The Efficiency Comparison of Taxes under Monopolistic Competition with Heterogenous Firms and Variable Markups

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Abstract

This paper compares the efficiency implications of aggregate output equivalent unit versus ad-valorem tax regimes when monopolistically competitive firms produce differentiated products with either homogenous or heterogenous costs. The model allows for firms to price at a variable markup over marginal cost. In line with most prior findings the superiority of ad-valorem tax continues to hold when firms have homogenous costs. However, I find that a unit tax becomes more efficient when firms have heterogenous costs and unit tax is relatively high. The model generates both the selection of firms and reallocation of resources, in addition to the well-documented effects of tax regimes on firms' output and pricing decisions. Furthermore, these two tax regimes have differential effects on mark-up distributions: an ad-valorem tax distorts the mark-up distribution of firms in favor of more productive firms. The aggregate productivity is therefore higher compared to an output equivalent unit tax. A more productive market with lower prices amplifies the superiority of the ad-valorem tax at lower revenue requirements. However, I find that when the unit tax is relatively high, the excessive exit rate under an ad-valorem tax regime overturns the welfare superiority argument in favor of a unit tax regime.

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Key Words: Unit Tax, Ad-valorem Tax, Efficiency, Monopolistic Competition, Heterogenous Firms

1 Introduction

Governments use unit or ad-valorem tax regimes not only as a form of revenue extraction, they also aim to target a consumption/production level in an industry. They have environmental or health concerns or they use import quotas to protect domestic industries from foreign competition. These taxes are usually refered to as corrective taxes. The relative efficiency of two different ways of implementing taxation for perfectly competitive markets, monopolies and oligopolies, has been extensively discussed. Little attention has been devoted to monopolistically competitive markets.[1] Furthermore, there is a large empirical literature documenting firm heterogeneity even in narrowly defined industries[2]. Meanwhile, empirical evidence supports that there is an adjustment in mark-ups when firms face competitive pressure[3]. Therefore, analyzing the relative efficiency of unit and ad-valorem corrective tax regimes in a monopolistically competitive market with heterogenous firms and endogenous markups fills an important gap in the public economics literature.

In this paper I first show that in a model of monopolistic competition where homogenous cost firms produce differentiated products and consumer preferences are described such that firms can endogenously adjust their markups, an ad-valorem tax welfare dominates an *output equivalent* unit tax with redistributed tax revenue to consumers. The result is driven solely by the typical trade-off between revenue

[1] Except Schröder (2004), and Schröder and Sørensen (2010), Dröge and Schröder (2008)

[2] See Bartelsman and Doms (2000) for a survey of empirical evidence on firm level heterogeneity in productivity.

[3] See , De Loecker et al (2012).for recent discussions on how a trade liberalization affects the mark-up distribution of firms over marginal costs.

extraction and variety generation. On one hand, under an ad-valorem tax regime firms tend to decrease their price and increase their output. An ad-valorem tax is therefore a better revenue extractor. On the other hand, a unit tax generates greater variety due to the larger tax overshift, enabling firms to survive at lower output levels. This result contradicts with the findings of Dröge and Schröder (2009). They compare the welfare effects of unit and ad-valorem taxes in a Dixit-Stiglitz type monopolistic competition model using equal output criterion. They argue that unit tax by generating many small firms welfare dominates the ad-valorem tax. Yet, the same model with equal yield comparison confirms the superiority of ad-valorem tax in Schröder (2004). Next, when one allows for heterogenous cost the superiority of an ad-valorem tax is challenged. A unit tax becomes welfare-superior when the government tax requirement is relatively high. The reasons for the inverse ranking are two-fold. Firstly, firm heterogeneity in costs increases both the gap in prices and number of firms between the two tax regimes. Secondly, variable markup pricing amplifies this gap even further. I can only observe these effects under heterogenous cost and variable markup assumptions since the two tax regimes affect firms' markup distribution and thus prices differently. More specifically, the ad-valorem tax distorts the relative cost advantage of firms in favor of more productive firms. The selection and reallocation effects among heterogeneous firms therefore allow only relatively more productive firms to survive in the market. Aggregate productivity is therefore higher compared to an output equivalent unit tax. This has two opposing effects on welfare. On the one hand, higher aggregate productivity results in even lower prices by amplifying the lower price advantage of ad-valorem taxes. On the other hand, higher aggregate productivity decreases total variety further since firms can only survive by operating as larger firms. At higher tax levels, the welfare loss from lesser variety overturns the superiority of ad-valorem tax in favor of the unit tax.

Contrary to the focus of this paper, generated tax revenue is the focus of the majority of the publics economics literature. The early contributions state that in a perfectly competitive market whether tax is ad-valorem or unit does not matter; since firms are price takers, only the cost-price increase generated by the tax is relevant. Consequently, for every unit tax rate there exists an equivalent ad-valorem tax level. On the other extreme, when there is a monopoly this equivalence result breaks down: an ad-valorem tax generates more welfare than a unit tax (see Suits and Musgrave (1953), and Skeath and Trendel (1994)). The result is driven by the fact that a profit-maximizing monopolist increases its output when an ad-valorem tax is imposed. Higher output reduces prices, decreasing the wedge between the price consumers pay and the price producers receive. Consumers are therefore better off with greater output and lower prices compared to a unit tax. The superiority of ad-valorem tax continues to hold for a wide range of market structures.[4] The recent contribution to the equal yield tax criterion literature can be discussed in two dimensions: cost asymmetries and short run versus long run analysis. A unit tax allows firms to survive at lower output levels. Thus more firms/varieties can survive compared to an ad-valorem tax. Since the number of firms is fixed in the short run, the variety effect that usually favors unit taxation is shut down. The ability of ad-valorem taxes to create lower prices still holds. As a result, analysis with homogenous costs in the short run supports ad-valorem taxation (Delipalla and Keen (1992), and Anderson et al. (2001)). In the long run both the variety effect and the price effect are present. Schröder (2004) choose a Dixit-Stiglitz utility in order to model consumers' love of variety in a monopolistic competition setting. He shows that an equal yield ad-valorem tax remains welfare superior under monopolistic competition settings. Adding cost asymmetries to Schröder's (2004) model does not change the results for monopolistic competition models (Schröder and Sørensen (2010)).

There is a recent discussion in international trade literature that recalculates gains from trade with variable mark-ups (Arkolakis et al. (2012) and Edmond et al. (2012)). They mainly argue that markups are incresing with firm level productivity. With trade liberalization, through the exit of low productivity firms, consumer expenditures are transefered towards more productive firms. The prices of those higher productive firms are lower. On the other hand, the price cost margins are higher. Thus, when we aggregate the markups with market shares, the aggregate markups may increase due to trade liberalization. In this

[4] See Keen (1998) for a review of the literature.

paper, the tax regimes distorts the market such that unit taxes have no effect on the markup distribution since the firms can fully pass the burden onto consumers. On the other hand, under an output equivalent ad-valorem tax regime firms charge lower markups. This further decreases prices compared to unit taxes. As a result, under an ad valorem tax the market becomes more competitive, resulting in even lower prices but fewer varieties.

The model used in this paper is based on Melitz and Ottaviano (2008) which gives closed form solutions. This allows the policy maker to acquire comparative statistics with respect to market size, dispersion of marginal costs, and the level of love for variety. We also learn that tax regimes are not simply revenue extraction or output corrective instruments for governments but are also exogenous mechanisms that affect the market structure and aggregate productivity within an industry. If the government prefers to support productive firms and eliminate relatively less productive ones, then an ad-valorem tax is the appropriate tax regime.

2 Model

The model used in this paper is based on Melitz and Ottaviano (2008)[5] There are L identical consumers of size 1. Their preferences are defined over a continuum of differentiated products and a homogenous good. They choose differentiated products from the set of varieties, Ω. A homogenous good is indexed by 0, and a differentiated good is indexed by i. A consumer utility function is then:

$$U = q_0 + \alpha \int_{i\in\Omega} q_i di - \frac{1}{2}\gamma \int_{i\in\Omega} (q_i)^2 di - \frac{1}{2}\eta \left(\int_{i\in\Omega} q_i di \right)^2 , \tag{1}$$

where q_0 is the homogenous good consumption and q_i is the differentiated good consumption of variety i. α, η, and γ are the positive demand parameters. The degree of product differentiation increases with γ and consumers' love for variety is reflected in $\int_{i\in\Omega}(q_i)^2 di$.

The demand for the homogenous good is assumed to be positive, and its price is normalized to one. From utility maximization, a consumer's inverse demand for each differentiated variety is then given as:

$$p_i = \alpha - \gamma q_i - \eta Q, \tag{2}$$

where $Q = \int_{i\in\Omega} q_i di$ is the total quantity consumed. When I aggregate over all consumers, the linear market demand for variety i which is given as:

$$q_i = \frac{\alpha}{\gamma + \eta N} - \frac{1}{\gamma} p_i + \frac{\eta N}{\gamma + \eta N} \frac{1}{\gamma} \widetilde{P},$$

where N is the mass of differentiated varieties, and $\widetilde{P} = \frac{1}{N} \int_{i\in\Omega} p_i di$ is the average price over all prices.

In this economy the technology to produce the homogenous good is identical across firms. It is produced under constant returns to scale at a cost of one unit of labor. Consumers in this economy are endowed with one unit of labor. Labor is inelastically supplied, and there is no leisure in the utility function. Furthermore, labor is the only factor of production. The demand for the homogenous good is ensured to be positive with the assumption that income is high enough and the homogenous good is freely traded in a perfectly competitive market. If the price of the homogenous good is normalized to one and since workers receive their revenue of marginal product, the wage is unity.

[5] See Melitz and Ottaviano (2008) for a detailed description of the model.

The model features of consumers and homogenous good producers are identical under both homogenous and heterogenous cost cases. Going forward, I lay out the remaining features of the model that differ for differentiated good producers when they have either homogenous or heterogenous costs, and when they face either ad-valorem or unit tax regimes.

3 Relative Efficiency of Unit and Ad-valorem Taxes with Symmetric Costs

Firms produce differentiated goods at a constant marginal cost of c.[6] These firms must pay a sunk entry cost of f_e in order to enter the market.[7] There is free entry and exit. Firms therefore enter the market if the expected profit of a firm covers the sunk entry cost. This condition determines the total mass of firms and variety in the market, and is called the free entry condition.

Ad-Valorem Tax Regime:

I first analyze the market if the government collects ad-valorem taxes as the fraction t of the price per unit of a good sold in the market. In this economy a profit-maximizing firm chooses an optimal amount of output given the inverse demand it faces. A firm supplies $q_t(c)$ units given as:

$$q_t(c) = \frac{1}{\gamma}\left(p_t(c) - \frac{c}{1-t}\right). \tag{3}$$

where going forward subscript t refers to ad-valorem taxing economy parameters. There is no uncertainty regarding the technology of a firm in differentiated markets. A potential entrant will enter the market if the profit covers the sunk entry cost. The free entry condition of firms is therefore given as:

$$\pi_t(c) - f_e = 0.$$

The equilibrium in the market is characterized by the profit maximizing price, output by each firm, and total varieties in the market given as:

$$\begin{aligned}
q_t(c) &= \sqrt{\frac{f_e}{\gamma(1-t)}}, \\
p_t(c) &= \sqrt{\frac{f_e\gamma}{(1-t)}} + \frac{c}{1-t}, \text{ and} \\
N_t &= \frac{Q_t}{q_t(c)} = \frac{\alpha - \frac{c}{1-t} - 2\sqrt{\frac{\gamma f_e}{(1-t)}}}{\eta\sqrt{\frac{f_e}{\gamma(1-t)}}}.
\end{aligned}$$

Unit Tax Regime:

Similarly, the market equilibrium is defined if the government collects s for every unit sold in the market. As a result the firms's profit maximizing output becomes:

$$q_s(c) = \frac{1}{\gamma}\left(p_s(c) - (c+s)\right).$$

where going forward subscript s refers to unit taxing economy parameters. The free entry condition is characterized similarly to that of an ad-valorem tax as $\pi_s(c) - f_e = 0$. The equilibrium values of profit

[6] There is no need to add a fixed cost of production in order to generate a finite mass of firms in the market. The linear demand caps the maximum price a firm can charge in order to make positive profit.

[7] Since wage is unity, all cost figures mentioned in this paper are in unit labor requirements.

maximizing the price, quantity, and equilibrium number of varieties are given as:

$$q_s(c) = \sqrt{\frac{f_e}{\gamma}},$$
$$p_s(c) = \sqrt{f_e\gamma} + c + s, \text{ and}$$
$$N_s = \frac{Q_s}{q_s(c)} = \frac{\alpha - c - s - 2\sqrt{\gamma f_e}}{\eta\sqrt{\frac{f_e}{\gamma}}}.$$

The welfare is calculated as the sum of consumer surplus and tax revenue and producer surplus in this economy. The producer surplus is zero since there is free entry and exit. Since tax revenue is redistributed back to consumers, the calculated welfare per person is identical to the utility (expression (1)) derived from consuming all the varieties in the market. Therefore, the welfare rankings for the two tax regimes are also valid for utility of consumers.

Proposition 1 *The equilibrium values of output per firm, profit maximizing price, variety, and tax revenue for an ad valorem and a unit tax under output equivalence are compared as:*

1. *An ad-valorem tax regime creates larger firms, i.e.* $q_s < q_t$.
2. *Firms under an ad-valorem tax regime price lower, i.e.* $p_s > p_t$.
3. *An ad-valorem tax creates less variety, i.e.* $N_s > N_t$,
4. *The tax revenue and consumer surplus created by the ad-valorem tax regime is* ***greater*** *compared to that of an output equivalent unit tax regime.*
5. *Welfare if defined as the sum of tax revenue and consumer surplus is* ***superior*** *under an ad-valorem tax regime compared to that under an output equivalent unit tax regime.*

Proof. Provided in the appendix. ■

Proposition one states that when firms homogenous in costs compete in a monopolistically competitive markets and consumers have a linear demand for differentiated products, then an ad-valorem tax is a welfare superior method of corrective tax. This result contradicts the previous findings of welfare rankings with homogenous firms in monopolistically competitive markets by Dröge and Schröder (2009) but confirms the results of Schröder(2008) when equal yield criterion is used. In both papers, consumer preferences are characterized by constant elasticities of demand. This result further strengthens the superiority of ad-valorem taxes under Cournot competition with free entry and exit (Anderson et al. (2001). However, it contradicts the inverse welfare ranking of Anderson et al. (2001) for the case of Bertrand competition and product differentiation with a discrete choice framework of exponentially distributed match values. All of the above mentioned models have two common forces at work. First, an ad-valorem tax makes the demand curve more elastic. As a result, a profit-maximizing firm produces more at a lower price. This decreases the wedge between the price consumers pay and the price producers receive. Consumers therefore benefit from lower prices compared to a unit tax. Second, a unit tax acts like an increase in marginal cost. Firms therefore tend to decrease their output while they increase their prices. A higher operating surplus and smaller outputs are therefore sufficient to offset the fixed entry cost of entering the market. This allows more firms to exist in the market under unit taxes. For ad-valorem taxes lower prices tend to increase welfare, while less variety decreases welfare if consumers have love for variety. The relative efficiency results are driven solely by the dominance of one over the other. In this model specification firms fully pass the unit tax on to consumers, while an ad-valorem tax is shared between both producers and consumers. As a result the price effect dominates the variety effect; an ad-valorem tax generates greater consumer surplus, tax revenue, and as a result welfare.

4 Relative Efficiency of Unit and Ad-Valorem Taxes with Asymmetric Costs

I now reconstruct a model of firms producing differentiated products at heterogenous marginal cost of production, ω. Potential entrants must pay a sunk entry cost f_e in order to learn their marginal cost of production. Once the entrants pay the entry cost, they draw their marginal costs $1/\omega$ from a common Pareto distribution with support on $[0, \overline{\omega}]$ and dispersion parameter k. This implies that marginal cost draws come from a cumulative distribution $G(\omega) = \left(\frac{\omega}{\overline{\omega}}\right)^k$. The parameter k indexes the dispersion of cost draws.

Once a firm is in the market profit is maximized by taking the total number of varieties and average prices in the market as given. Since the entry cost f_e is sunk, firms that are able to cover their marginal costs survive in the market and continue to produce. This implies that there exists a marginal firm making zero profit. The marginal firm's marginal cost of production is labeled as ω^* (zero cutoff condition). Finally, prior to entry, the expected profit of a firm is $\int_0^{\omega^*} \pi(\omega) dG(\omega) - f_e$. Firms will enter until this profit is driven to zero giving us the free entry condition. Notice that both the zero cutoff condition and the free entry condition can be written as functions of ω^*, the number of firms and model parameters. Both the cutoff marginal cost of production and the number of firms can therefore be uniquely identified.

I further analyze the relative efficiency of ad-valorem and unit taxes for a monopolistically competitive market of firms selling differentiated goods produced with heterogenous costs. I show that the heterogeneity of firms unseats the superiority of ad-valorem tax at higher levels of unit taxes. I previously discussed the general properties of the model for firms of heterogenous costs; I now detail the differences caused by different regimes and heterogenous costs.

Ad-valorem Tax Regime:

If the government collects t percent of the price per unit of a good sold, then the profit maximizing output of a firm with marginal cost of production ω is:

$$q_t(\omega) = \frac{1}{\gamma}\left(p_t(\omega) - \frac{\omega}{1-t}\right). \tag{4}$$

Any potential entrant who pays the sunk entry cost and learns its marginal cost of production decides whether to stay in the market or exit immediately depending on the profit it can make. A marginal firm therefore makes zero profit. The expression below defines ω_t^* as the marginal cost of production for the marginal firm:

$$\frac{\omega_t^*}{1-t} = \alpha - \eta Q_t. \tag{5}$$

The cutoff marginal cost ω_t^* summarizes the effects of both the average price and the number of firms on the price and output measures of all firms. All of these measures can be written as functions of only the firm's own marginal cost ω and the marginal firm's ω_t^* as:

$$q_t(\omega) = \frac{1}{2\gamma}\frac{(\omega_t^* - \omega)}{1-t}, \text{ and} \tag{6}$$
$$p_t(\omega) = \frac{1}{2}\frac{(\omega_t^* + \omega)}{1-t}.$$

The free entry condition is also redefined as $\int_0^{\omega_t^*} \pi_t(\omega) dG(\omega) - f_e$. If the above measures are used and ω_t^* is solved for, I can then define the cut off marginal cost as a function of the model parameters:

$$\omega_t^* = \left(f_e(k+1)(k+2)2\gamma\left(\overline{\omega}\right)^k(1-t)\right)^{\frac{1}{k+2}}. \tag{7}$$

The total number of varieties N_t is calculated using the zero-cutoff condition and by calculating the total output Q_t.

Unit Tax Regime:

I now define the marginal firm, output, and price measures for all firms under a unit tax policy where the government collects s for each unit sold. A firm's profit maximizing output therefore becomes:

$$q_s(\omega) = \frac{1}{\gamma}\left(p_s(\omega) - (\omega + s)\right). \tag{8}$$

If the cost of production of the marginal firm making zero profit in this economy is labeled as ω_s^*, then equating the profit of the marginal firm to zero gives us the zero cutoff condition as:

$$\omega_s^* + s = \alpha - \eta Q_s. \tag{9}$$

I can rewrite the output and price measures of all firms in terms of cutoff marginal cost ω_s^* and marginal cost of the firms as:

$$q_s(\omega) = \frac{1}{2\gamma}(\omega_s^* - \omega), \text{ and} \tag{10}$$
$$p_s(\omega) = \frac{1}{2}(\omega_s^* + \omega) + s.$$

Furthermore, the free entry condition also defines the marginal firm by equating the ex-ante expected profits to the sunk entry cost paid. I can define ω_s^* as:

$$\omega_s^* = \left(f_e(k+1)(k+2)2\gamma\left(\overline{\omega}\right)^k\right)^{\frac{1}{k+2}}. \tag{11}$$

Notice that the cutoff marginal cost for the unit tax is independent of the tax rate. This is because a unit tax is fully passed on to consumers. Furthermore, all tax revenue collected by the government is redistributed back to consumers. The marginal firm is therefore not affected by the unit tax regime.

I have described the model and two different taxation methods. The aim of this paper is to compare the resulting differences in the welfare, created number of varieties, and most importantly the relative efficiency of the industry as a whole. I provide this using the total output equivalence condition.

Proposition 2 *The equilibrium values of variety, tax revenue, consumer surplus, the cutoff marginal cost of production for ad valorem and unit taxes are compared as:*

1. *The marginal firm has lower marginal cost of production under an ad-valorem tax regime, i.e.* $\omega_s^* > \omega_t^*$. *Thus the industry is more productive under ad-valorem tax regime.*

2. *The variety created under an ad-valorem tax is less than a unit tax, i.e.* $N_t < N_s$.

3. *The tax revenue created by the ad-valorem tax regime is* ***less*** *compared to that of a unit tax regime,* $TR_s > TR_t$.

4. *The consumer surplus from the ad-valorem tax regime is* ***greater*** *compared to that of a unit tax regime,* $CS_s < CS_t$.

5. *Welfare is defined as the sum of consumer surplus and tax revenue and it is* ***superior*** *under a unit tax regime compared to that of an ad-valorem tax regime when unit taxes are higher.*

Proof. Provided in the appendix. ■

I find that when cost asymmetry is added to a model of firms competing monopolistically and consumers having quadratic utility functions a unit tax is welfare superior to an output equivalent ad-valorem tax for higher values of unit taxes. This result challenges the parameter-independent superiority of ad-valorem taxes (unit taxes) with homogenous costs in this paper (Dröge and Schröder (2009)). A unit tax unseats an ad-valorem tax in this model is not only due to the appreciation of higher variety generated by unit taxes. In the presence of cost asymmetries and variable markup pricing these tax instruments affect the distribution of mark-ups, thus prices differently. A unit tax is fully passed onto consumers, and the distribution of mark-ups is not affected. However, an ad-valorem tax distorts the distribution of mark-ups in favor of more productive firms. Market production is therefore reallocated toward more productive firms. The productivity of the marginal firm that makes zero profit becomes less than that under a unit tax. The selection and reallocation of recourses exacerbate the price efficiency of ad-valorem taxes while decreasing the number of varieties that can survive even further compared to unit taxes. In Schröder and Sørensen's (2010) model where heterogenous firms compete in monopolistically competitive markets and consumer preferences are represented by CES utility functions, the only force that is present is the selection of firms and reallocation of resources. Because of the CES preferences (constant mark-up assumption), they can not generate the differential effects of tax regimes on markup distribution. Surprisingly, having only selection effects is not enough to unseat the superiority of ad-valorem tax whereas having also the existence of variable markup pricing overturns this superiority in favor of the unit tax. When firms face an ad-valorem tax regime they pay part of the tax burden, and this burden increases as firms becomes less productive. Profit-maximizing firms therefore decrease their mark-ups and increase their production in order to avoid paying this burden; this in return decreases the relative demand for their products. Thus, the productivity of the surviving marginal firm has to be even higher to offset the lower mark-up and residual demand. That is to say heterogeneity exacerbates the price and variety gap between the two tax regimes, and variable mark-up pricing widens this gap even further.

Surprisingly, contrary to many of the welfare ranking analysis, this model generates a higher consumer surplus under the ad-valorem tax regime and a higher tax revenue under the unit tax regime. This inverse ranking is a result of the existence of firm heterogeneity and variable mark-up pricing. Under an ad-valorem tax regime both the prices and number of varieties are lower. An output equivalent unit tax therefore generates more revenue. On the other hand, lower prices are valued by consumers even when they also have preferences for variety.

5 Conclusion

The effect of market structure and cost asymmetries of equal yield unit and ad-valorem taxes on welfare of consumers has been extensively discussed. The importance of variable mark-ups when calculating welfare especially with heterogenous firms is the recent discussion in international trade. Thus, this paper studies the welfare implications of output equivalent unit and ad-valorem taxes in a model of monopolistic competition with heterogenous firms and a utility function that allows variable mark-ups. The discussion contributes mainly to the public economics and the environmental economics literature on corrective taxes where little has been done with heterogenous firms.

Without cost asymmetries, an ad-valorem tax is superior. However when including cost asymmetries I observe that a unit tax dominates an ad-valorem tax for higher levels of unit taxes. This inverse ranking is a result of both heterogeneity and variable markup pricing. Both effects increase the gap between the price and variety generated under these two tax regimes. Thus at higher levels of taxation, the market under an ad-valorem tax becomes so competitive that the greater variety generated by the unit tax is more appreciated by society since it also values variety.

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APPENDIX

Proof of Proposition 1 (Symmetric Cost Case):

I must first answer the following question: what is the level of unit tax that creates the same level of output as the ad-valorem tax rate t. I therefore rearrange inverse demand functions (eq.(2)) for the two tax regimes. I find that $\alpha - \eta Q_t = p_t + \gamma q_t$, and similarly $\alpha - \eta Q_s = p_s + \gamma q_s$. Since our comparison unit is equal total output, I can conclude that:

$$p_t + \gamma q_t = p_s + \gamma q_s. \tag{12}$$

When I use the supply function (eq.(4) and eq.(8)) and equilibrium values for both regimes (eq.(6) and eq.(10)), I find the output equivalent unit tax rate as a function of model parameters:

$$s = \frac{tc}{1-t} + 2\sqrt{\gamma f_e}\left(\frac{1}{\sqrt{1-t}} - 1\right) \tag{13}$$

Firms under a unit tax regime are smaller and prices are higher than those under an ad-valorem tax regime. The output per-firm comparison is straightforward from the equilibrium values, $q_t = \sqrt{\frac{f_e}{\gamma(1-t)}}$ and $q_s = \sqrt{\frac{f_e}{\gamma}}$. For any $t \in (0,1)$, $q_s < q_t$. Furthermore, following eq.(12) I can conclude that $p_s > p_t$.

Similarly, the total output equivalence gives fewer total varieties under an ad-valorem tax compared to a unit tax regime; $N_s > N_t$.

Tax revenue on the other hand is not straightforward. Since the total output level is equal, one can simply compare the tax revenue collected per unit of output. Under a unit tax this value is s, whereas under an ad-valorem tax regime the per unit tax revenue is tp_t. From eq.(13), $s = \frac{tc}{1-t} + 2\gamma(q_t - q_s)$. Similarly, $tp_t = t\gamma q_t + \frac{tc}{1-t}$. The difference between the tax revenues per unit is therefore equal to:

$$\begin{aligned}\frac{TR_t - TR_s}{Q} &= tp_t - s, \\ &= \gamma\left(2q_s - (2-t)q_t\right), \text{ and} \\ &> 0 \text{ for all } t \in (0,1).\end{aligned}$$

The consumer surplus under both regimes is the utility created by consuming both the numeraire good and differentiated goods net of money spent on them. The consumer surplus values under both regimes can therefore be written as:

$$\begin{aligned}CS_t &= q_o + \alpha Q_t - \frac{1}{2}\gamma N_t(q_t)^2 - \frac{1}{2}\eta(Q_t)^2 - p_t Q_t - p_o q_o, \text{ and} \\ CS_s &= q_o + \alpha Q_s - \frac{1}{2}\gamma N_s(q_s)^2 - \frac{1}{2}\eta(Q_s)^2 - p_s Q_s - p_o q_o.\end{aligned}$$

The tax regimes are output equivalent and the price of the numeraire good is normalized to 1. If I use these two information and take the difference between the two consumer surpluses, I find

$$\begin{aligned}CS_s - CS_t &= Q(\frac{1}{2}\gamma q_t - \frac{1}{2}\gamma q_s + \gamma q_s - \gamma q_t), \text{ and} \\ &= Q(\frac{1}{2}\gamma q_s - \frac{1}{2}\gamma q_t).\end{aligned}$$

Using eq. (12), I can further simplify the above expression to: $CS_s - CS_t = Q(\frac{1}{2}\gamma q_s - \frac{1}{2}\gamma q_t)$. Since $q_s < q_t$, the difference in consumer surpluses under two regimes is: $CS_s - CS_t < 0$ for all model parameters and $t \in (0,1)$. Finally, welfare under an ad-valorem tax regime is higher compared to unit tax regime because it creates greater consumer surplus and tax revenue.■

Proof of Proposition 2 (Asymmetric Cost Case):

I should first compare the cutoff marginal cost values under both regimes. Eq.(7) and (11) give the direct relationship between ω_s^* and ω_t^* as $\omega_t^* = (1-t)^{\frac{1}{k+2}}\omega_s^*$. Since t is between 0 and 1, I conclude that $\omega_t^* < \omega_s^*$.

I use equal output criterion with redistributed tax revenue in order to show the relative ranking of the variety created. The output created by all the firms in the market under an ad-valorem tax is given as:

$$\begin{aligned}Q_t &= \int_0^{\omega_t^*} q(w)dG(w|w < \omega_t^*), \\ &= \int_0^{\omega_t^*} \frac{1}{2\gamma}(\omega_s^* - \omega)dG(w|w < \omega_t^*), \text{ and} \\ &= \frac{1}{2\gamma(k+1)}\frac{\omega_t^*}{1-t}N_t.\end{aligned}$$

Similarly, the total output under a unit tax regime is $Q_s = \frac{1}{2\gamma(k+1)}\omega_s^* N_s$, and additionally $\frac{\omega_t^*}{1-t} > \omega_s^*$. Furthermore, I defined the equivalency of these two regimes through output; as a result $N_s > N_t$. A unit tax creates greater variety than the output equivalent ad-valorem tax.

The total tax collected from a firm with a marginal cost of production ω is $tp_t(w)q_t(w)$. In order to calculate the total tax collected from all the firms I aggregated the per-firm collected tax over their respective marginal cost values given as:

$$\begin{aligned} TR_t &= \int_0^{\omega_t^*} tp(w)q(w)dG(w|w<\omega_t^*), \\ &= \int_0^{\omega_t^*} t\frac{1}{4\gamma}\frac{(\omega_t^*+\omega)}{1-t}\frac{(\omega_t^*-\omega)}{1-t}dG(w|w<\omega_t^*), \text{ and} \\ &= \frac{1}{2\gamma}\frac{1}{k+2}\frac{t}{(1-t)^2}(\omega_t^*)^2 N_t. \end{aligned}$$

If I further simplify the expression using the total output Q_t calculated above, I find $TR_t = \frac{t}{1-t}\frac{k+1}{k+2}\omega_t^* Q_t$. I can similarly aggregate the tax collected from a single firm with a marginal cost of production ω in order to calculate the total tax revenue created under a unit tax. The per-firm tax revenue is $sq_s(w)$. If I aggregate the overall surviving firms in the market, I find that TR_s equals $\frac{1}{2\gamma}\frac{1}{k+1}s\omega_s^* N_s$, or simply sQ_s. In order to compare the tax revenue collected under both regimes I take the difference of tax revenues calculated above:

$$TR_s - TR_t = sQ_s - \frac{t}{1-t}\frac{k+1}{k+2}\omega_t^* Q_t.$$

Since the total output is equal under both regimes I use the total output , call it Q, as a common factor. Furthermore, by using the zero cut off conditions in eq.(5), (9), and the equivalency definition, I find the output equivalent tax rate s as a function of a given ad-valorem rate t as $s = \frac{\omega_t^*}{1-t} - \omega_s^*$. If I insert in the expression for s and common factor Q I find:

$$TR_s - TR_t = Q\left(\frac{\omega_t^*}{1-t} - \omega_s^* - \frac{t}{1-t}\frac{k+1}{k+2}\omega_t^*\right).$$

If I insert the equality between the cutoff rates driven from free entry condition $\omega_t^* = (1-t)^{\frac{1}{k+2}}\omega_s^*$ back into the above expression, the expression becomes a function of t, k and common multipliers:

$$TR_s - TR_t = Q\omega_s^*\left(\frac{(1-t)^{\frac{1}{k+2}}}{1-t} - 1 - \frac{t}{1-t}\frac{k+1}{k+2}(1-t)^{\frac{1}{k+2}}\right).$$

The expression above is a continuous function for $t \in (0,1)$, and at $t = 0$ the difference is zero. Furthermore, $lim_{t\to 1}(TR_s - TR_t) = \infty$. Finally, $\frac{d(TR_s - TR_t)}{dt} = \frac{k+1}{(k+2)^2}(1-t)^{-(k+1)/(k+2)}\frac{t}{1-t} > 0$ for all t values between 0 and 1. This means that the difference of tax revenues under a unit tax and an output equivalent ad-valorem tax is not only always positive but is also increasing for $t \in (0,1)$.

The consumer surplus under a tax regime is the utility driven by consuming the differentiated products and the numeraire good minus the cost of consuming those goods. The consumer surplus under an ad-valorem tax is therefore:

$$\begin{aligned} CS_t &= q_0 + \alpha Q_t - \frac{1}{2}\gamma\int_0^{\omega_t^*} q_t^2(w)dG(w|w<\omega_t^*) - \frac{1}{2}\eta(Q_t)^2 - p_0q_0 - \int_0^{\omega_t^*} p_t(\omega)q_t(w)dG(w|w<\omega_t^*), \text{ and} \\ &= q_0 + \alpha Q_t - \frac{1}{2(k+2)}\frac{\omega_t^*}{1-t}Q_t - \frac{1}{2}\eta(Q_t)^2 - p_0q_0 - \frac{k+1}{k+2}\frac{\omega_t^*}{1-t}Q_t. \end{aligned}$$

Similarly, the consumer surplus under a unit tax is $q_0+\alpha Q_s-\frac{1}{2(k+2)}\omega_s^* Q_s-\frac{1}{2}\eta(Q_s)^2-p_0q_0-\frac{k+1}{k+2}\omega_s^* Q_s-sQ_s$. If I calculate the difference between the consumer surplus under a unit tax and an ad-valorem tax taking into account that the price of a numeraire good is one and total output levels are equal at Q I find:

$$\begin{aligned} CS_s-CS_t &= -\frac{1}{2(k+2)}\omega_s^*Q-\frac{k+1}{k+2}\omega_s^*Q-sQ+\frac{1}{2(k+2)}\frac{\omega_t^*}{1-t}Q+\frac{k+1}{k+2}\frac{\omega_t^*}{1-t}Q, \text{ and} \\ &= Q\left(-\frac{1}{2(k+2)}\omega_s^*-\frac{k+1}{k+2}\omega_s^*-s+\frac{1}{2(k+2)}\frac{\omega_t^*}{1-t}+\frac{k+1}{k+2}\frac{\omega_t^*}{1-t}\right). \end{aligned}$$

I insert unit tax rate s as a function of the cutoff marginal cost values $s=\frac{\omega_t^*}{1-t}-\omega_s^*$ back into the above expression and find:

$$\begin{aligned} CS_s-CS_t &= Q\frac{1}{2(k+2)}\left(\omega_s^*-\frac{\omega_t^*}{1-t}\right), \text{ and} \\ &< 0. \end{aligned}$$

Thus, the consumer surplus generated under an ad-valorem tax is always greater than the consumer surplus generated under a unit tax.

Welfare is on the other hand does not have a clear ranking. Under a unit tax regime welfare is therefore:

$$\begin{aligned} W_s &= CS_s+TR_s\ , \\ &= q_0+\alpha Q_s-\frac{1}{2(k+2)}\omega_s^*Q_s-\frac{1}{2}\eta(Q_s)^2-p_0q_0-\frac{k+1}{k+2}\omega_s^*Q_s-sQ_s+sQ_s \text{ and} \\ &= Q_s\left(\alpha-\frac{1}{2(k+2)}\omega_s^*-\frac{1}{2}\eta Q_s-\frac{k+1}{k+2}\omega_s^*\right). \end{aligned}$$

Similarly, welfare under an ad-valorem tax is:

$$\begin{aligned} W_t &= CS_t+TR_t \\ &= q_0+\alpha Q_t-\frac{1}{2(k+2)}\frac{\omega_t^*}{1-t}Q_t-\frac{1}{2}\eta(Q_t)^2-p_0q_0-\frac{k+1}{k+2}\frac{\omega_t^*}{1-t}Q_t+\frac{t}{1-t}\frac{k+1}{k+2}\omega_t^*Q_t \text{ and} \\ &= Q\left(\alpha-\frac{1}{2(k+2)}\frac{\omega_t^*}{1-t}-\frac{1}{2}\eta Q_t-\frac{k+1}{k+2}\frac{\omega_t^*}{1-t}+\frac{t}{1-t}\frac{k+1}{k+2}\omega_t^*\right). \end{aligned}$$

By taking the difference between both regimes I find:

$$\begin{aligned} W_s-W_t &= Q\left(-\frac{1}{2(k+2)}\omega_s^*-\frac{k+1}{k+2}\omega_s^*+\frac{1}{2(k+2)}\frac{\omega_t^*}{1-t}+\frac{k+1}{k+2}\frac{\omega_t^*}{1-t}-\frac{t}{1-t}\frac{k+1}{k+2}\omega_t^*\right), \text{ and} \\ &= Q\omega_s^*\frac{1}{k+2}\left(-k-\frac{3}{2}+\frac{1}{2}\frac{(1-t)^{1/(k+2)}}{(1-t)}+(k+1)(1-t)^{1/(k+2)}\right). \end{aligned}$$

The expression above is zero for $t=0$ and is continuous for $t\in(0,1)$. Furthermore, $lim_{t\to 1}(W_s-W_t)=\infty$. The derivative of the difference function with respect to t is $Q\omega_s^*\frac{k+1}{(k+2)^2}(1-t)^{-(k+1)/(k+2)}\frac{2t-1}{1-t}$. The derivative is positive for $t>0.5$, and zero for $t=0.5$. This implies that the difference function begins at zero, and decreases up to $t=0.5$. The difference reaches its minimum at $t=0.5$ and begins to increase until it reaches ∞ for $t=1$. Thus, welfare under a unit tax regime is greater than an output equivalent ad-valorem tax regime if t is large. ■