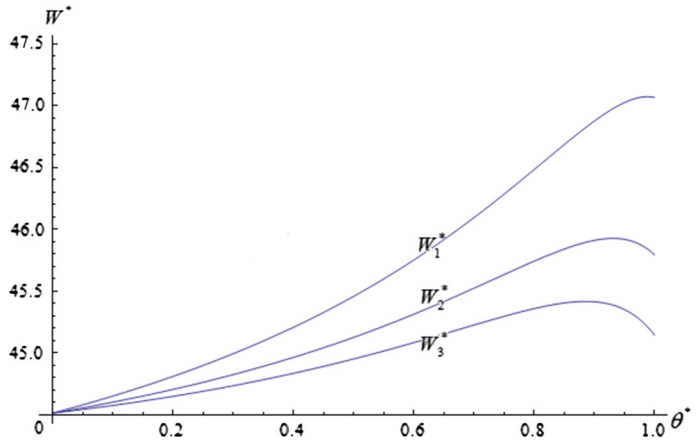

Fig. 2 Equilibrium configuration of social welfare

By maximizing social welfare with respect to the level of θ, we can solve an optimal θ^*. Social welfare after the implementation of privatization is closely related to the form of the firms' cost functions. Therefore, the optimal social welfare is derived as follows:

$$W^* = \frac{\left[\begin{array}{l} a^2\{(1+n(1-\theta^*))(3+n(1-\theta^*)-2\theta^*)+g_0^2(\theta^*)(3+6n+2n^2-2(1+n)^2\theta^*) \\ +2g_0(\theta^*)(-a(3+n)+a(2+n)\theta^*-ng_e(5+2n(1-\theta^*)-3\theta^*)) \\ +ng_e(2a(1-\theta^*)(-3-n+(2+n)\theta^*)+(8+3n-4(2+n)\theta^*+(2+n)\theta^{*2})g_e)\} \end{array}\right]}{2(n+2-(n+1)\theta^*)^2}. \tag{18}$$

Consider $a = 10$, $n = 2$, $g_e = 0.4$ and $g_0(\theta) = \beta\theta$, where $\Gamma' = \beta < 1$ denotes the efficiency-enhancing parameter. Using β's separately with the values of 0.3, 0.43, and 0.5 in $g_0(\theta)$, we can numerically show that the optimal values of θ^* are 0.988, 0.931, and 0.885, respectively. In relation to the associated level of θ^*, $g_0(\theta^*)$is thus 0.296, 0.400, and 0.443, respectively, which represents three possible scenarios ($g_0(\theta^*) \gtreqless g_e$) when privatization is implemented in the short run. Optimally, we also obtain the following results: $Q|_{g_0(\theta^*)<g_e} = 9.589$, $Q|_{g_0(\theta^*)=g_e} = 9.050$ and $Q|_{g_0(\theta^*)>g_e} = 8.749$. It, therefore, follows that $Q^S|_{g_0(\theta^S)<g_e} > Q^S|_{g_0(\theta^S)=g_e} > Q^S|_{g_0(\theta^S)>g_e}$, thus confirming Proposition 2.

In Fig. 2, we illustrate the equilibrium configuration of social welfare for three scenarios: $W^*|_{g_0(\theta^*)<g_e} \equiv W_1^*$, $W^*|_{g_0(\theta^*)=g_e} \equiv W_2^*$, and $W^*|_{g_0(\theta^*)>g_e} \equiv W_3^*$.

Evidently, if privatization cannot sufficiently enhance an SOE's production efficiency to be better than that of private firms, $W^*|_{g_0(\theta^*)>g_e}$is the worst. If the efficiency-enhancing parameter is sufficiently large (for instance, $\beta = 0.5$ in the present case), the change to the level of privatization, θ, will have a weak influence on the output, as shown in Proposition 1. Ultimately, the magnitude of welfare improvement will be reduced.

In the short run, a higher level of privatization sharply decreases the total output and intensifies the market. Once the SOE becomes the most efficient firm in the market, the

output substitution effect occurs from private firms to the SOE and the magnitude of the *efficiency-enhancing effect* influences the output substitute. The following proposition characterizes these findings:

Proposition 4 *In the short run, the form of a state-owned enterprise's cost function matters concerning the extent of optimal social welfare. If the efficiency-enhancing effect is sufficiently small, then the magnitude of welfare improvement is reduced.*

In the long run, which is associated with the zero profit conditions of private firms, the presence of Γ' reduces the magnitude of $(\partial q_0^L/\partial\theta^L)$in Eq. (9). In other words, when privatization occurs, the magnitude of the reduction of q_0^L is relatively small compared to cases where Γ' is absent. A decrease in Γ'reduces an SOE's marginal cost and subsequently increases social welfare; that is,$W^L|_{g_0(\theta^L)<g_e} > W^L|_{g_0(\theta^L)=g_e} > W^L|_{g_0(\theta^L)>g_e}$, where W^L denotes social welfare in the long run. Thus, we have the following corollary:

Corollary 2 *In the long run, associated with zero-profit conditions of private firms, social welfare increases as a state-owned enterprise becomes more efficient in its production through the implementation of partial privatization.*

4 Some discussions on an excessive entry

Is free entry socially desirable? In an influential work, Mankiw and Whinston (1986) revealed that the answer to this question is generally negative in an oligopolistic market with homogeneous products and scale economies, thus creating the rationale for anti-competitive entry regulation in certain markets. The reason for "excess entry" in their work is the business stealing effect of entry. A business stealing effect reduces the equilibrium output of each firm—as the number of firms increase, so does mixed oligopoly (see e.g., Ino and Matsumura 2010; Bennett and La Manna 2012). Therefore, if we totally differentiate first-order conditions with respect to q_0, q_n and n,[19] we can obtain:

$$\tilde{A}_{11}dq_0 + \tilde{A}_{12}dq_n = -P'q_n[1-(1-\theta)\eta s_0]dn, \tag{19}$$

$$\tilde{A}_{21}dq_0 + \tilde{A}_{22}dq_n = -P'q_n(1-\eta s_n)dn, \tag{20}$$

where $\tilde{A}_{11} = (1-\theta)P'(1-\eta s_0)+P'$, $\tilde{A}_{12} = nP'[1-(1-\theta)\eta s_0]$, $\tilde{A}_{21} = P'(1-\eta s_n)$ and $\tilde{A}_{22} = nP'(1-\eta s_n)+P'$.

Applying also Cremer's rule, we obtain the comparative statics as:

$$\frac{dq_0}{dn} = \frac{-P'P'q_n[1-(1-\theta)\eta s_0]}{\tilde{\Delta}} < 0, \text{ and} \tag{21}$$

[19] The reason for selecting q_n is as we explained in footnote 10.

$$\frac{dq_n}{dn} = \frac{-P'P'q_n(1-\theta)(1-\eta s_n)}{\tilde{\Delta}} < 0 \tag{22}$$

where $\tilde{\Delta} = P'P'[n(1-\theta)(1-\eta s_n) + (1-\theta)(1-\eta s_0) + 1] > 0$.

If the government requires an entry regulation, $\max_n W(n)$, we obtain:

$$\begin{aligned}\frac{\partial W(n)}{\partial n} &= \frac{\partial CS(n)}{\partial n} + \frac{\partial \pi_0(n)}{\partial n} + \frac{\partial n\pi_n(n)}{\partial n} + F \\ &= (Pq_n - g_e q_n) + (P - g_0)\frac{\partial q_0(n)}{\partial n} + n(P - g_e)\frac{\partial q_n(n)}{\partial n} + F \\ &= \pi_n + (P - g_0)\frac{\partial q_0(n)}{\partial n} + n(P - g_e)\frac{\partial q_n(n)}{\partial n} + 2F = 0. \end{aligned} \tag{23}$$

Suppose $n^L$is optimal in Eq. (23) for the maximization of social welfare. If the government sets $n^{**} \geq n^L$, private firms enter the market in a free entry scenario until the zero-profit conditions hold. Notice that n^L is the number of private entrants in the long-run. Then, entry regulation fails and the optimal outcomes will directly be the ones we obtained in the long-run case. Given our assumptions, welfare function in terms of n is strictly concave. From Eq. (23) together with Eqs. (21) and (22), it is apparent that if $n = n^L$, $\pi_x|_{n=n^L} = 0$ and $\frac{\partial W(n)}{\partial n}|_{n=n^L}$is negative.[20] On the other hand, $\pi_i|_{n=n^{**}\in(1,n^L)} > 0, i = 1, \ldots, n$, and $\frac{\partial W^*(n)}{\partial n}|_{n=n^{**}} = 0$. It implies that $W|_{n=n^{**}} > W|_{n=n^L}$, where $n^{**} \in (1, n^L)$, and an excess entry exists in a mixed oligopoly. Ghosh and Saha (2007) pointed out that under economies of scale, ignorance of cost asymmetry leads to an entry regulation policy that may be regarded as quantitatively wrong. Welfare loss due to a shift in output from an incumbent firm to an entrant complements the negative effect of entry due to economies of scale. In a mixed oligopoly, cost asymmetry results from different objectives set by the SOE and the private firm. As we analyzed the mechanism in Sect. 3, once the efficiency-enhancing effect occurs as privatization proceeds, the cost asymmetry and cost differentials among firms will be endogenously determined. As a result, partial privatization for a state-owned enterprise can be an indirect instrument of entry regulation.

5 Concluding remarks

To consider a reform of a state-owned enterprise, privatization is a way for the government to improve the production efficiency and maintain a desirable social welfare. In the quantity setting mixed market, privatization makes following three effects: welfare-reducing effect, output substitution effect, and efficiency-enhancing effect. In Matsumura (1998), welfare-reducing effect and output substitution effect are argued. In addition to these two effects, we in this paper present an in depth analysis of

[20] If F is very large so that $\frac{\partial W(n)}{\partial n}|_{n=n^L}$ is non-negative, we then face no excessive entry problem, and the optimal outcomes is identical as the one obtained in the long-run case.

efficiency-enhancing effect. To achieve the purpose, we constructed a model with the connection between the level of privatization and the efficiency improvement of the state-owned enterprise, and elaborated the mechanism of efficiency improvement of partial privatization in the short-run and in the long-run, respectively.

In the short run, we showed that if the partial privatization of the state-owned enterprise is made to improve its production efficiency being better than that of all private entrants, the total output will be higher, leading to a higher consumer surplus. When privatization occurs, the total output decreases. An efficiency-enhancing effect subsequently reduces the extent of the output substitution effect from an inefficient firm to an efficient firm. Specifically, if the effect of efficiency improvement is small enough, the magnitude of the improvement of social welfare is reduced.

In the long run, in association with private competitors' zero-profit conditions, through privatization, the efficiency-enhancing effect reduces the marginal cost of the state-owned enterprise, consequently improving producer surplus as well as social welfare. As a result, the optimal policy for a state-owned enterprise is partial privatization instead of full nationalization, which is totally different from the argument in Matsumura and Kanda (2005). Furthermore, the efficiency-enhancing effect resulting from privatizing a state-owned enterprise can function as an indirect entry regulation for determining the optimal number of private entrants.

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