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Revenue-Neutral Tax Reform in Vertically Related Markets

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Abstract

This paper examines the effects of a tax reform when final goods are produced in an oligopoly and intermediate goods are produced in monopolistic competition. In particular, we address the effect of a shift from upstream to downstream taxation that leaves government revenue unchanged. This tax reform raises the consumer and producer prices of final goods, lowers the demand price of intermediate goods, and has no effect on the producer price of intermediate goods. Finally, we find that welfare improves with this tax reform.

Keywords: Tax, Final Goods, Intermediate Goods, Oligopoly, Monopolistic Competition, Tax Incidence, Welfare.

JEL classification: D43, H21, H22, L13.

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1 Introduction

The effects of taxation on incidence and welfare are the central issues in public economics. While there are many questions in taxation theory, one practical question is how to design the tax system when the government faces a budget constraint. If the government is to supply a variety of public services and remedy income inequality, it needs a certain level of tax revenue. Under this motivation, two approaches have been developed.[1] The first approach characterizes optimal taxation by assuming that the welfare-maximizing government chooses tax rates so as not to decrease tax revenue.[2] The second approach examines the welfare effect of the change in multiple tax rates that leaves tax revenue unchanged.[3] Both of these approaches provide useful answers to the question raised above, but the optimal taxation theory has been criticized because it is almost impossible for the government to correctly know the necessary information on consumer preferences and production technologies. The tax reform theory complements this limitation of the optimal taxation theory.

This paper examines the effects of revenue-neutral tax reform in vertically related industries. One notable difference from the existing literature is that we assume an oligopoly in the final goods industry and monopolistic competition in the intermediate goods industry. There are two reasons for considering the revenue-neutral tax reform and the above-mentioned market structure. First, there is no literature that examines the revenue-neutral tax reform in this case, except for Colangelo and Galmarini (2001). Second, there is evidence that supports our modelling.

[1] See, for example, Atkinson and Stiglitz (2015) and Salanie (2011) for a comprehensive account.

[2] Instead of welfare, the government's objective is assumed to be the weighted sum of welfare and campaign contribution in the political economy literature.

[3] Depending on the purpose of the paper, different constraints are assumed. For example, Keen and Ligthart (2002, 2005) consider the change in import tariff and domestic tax that keeps the consumer price constant. In other words, these authors stress the tax reform such that consumer's utility remains unchanged.

Referring to the evidence of the *Economist*, Shapiro (2018) lists several examples of industries that experience a rise in the four-firm concentration ratio from 1997 to 2012.[4] Grullon et al. (2019) also provides evidence that during the same period the Herfindahl-Hirschman index has risen in more than 75% of US industries (mainly manufacturing industries), and that the average increase in concentration levels has reached 90%. While the above evidence concerns the final goods industry, there is an empirical literature finding that monopolistic competition well describes the intermediate goods industry. For instance, Liu et al. (2013, p. 740) empirically show that 'China's construction industry is in monopolistic competition' from 2009 to 2011. Apergis and Polemis (2015, p. 6) add further evidence showing monopolistic competition in several intermediate goods industries.

These data justify the situation in which the downstream industry is oligopolistic and the upstream industry is monopolistically competitive. And, we assume that both final and intermediate goods are taxed. The main results are as follows. First, the revenue-neutral shift from intermediate goods taxes to final goods taxes lowers both the consumer and producer prices of final goods. And, the demand price of intermediate goods falls, but the producer price of intermediate goods is unaffected by this policy reform. Second, this tax reform raises welfare.

This paper draws on the literature on commodity taxation under imperfect competition.[5] The literature is so large that we list two closely-related papers. Delipalla and Keen (1992) develop a homogeneous good Cournot model to examine the revenue-neutral tax shift from specific to ad valorem taxation. While Delipalla and Keen (1992) assume a homogeneous good, Anderson et al. (2001a, b) consider how product differentiation, the mode of competition (Cournot or Bertrand) and free entry affect Delipalla and

[4] The Economist, 26 March 2016, "Too Much of a Good Thing," available at https://www.economist.com/news/briefing/21695385-profits-are-too-high-america-needs-giant-dose-competition-too-much-good-thing.

[5] Keen (1998) provides a comprehensive survey.

Keen's (1992) result. Anderson et al. (2001b) show that specific taxation can involve higher welfare than ad valorem taxation in a free entry Bertrand oligopoly.

The literature introduced above focuses on final goods taxation, but Konishi (1990), Colangelo and Galmarini (2001) and Peitz and Reisinger (2014) allow for a vertical market.[6] Assuming perfect competition in the upstream industry and a free entry oligopoly in the downstream industry, Konishi (1990) finds that intermediate goods taxation raises welfare. The comparison with the other papers is given in Table 1. Assuming a free entry oligopoly both in the upstream and downstream industries, Peitz and Reisinger (2014) demonstrate that ad valorem taxation for the downstream industry is the most efficient. It should be noted that Peitz and Reisinger (2014) ignore the government's budget constraint.

(Table 1 around here)

Colangelo and Galmarini (2001) are the most closely-related paper. In contrast to Peitz and Reisinger (2014), they assume a restricted entry oligopoly in both industries. As mentioned earlier, Colangelo and Galmarini (2001) are the only paper to examine the revenue-neutral tax reform in vertically related markets. Their novel result is that the revenue-constrained government should tax final goods and subsidize intermediate goods. There are two differences among Colangelo and Galmarini (2001), Peitz and Reisinger (2014) and this paper. First, as Table 1 shows, we assume that the number of final goods firms is exogenous and that the number (mass) of intermediate goods is endogenous. This modelling reflects the empirical evidence noted earlier. Second, we allow product differentiation of both final and intermediate goods while the above two authors assume homogeneous goods.

[6] In a context of environmental economics, Sugeta and Matsumoto (2007) show that a tax shift from intermediate goods to final goods raises welfare.

This paper is organized as follows. Section 2 presents a model. Sections 3 and 4 consider the effects of the revenue-neutral tax reform on incidence and welfare, respectively. Section 5 concludes.

2 Model

This section presents the model. Since our model is seemingly complicated, we begin by listing the assumptions.

1. A representative consumer consumes horizontally differentiated goods and a homogeneous good. The homogeneous good serves as a numeraire good, and its price is normalized to one.

2. Labor is the only primary factor of production.

3. One unit of labor produces one unit of the numeraire good under perfect competition. Hence, from the profit maximizing condition, the wage rate is equal to one.

4. Each differentiated good is produced by assembling a variety of intermediate goods under the CES technology.

5. Each intermediate good is produced from labor with constant marginal cost and fixed cost.

6. Downstream (final goods) firms choose output under Cournot oligopoly, taking the intermediate goods prices as given. The number of downstream firms is exogenously given.

7. Upstream (intermediate goods) firms choose output/price in monopolistic competition.

8. An ad valorem commodity tax is imposed on final and intermediate goods.

9. Profits of downstream firms and tax revenue are redistributed to the consumer in a lump-sum fashion.

Based on these assumptions, we will derive the equilibrium.[7]

2.1 Consumer Behavior

The representative consumer chooses consumption to maximize utility. As to the consumer's preference, we follow Pflüger (2001, 2004) and Haufler and Pflüger (2004), and assume a quasi-linear utility function. Noting Assumption 1 above, we consider the following utility maximization problem.

$$\max \quad \ln Y + z, \quad Y \equiv \left(\sum_{i=1}^{n} y_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \quad \sigma > 1, \tag{1}$$

$$\text{s.t.} \quad \sum_{i=1}^{n} p_i y_i + z = I, \tag{2}$$

where Y is the quantity index, $n \geq 1$ is the number of differentiated goods, y_i is consumption of variety i, z is consumption of homogeneous good, p_i is the consumer price of variety i, and I is national income. σ is the elasticity of substitution among differentiated goods.

Solving the above problem yields the inverse demand and demand functions of variety i:

$$p_i = \frac{y_i^{-\frac{1}{\sigma}}}{\sum_{i=1}^{n} y_i^{\frac{\sigma-1}{\sigma}}}, \quad y_i = \frac{p_i^{-\sigma}}{\sum_{i=1}^{n} p_i^{1-\sigma}}. \tag{3}$$

We now introduce the price index of differentiated goods P.

$$P \equiv \left(\sum_{i=1}^{n} p_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}}. \tag{4}$$

This price index plays a useful role in welfare analysis, and has the following property.

$$\sum_{i=1}^{n} p_i y_i = PY = 1.$$

[7]Robustness of the main result is in alternative assumptions is left in Supplementary Note.

2.2 Final Goods Industry

The unit cost function of downstream firms is assumed to be

$$Q \equiv \left(\int_0^m q_j^{1-\eta} dj \right)^{\frac{1}{1-\eta}}, \quad \eta > 1,$$

where m is the mass of intermediate inputs, q_j is the price of intermediate good j, and η is the elasticity of substitution among intermediate inputs. Then, the profit of downstream firm i is defined by

$$\pi_i \equiv \frac{p_i y_i}{1+t} - Q y_i,$$

where t is an ad valorem tax rate on the final goods, and the inverse demand function is given by (3). Noting Assumption 6 above, maximizing this profit with respect to y_i, we obtain the per-firm output, industry output and consumer price as follows.

$$y = \frac{(\sigma-1)(n-1)}{(1+t)\sigma n^2 Q}, \quad ny = \frac{(\sigma-1)(n-1)}{(1+t)\sigma n Q}, \quad p = \frac{(1+t)\sigma n Q}{(\sigma-1)(n-1)}. \tag{5}$$

2.3 Intermediate Goods Industry

Utilizing (5), we now characterize the equilibrium in the intermediate goods market. Applying Shephard's Lemma to the unit cost function Q, the market-clearing condition of intermediate good j becomes

$$\begin{aligned} &\underbrace{\frac{1}{1-\eta} \left(\int_0^m q_j^{1-\eta} dj \right)^{\frac{1}{1-\eta}-1} (1-\eta) q_j^{-\eta} ny}_{\text{demand}} \\ = \ & Q^\eta q_j^{-\eta} \frac{(\sigma-1)(n-1)}{(1+t)\sigma n Q} = \frac{(\sigma-1)(n-1)q_j^{-\eta}}{(1+t)\sigma n Q^{1-\eta}} = \underbrace{x_j}_{\text{supply}}, \end{aligned} \tag{6}$$

where x_j is supply of intermediate good j.

As assumed in Assumption 7 above, monopolistic competition prevails in the upstream industry. Upstream firms choose either price or output by taking the price index Q as given, and free entry drives profit to zero. Each firm produces one variety of intermediate good with marginal cost $c > 0$ and fixed cost $f > 0$. Summarizing these assumptions, the profit of firm j is defined by

$$\pi_j \equiv \frac{q_j x_j}{1+\tau} - c x_j - f,$$

where τ is an ad valorem tax on the intermediate goods.

As in Dixit and Stiglitz (1977) and Ethier (1982), the first-order condition for profit maximization, the zero profit condition, and the market-clearing condition (6) jointly determine the price, output and mass of intermediate goods. The closed form of these variables is derived as follows.

$$q = \frac{(1+\tau)\eta c}{\eta - 1}, \quad x = \frac{(\eta - 1) f}{c}, \quad m = \frac{(\sigma - 1)(n-1)}{(1+t)(1+\tau)\sigma\eta n f}. \tag{7}$$

This completes the description of our model. Once q, x and m are determined in (7), all the other endogenous variables are obtained by substituting (7).

3 Incidence of the Revenue-Neutral Tax Reform

Making use of the model above, we explore the effects of a tax reform. As mentioned in Introduction, keeping a certain level of tax revenue is arguably the most important concern from the government's point of view. For this reason, this paper focuses on an increase in the final goods tax and a decrease in the intermediate goods tax that leave total tax revenue unchanged.

Total tax revenue T is defined as follows.

$$T = n\frac{tp}{1+t}y + m\frac{\tau q}{1+\tau}x = \frac{t}{1+t} + \frac{(\sigma-1)(n-1)\tau}{(1+t)(1+\tau)\sigma n},$$

where the first term in the middle and last equations is the revenue from downstream taxation, and the second term is the revenue from upstream taxation. Note that the last equation is obtained by substituting (7) and (5). Totally differentiating T and setting the resulting expression to zero, the revenue-neutral tax reform requires that $dT = (\partial T/\partial t)dt + (\partial T/\partial \tau)d\tau = 0$. Rearranging this equation, we have

$$d\tau = -\frac{\partial T/\partial t}{\partial T/\partial \tau}dt = -\frac{(1+\tau)[\sigma n(1+\tau) - (\sigma-1)(n-1)\tau]}{(\sigma-1)(n-1)(1+t)}dt. \qquad (8)$$

This is the rule of the revenue-neutral tax reform. Eq. (8) suggests that the upstream tax must be lowered ($d\tau < 0$) if the government raises the downstream tax ($dt > 0$) and keeps tax revenue constant. In what follows, we assume this case: the other polar case is considered just by reversing the sign of dt.

The reason for the opposite sign of dt and $d\tau$ is as follows.[8] In our model, final goods taxation not only influences the final goods market but also influences the intermediate goods market by changing the downstream firms' demand for intermediate goods. When the government raises t, revenue from final goods tax and that from intermediate goods tax as follows. First, due to the assumption of constant elasticity demand, the consumer's total expenditure (npy) remains constant. Thus, as a direct effect, revenue from final goods tax increases. Second, an increase in t reduces the downstream firms' demand for intermediate goods and the mass of intermediate goods. But, from Eq. (7) the price and output of intermediate goods does not change. As a result of this indirect effect, revenue from intermediate goods tax decreases with t. Summing these conflicting effects up, total tax revenue rises with t since the direct effect dominates the indirect effect.

As explained above, final goods taxation influences revenue from final goods tax and that from intermediate goods tax. In contrast, this is not the case of intermediate goods taxation. Any tax change has no effect on the consumer's total expenditure because of the constant demand elasticity. And, the same observation is true of the total expenditure for intermediate goods (mqx). This is because the CES unit cost function is assumed. Therefore,

[8] Eq. (24) in Colangelo and Galmarini (2001, p. 61) also shows a similar result in the context of vertical oligopoly.

as a direct effect, an increase in τ monotonically increases revenue from intermediate goods taxation and total tax revenue. In summary, tax revenue increases with t and/or τ, and hence these taxes must change in the opposite way in order to freeze total tax revenue.

Before proceeding further, it is convenient to identify the effect of the above tax reform on $(1+t)(1+\tau)$ because it will often appear in the subsequent analysis.

Lemma 1 $(1+t)(1+\tau)$ decreases under the revenue-neutral shift from intermediate goods taxation to final goods taxation.

Proof. Totally differentiating $(1+t)(1+\tau)$ and substituting (8), we have

$$\begin{aligned} d[(1+t)(1+\tau)] &= (1+\tau)dt + (1+t)d\tau \\ &= -\frac{(\sigma+n-1)(1+\tau)^2}{(\sigma-1)(n-1)}dt < 0. \end{aligned}$$

||

We now explain why the revenue-neutral tax reform reduces $(1+t)(1+\tau)$. As mentioned earlier, final goods taxation changes tax revenue through two channels, but intermediate goods taxation does not. That is, an increase in t raises total tax revenue by affecting revenue from final goods tax and that from intermediate goods tax. By contrast, an increase in τ raises total tax revenue by raising revenue from intermediate goods tax only. Therefore, if the government raises t and lowers τ by the same amount, total tax revenue increases. In order to offset the effect of raising t, the government must lower τ by a larger amount.

In the rest of this section, we examine how the revenue-neutral tax reform affects the prices of final and intermediate goods. We begin with the tax incidence on final goods prices. Substituting (7) into (5), the consumer price of final goods is expressed by

$$
\begin{aligned}
p &= \frac{(1+t)\sigma n m^{\frac{1}{1-\eta}} q}{(\sigma-1)(n-1)} \\
&= \frac{(1+t)\sigma n}{(\sigma-1)(n-1)} \left[\frac{(\sigma-1)(n-1)}{(1+t)(1+\tau)\sigma\eta n f}\right]^{\frac{1}{1-\eta}} \frac{(1+\tau)\eta c}{\eta-1} \\
&= [(1+t)(1+\tau)]^{\frac{\eta}{\eta-1}} \left[\frac{\sigma\eta n}{(\sigma-1)(n-1)}\right]^{\frac{\eta}{\eta-1}} \frac{c f^{\frac{1}{\eta-1}}}{\eta-1}.
\end{aligned}
$$

The price that the final goods producer receives is given by

$$
\frac{p}{1+t} = (1+t)^{\frac{1}{\eta-1}}(1+\tau)^{\frac{\eta}{\eta-1}} \left[\frac{\sigma\eta n}{(\sigma-1)(n-1)}\right]^{\frac{\eta}{\eta-1}} \frac{c f^{\frac{1}{\eta-1}}}{\eta-1}.
$$

Using these definitions of consumer and producer prices, the effect of the revenue-neutral tax reform on them is stated as follows.

Proposition 1 Both the consumer and producer prices of final goods decrease under the revenue-neutral shift from intermediate goods taxation to final goods taxation.

Proof. It follows from $\eta/(\eta-1) > 0$ that the consumer price increases with $(1+t)(1+\tau)$. Relating this result to Lemma 1, p also declines.

The tax reform affects the producer price only through the term $(1+t)^{\frac{1}{\eta-1}}(1+\tau)^{\frac{\eta}{\eta-1}}$. Therefore, all we have to do is to totally differentiate it and substitute (8) into the resulting expression. Then, we obtain

$$
\begin{aligned}
d\left[(1+t)^{\frac{1}{\eta-1}}(1+\tau)^{\frac{\eta}{\eta-1}}\right] &= \frac{1}{\eta-1}(1+t)^{\frac{2-\eta}{\eta-1}(1+\tau)^{\frac{\eta}{\eta-1}}} dt + \frac{\eta}{\eta-1}(1+t)^{\frac{1}{\eta-1}}(1+\tau)^{\frac{1}{\eta-1}} d\tau \\
&= -\frac{[\sigma(\eta-1)n + (\sigma+n-1)(1+\eta\tau)](1+t)^{\frac{2-\eta}{\eta-1}}(1+\tau)^{\frac{\eta}{\eta-1}}}{(\sigma-1)(\eta-1)(n-1)} dt < 0,
\end{aligned}
$$

because the coefficient of dt in the last equation is positive. ||

The intuitions for Proposition 1 are as follows. The effect on the consumer price is so straightforward that we need no further explanation. In contrast, the effect on the producer price of final goods is less transparent than that on the consumer price. In order to neutralize the effect on tax revenue, the government lowers τ by more than the initial increase in t as shown in Lemma 1. This reform reduces unit cost of final goods firms Q.[9]

We now turn to the effect of the revenue-neutral tax reform on the prices of intermediate goods. The demand price of intermediate goods is $q = (1 + \tau)\eta c/(\eta - 1)$, and the producer price is $q/(1+\tau) = \eta c/(\eta - 1)$ in equilibrium.[10] These expressions of intermediate goods prices lead to:

Proposition 2 The demand price of intermediate goods decreases, and the producer price of intermediate goods is unchanged under the revenue-neutral shift from intermediate goods taxation to final goods taxation.

This result is interpreted as follows. As Eq. (7) indicates, the final goods tax affects the upstream industry just by affecting the mass of intermediate goods. In other words, the producer price of intermediate goods is equal to marginal cost multiplied by the constant markup $1/(\eta - 1)$. So, it is independent of any tax, and thereby q is affected by τ only. Since the tax reform reduces τ, the demand price of intermediate goods falls.

4 Welfare Effect

This section examines the welfare effect of the revenue-neutral tax reform. Since the direct utility function is given by (1), indirect utility or welfare W is obtained as[11]

$$W = \ln\left(\frac{1}{P}\right) + I - 1 = -\ln\left(n^{\frac{1}{1-\sigma}} p\right) + I - 1 = \frac{1}{\sigma - 1}\ln n - \ln p + I - 1, \quad (9)$$

[9] The revenue-neutral tax reform reduces the unit cost of downstream firms $Q = m^{1/(1-\eta)}q$ because both $m^{1/(1-\eta)}$ and q fall under the reform.

[10] We use the term 'demand price,' instead of 'consumer price' to avoid unnecessary misleading because the consumer does not buy intermediate goods.

[11] Recall that the oligopolistic firms' profits and tax revenue are redistributed to the consumer in a lump-sum way.

where the last two equations follow from Eq. (4). In the right-hand side, the first two terms represent the consumer surplus. Invoking the preceding arguments on the tax incidence, the consumer price of final goods depends on the two tax rates as follows.

$$p = [(1+t)(1+\tau)]^{\frac{\eta}{\eta-1}} \left[\frac{\sigma\eta n}{(\sigma-1)(n-1)}\right]^{\frac{\eta}{\eta-1}} \frac{cf^{\frac{1}{\eta-1}}}{\eta-1}.$$

Since the revenue-neutral tax reform reduces the consumer price of final goods from Proposition 1, the consumer surplus increases.

In contrast, the effect on the profit of each downstream firm and the downstream industry is shown to be negative. To see this, let us rewrite the per-firm profit as follows.

$$\pi_i = \left(\frac{p}{1+t} - Q\right) y = \frac{\sigma n - (\sigma-1)(n-1)}{\sigma n^2(1+t)},$$

where the right-hand side follows by utilizing (5). It is obvious from this expression that the profit of each firm and the final goods industry decreases with the suggested tax reform.

By the definition of the reform, tax revenue is unchanged. Accordingly, the revenue-neutral tax reform increases consumer surplus and decreases aggregate profits of the final goods industry. Despite these conflicting effects, we can establish that welfare improves under this reform. To this end, let us derive the closed form of national income I:

$$I = L + \frac{\sigma n(1+t) - (\sigma-1)(n-1)}{\sigma n(1+t)} + \frac{(\sigma-1)(n-1)\tau}{(1+t)(1+\tau)\sigma n}.$$

Substituting the above expressions of p and I into (9) and rearranging terms, welfare depends on the two tax rates as follows.

$$W = -\frac{\eta}{\eta-1}\ln[(1+t)(1+\tau)] - \frac{(\sigma-1)(n-1)}{(1+t)(1+\tau)\sigma n} + const. \qquad (10)$$

where $const. \equiv L + \frac{1}{\eta-1}\ln\left[\frac{(\sigma-1)(n-1)}{\sigma\eta n f}\right] - \ln\left[\frac{\sigma\eta n c}{(\sigma-1)(\eta-1)(n-1)}\right] + \frac{1}{\sigma-1}\ln n.$

Relating this welfare measure to (8), we establish:

Proposition 3 Welfare increases under the revenue-neutral shift from intermediate goods taxation to final goods taxation.

Proof. Differentiating (10) with respect to $(1+t)(1+\tau)$, we have

$$\begin{aligned}\frac{dW}{d[(1+t)(1+\tau)]} &= -\frac{\eta}{(\eta-1)(1+t)(1+\tau)} + \frac{(\sigma-1)(n-1)}{\sigma n[(1+t)(1+\tau)]^2} \\ &= -\frac{\sigma\eta n(1+t)(1+\tau) - (\sigma-1)(\eta-1)(n-1)}{\sigma(\eta-1)n[(1+t)(1+\tau)]^2} < 0.\end{aligned}$$

From Lemma 1, the revenue-neutral tax reform reduces $(1+t)(1+\tau)$. Consequently, the above inequality implies that the suggested tax reform raises welfare. ||

As mentioned before, the reform-induced increase in consumer surplus tends to raise welfare, but the decrease in aggregate downstream profits tends to lower welfare. However, the positive effect on consumer surplus dominates the negative effect on aggregate downstream profits, and hence the proposed tax reform is welfare-enhancing.

In order to better understand Proposition 3, it is useful to characterize the first-best solution of our model.[12] Following Dixit and Stiglitz (1977) and Suzumura and Kiyono (1987), the first-best is defined by[13]

$$\max_{y,x,q,m} \quad \underbrace{\ln\left(n^{\frac{\sigma}{\sigma-1}}y\right) - npy}_{\text{consumer surplus}} + \underbrace{n\left(py - m^{\frac{1}{1-\eta}}qy\right)}_{\text{final good firms' profit}} + \underbrace{m(qx - cx - f)}_{\text{intermediate good firm's profit}} + \underbrace{L}_{\text{labor income}}.$$

[12]This explanation is highly draws on the suggestions of the referees.

[13]Note that the tax terms are absent in this objective function from the assumption that tax revenue is redistributed to the consumer. In other words, this objective function is obtained even if the tax rates are non-zero.

The first-order conditions for this maximization problem are

$$
\begin{aligned}
0 &= \frac{1}{y} - nm^{\frac{1}{1-\eta}}q && (11)\\
0 &= q - c && (12)\\
0 &= \frac{-1}{1-\eta}nm^{\frac{1}{1-\eta}-1}qy + qx - cx - f && (13)\\
0 &= -nm^{\frac{1}{1-\eta}}y + mx. && (14)
\end{aligned}
$$

Eq. (11) means equalization of marginal utility and marginal cost with respect to y. Eq. (20) is marginal cost pricing of intermediate goods. Eq. (13) means equalization of marginal benefit and marginal cost with respect to m. Eq. (14) is market-clearing of intermediate goods. Solving these equations, the first-best allocation is[14]

$$
y = \frac{[(\eta-1)f]^{-\frac{1}{\eta-1}}}{nc}, \quad x = \frac{(\eta-1)f}{c}, \quad q = c, \quad m = \frac{1}{(\eta-1)f}. \tag{15}
$$

Using y above, the first-best price of final goods becomes

$$
p = \frac{1}{ny} = c[(\eta-1)f]^{\frac{1}{\eta-1}}. \tag{16}
$$

Not surprisingly, the right-hand side of (16) is marginal cost of final goods, and hence both final and intermediate goods are priced at marginal cost. In contrast, the market equilibrium value of q, m, x and p is given by (5) and (7). Comparing the first-best and market equilibrium, the mass of intermediate goods is smaller and the price of final and intermediate goods is higher in the market equilibrium than in the first-best.

In order to correct for the insufficient mass of intermediate goods, the government needs to cut taxes for intermediate goods. And, the government must raise the final goods tax to finance the tax cut for intermediate goods. A similar conclusion is proved in Corollary 2 of Colangelo and Galmarini

[14]The same value of x and m is obtained if we solve the second-best problem in which the government chooses only m, taking as given non-competitive pricing of final and intermediate goods.

(2001, p. 65), where the revenue-neutral tax reform should consist of final goods taxation and intermediate goods subsidization. Final goods taxation alone is welfare-reducing because it raises the final goods price. However, the tax cut for intermediate goods compensates this negative welfare effect. This is because the cut of intermediate goods tax reduces marginal cost of final goods by raising the mass of intermediate goods and lowering their price. In addition, as Lemma 1 claims, the revenue-neutrality requires that the magnitude of tax cut for intermediate goods be larger than the tax increase for final goods. As a result of these observations, the final goods price falls under our tax reform (Proposition 1). Summarizing these arguments, the revenue-neutral tax reform corrects for both the insufficient mass of intermediate goods and the distortion from monopolistic pricing of final goods firms. Therefore, by making the market equilibrium closer to the first-best, welfare improves under the reform.

5 Concluding Remarks

Assuming an oligopoly in the downstream industry and monopolistic competition in the upstream industry, this paper has explored the effects of the revenue-neutral shift from upstream taxation to downstream taxation. First, this tax reform reduces the consumer and producer prices of final goods. Second, it reduces the demand price of intermediate good, and has no effect on the producer price of intermediate goods. Third, welfare improves with this tax reform.

As noted in Introduction, to our knowledge, there is no literature that analyzes the effects of the revenue-neutral tax reform in vertically related markets, except for Colangelo and Galmarini (2001). While Colangelo and Galmarini (2001) assume that both downstream and upstream industries are oligopolistic, and hence firms make positive profits. And, they assume away product differentiation. Instead, we have assumed that the intermediate goods market is monopolistically competitive, and all goods are differentiated. It is beyond the scope of this paper whether our model and assumptions describe the reality better than the previous papers, but we hopefully believe that we have provided an interesting insight into theoretical analyses of taxation.

However, we must recognize the limitations of this paper. First, we have used the CES function of the consumer's subutility and unit cost of final goods. This specification allows us to facilitate analysis and get the closed-form solutions of equilibrium. Second, we have resorted to a partial equilibrium analysis under the assumption of quasi-linear preference. If we take account of the income effect on the final goods demand, our results may be invalid. Third, we have employed the model of homogeneous firms, but it is theoretically and empirically well-established that firm heterogeneity plays a key role in shaping the industry structure since Melitz (2003). It is the future research agenda to enrich our analysis by taking into account of these limitations.

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	# of final good firms	# of intermediate goods firms
Colangelo & Galmarini (2001)	exogenous	exogenous
Peitz & Reisinger (2014)	endogenous	endogenous
This paper	exogenous	endogenous

Table 1:

Supplementary Note

The results in the main text are based on restrictive assumptions. This note discusses the robustness of the results in alternative settings.

Bertrand Oligopoly

It is the most important concern whether the above results survive a Bertrand downstream oligopoly. The Bertrand equilibrium price is given by

$$p = \frac{(1+t)(\sigma n - \sigma + 1)Q}{(\sigma - 1)(n-1)}.$$

In other words, the markup is $\sigma n/(\sigma-1)(n-1)$ and $(\sigma n-\sigma+1)/(\sigma-1)(n-1)$ in Cournot and Bertrand competition, respectively. Therefore, our results straightforwardly hold in both the Cournot and Bertrand cases.

Endogenous Number of Downstream Firms

While we have treated n as an exogenous variable, we now endogenize it. With this endogenization of n, the welfare effect of the revenue-neutral tax reform is shown to be ambiguous. To see this, denote by $F > 0$ the fixed cost of final goods firms. Then, the maximized profit per-firm becomes

$$\pi = \frac{\sigma n - (\sigma-1)(n-1)}{(1+t)\sigma n^2} - F.$$

Setting π to zero, we have a quadratic equation of n, and its solution is manipulated as

$$n = \frac{1+\sqrt{A}}{2(1+t)\sigma F}, \quad A \equiv 1 + 4(1+t)\sigma(\sigma-1)F > 0. \tag{17}$$

Differentiating this with respect to t yields

$$\frac{dn}{dt} = -\frac{2(1+t)\sigma(\sigma-1)F + \sqrt{A}}{2(1+t)^2\sigma F\sqrt{A}} dt < 0.$$

That is, the number of final goods firms decreases with t. Substituting (17) into m in (7), the mass of intermediate goods firms is given by

$$m = \frac{2\sigma - 1 - \sqrt{A}}{2(1+t)(1+\tau)\sigma\eta f}. \tag{18}$$

In order for m to be positive, we assume that $2\sigma - 1 - \sqrt{A} > 0$.

In the present case, neither upstream nor downstream firms make profit. Hence, national income consists of labor income and tax revenue, both of which are unchanged with the revenue-neutral tax reform. That is, the welfare change is exactly equal to the change in consumer surplus:

$$CS = \ln\left(n^{\frac{1}{\sigma-1}} p^{-1}\right), \tag{19}$$

where CS stands for consumer surplus. Noting that the final goods price is given by

$$p = \frac{(1+t)\sigma n Q}{(\sigma-1)(n-1)} = \frac{(1+t)\sigma n m^{\frac{1}{1-\eta}} q}{(\sigma-1)(n-1)} = \left[\frac{(1+t)(1+\tau)\sigma\eta n}{(\sigma-1)(n-1)}\right]^{\frac{\eta}{\eta-1}} \frac{c\eta^{\frac{1}{\eta-1}}}{\eta-1},$$

where use is made of (18) and (7). Substituting this expression of p into (19) and rearranging terms, we have

$$\begin{aligned} CS &= \frac{\eta - 1 - \eta(\sigma-1)}{(\sigma-1)(\eta-1)}\ln n + \frac{\eta}{\eta-1}\ln(n-1) \\ &\quad -\frac{\eta}{\eta-1}\ln[(1+t)(1+\tau)] + const., \qquad (20) \\ \text{where } \; const. &\equiv -\frac{\eta}{\eta-1}\ln\left(\frac{\sigma\eta}{\sigma-1}\right) - \ln\left(\frac{c\eta^{\frac{1}{\eta-1}}}{\eta-1}\right). \end{aligned}$$

Totally differentiating (20), the welfare effect of tax change is

$$dW = dCS = \frac{\eta(\sigma-1) + (\eta-1)(n-1)}{n(n-1)(\sigma-1)(\eta-1)}dn - \frac{\eta}{(1+t)(1+\tau)(\eta-1)}d[(1+t)(1+\tau)]. \tag{21}$$

The first term in the right-hand side is the effect through a change in n and the second term is the direct effect of the reform. The rest of our task is to compute the effect of the revenue-neutral tax reform on dn and $d(1+t)(1+\tau)$. Using (17) and (18), tax revenue in the present case is given by

$$T = \frac{t}{1+t} + \frac{\tau\left(2\sigma - 1 - \sqrt{A}\right)}{2(1+t)(1+\tau)\sigma}$$

Differentiating this with respect to t and τ, the revenue-neutral tax requires that

$$d\tau = -\frac{(1+\tau)\left[\tau + 2(1+t)\tau\sigma(\sigma-1)F + (2\sigma+\tau)\sqrt{A}\right]}{(1+t)\sqrt{A}\left[2\sigma - 1 - \sqrt{A}\right]}dt.$$

It follows from this equation that the revenue-neutral tax reform affects dn and $d[(1+t)(1+\tau)]$ in (21) as follows.

$$\begin{aligned} dn &= -\frac{2(1+t)\sigma(\sigma-1)F + \sqrt{A}}{2(1+t)^2\sigma F\sqrt{A}}dt < 0 \\ d[(1+t)(1+\tau)] &= -\frac{(1+\tau)\left[(1+\tau)\left(1+\sqrt{A}\right) + 2(1+t)(2+\tau)\sigma(\sigma-1)F\right]}{\left(2\sigma - 1\sqrt{A}\right)\sqrt{A}}dt < 0. \end{aligned}$$

In words, the revenue-neutral tax reform decreases n and $(1+t)(1+\tau)$. The reform-induced decrease in the number of final good firms tends to reduce welfare, but the decrease in $(1+t)(1+\tau)$ tends to raise welfare. Due to these conflicting effects, it is ambiguous that welfare improves. Indeed, substituting these results into (21) leads to

$$\begin{aligned} dW = &\left\{\underbrace{-\frac{\eta(\sigma-1) + (\eta-1)(n-1)}{n(n-1)(\sigma-1)(\eta-1)} \cdot \frac{2\sigma(\sigma-1)(1+t)F + \sqrt{A}}{2\sigma(1+t)^2F\sqrt{A}}}_{(-)}\right. \\ &\left. + \underbrace{\frac{\eta\left[(1+\tau)\left(1+\sqrt{A}\right) + 2(1+t)(2+\tau)\sigma(\sigma-1)F\right]}{(\eta-1)(1+t)\sqrt{A}\left(2\sigma - 1 - \sqrt{A}\right)}}_{(+)}\right\} dt. \end{aligned}$$

The intuition for this ambiguous result is obvious. As mentioned in the main text, the revenue neutrality requires the government to raise t and lower

τ. This increase in t leads to a decrease in the number of final goods firms. As a result of the decreased number of firms, the price of final goods becomes higher. This tends to reduce welfare. In contrast, the tax reform raises the mass of intermediate goods and lowere their price, as was the case in the main text. This tends to raise welfare. Due to these conflicting effects, it is unclear whether welfare improves.

Specific Tax

If the tax form is specific, m is not explicitly solved, and hence we can not obtain a clear result. Someone may claim that the welfare effect of the tax reform is possible to derive by using the implicit function theorem even if the closed form of m can not be obtained. However, at least for our purpose, solvability of m is very essential. In order to see this, let t and τ be the specific tax rate on final and intermediate goods, respectively. Then, the price and output of intermediate goods are obtained by

$$q = \frac{\eta(c+\tau)}{\eta-1}, \quad x = \frac{(\eta-1)f}{c+\tau}.$$

Substituting these results in (6), we have a non-linear equation in m.

$$\frac{(\sigma-1)(n-1)m^{\frac{\eta}{\eta-1}}}{\sigma n\left[\eta(c+\tau)m^{\frac{1}{1-\eta}} + (\eta-1)t\right]} = \frac{f}{c+\tau}.$$

Totally differentiating this equation, two taxes affect m as follows.

$$\frac{dm}{dt} = \frac{\sigma n m^{\frac{2\eta-1}{\eta-1}}(\eta-1)^2 f}{\eta(c+\tau)[\sigma n m f - (\sigma-1)(n-1)]} \tag{22}$$

$$\frac{dm}{d\tau} = \frac{m(\eta-1)[\sigma\eta n m f - (\sigma-1)(\eta-1)]}{\eta(c+\tau)[\sigma n m f - (\sigma-1)(n-1)]}. \tag{23}$$

We now find the rule of the revenue-neutral tax reform. Tax revenue in the present case is given by

$$T = \underbrace{\frac{(\sigma-1)(n-1)}{\sigma n(Q+t)}}_{\text{revenue from final good tax}} + \underbrace{\frac{\tau m(\eta-1)f}{c+\tau}}_{\text{revenue from intermediate goods tax}}$$

$$
= \quad (\eta-1)f \times \frac{tm^{\frac{\eta}{\eta-1}} + \tau m}{c+\tau}.
$$

Noting that taxes affect m and differentiating this expression with respect to t and τ, we obtain

$$
\begin{aligned}
\frac{dT}{dt} &= \frac{(\eta-1)f}{c+\tau}\left[m^{\frac{\eta}{\eta-1}} + \left(\frac{t\eta m^{\frac{1}{\eta-1}}}{\eta-1} + \tau\right)\frac{dm}{dt}\right] \\
\frac{dT}{d\tau} &= \frac{(\eta-1)f}{(c+\tau)^2}\left\{(c+\tau)\left[m + \left(\frac{t\eta m^{\frac{\eta}{\eta-1}}}{\eta-1} + \tau\right)\frac{dm}{d\tau}\right] - tm^{\frac{\eta}{\eta-1}} - \tau m\right\},
\end{aligned}
$$

where dm/dt and $dm/d\tau$ are given by (22) and (23), respectively. By dividing the first equation by the second equation, the revenue-neutral tax reform is obtained by

$$
d\tau = -\frac{dT/dt}{dT/d\tau}dt.
$$

However, the sign of both the denominator and the numerator in the right-hand side is unclear, and hence the welfare effect of the revenue-neutral tax reform is also unclear.