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Electronic Commerce and Environmental Welfare : An Analysis of Optimal Taxation

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■ Abstract ■

This article examines the impact of electronic commerce on environmental welfare. In particular, we analyze a game model of price competition between offline and online firms when consumption taxes are imposed on both offline and online transactions that produce environmental pollution. We investigate the properties of optimal taxation between offline and online markets and demonstrate that there is an optimal difference between the two taxes, depending upon not only the transaction cost between offline and online consumption, but also the environmental damage cost. We also investigate the effect of tax-free online transactions on tax revenues, and the financial feasibility of the optimal taxation.

Keyword : Electronic Commerce, Environmental Welfare, Offline Transaction, Online Transaction, Optimal Taxation

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1. Introduction

Since the emergence of the Internet in the mid 1990s, the explosive growth of the information and communication technology (ICT) sector-including the production of computers and peripheral equipment, software and programming services, and communication services-has resulted in a dramatic rise in electronic commerce (e-commerce). With the lowering of transaction barriers, new policy debates on the ICT-based digital economy have come to the forefront regarding its impact not only on business, the economy, and government, but also on the overall society, including environmental impact. In particular, e-commerce and environmental pollution have been an issue of discussion in the new ICT economy.

This article deals with the impact of e-commerce on environmental welfare. In an attempt to probe this relationship, it should be highlighted that some promising environmental policy issues have developed from the expansion of overall consumption and the reduction of transaction cost on the Internet. Concerning the sustainable development of e-commerce, one should pay more attention to whether e-commerce takes the pressure off the environment. This paper asks the question, "What impact does e-commerce have on the environmental pollution problem?" In particular, we seek to answer the question, "What is the optimal taxation regime for online purchases to benefit the society and environment?"

The ways e-commerce can impact the environment are complex and interconnected, but they can be broken down into a few broad categories. These include reduced use of paper and cement products in the industrial sectors, changes related to transportation behavior and supply chain management, improved penetration of heat and power technologies, and so on. Below, the aspects of e-commerce that affect the environment are outlined in four areas.[1)]

E-commerce and energy : In terms of basic energy consumption, the relationship between e-commerce and the environment may turn out to be a beneficial one. Laitner [12] and Laitner et al. [13] reported that between 1996 and 2000 the energy intensity-the amount of energy consumed for every dollar of economic output-dropped by more than 3.25% annually in the United States. The researchers explained that, in addition to climate change, the rapidly growing influence of ICT may account for a significant part of this sharp declining in energy intensity. If that trend in the ICT sectors is combined with efficiencies brought about by e-commerce in other sectors like paper and cement manufacturing and transportation, the outlook could be even rosier. In this sense, the impact of e-commerce on energy is enormous in the short term; such a correlation might be slow in the long term as the system adjusts over time.

E-commerce and product-process design : As more and more businesses adopt e-commerce practices, there will be increased opportunities for them to make their products and manufacturing processes more environmentally benign, as well as to plan "end-of-life" strategies for products, i.e., how the products will be recycled. In addition, e-commerce also has the potential to

1) The following descriptions are discussed in the Joint Symposium on E-Commerce and the Environment (http://www.greenhome.com/info/articles/is_ecommerce_green/).

create substantial efficiencies in the manufacturing process by improving the management of raw materials and providing digitized information goods.2) Thus, it is expected that e-commerce will make use, re-use, and recycling more efficient because the cost of the use of digitized information is actually zero.

E-commerce and logistics : Logistical decisions can have a serious impact on the environment since the transportation system relies on saturated networks of roads, railways, and airways and produces pollutants. E-commerce will improve the efficiency of logistical planning since digitally scheduled and networked "e-supply chain hubs" will remove inefficiency from the traditional logistical system, which will have a positive effect on environmental quality. In addition, consuming digitized information goods on the Internet might reduce personal travel to local stores. However, with more and more people buying non-digitized goods over the Internet, the use of supply and transportation networks could change, not necessarily for the better. Increased use of online shopping could lead to more airplane and truck traffic if overnight shipping becomes the delivery norm, which would have a negative effect on environmental quality. In addition, many consumers might rely on stores to experience products that they end up ordering online. This behavior places an increased burden on supply systems and the environment. Therefore, there might be a trade-off between the positive and negative effects of e-commerce on the environment.

E-commerce and land use : ICT is contributing to the reinvention of physical space for economic and business use with changes occurring on a number of different scales. On the micro scale, the shape of buildings will change as their function changes. On the macro scale, as high-growth areas set up traditional shops out of town, others are locating in inner city areas, which impacts people's daily commute.

Although e-commerce studies are still an emerging research field, recent work in e-commerce has been vigorously conducted. For instance, Shapiro and Varian [19], Weisman [23], Kauffman and Walden [11], and Brousseau and Currien [3] provided some important issues in e-commerce business and economics, such as online price competition and content differentiation, online communities and information goods, e-market performance and network externalities, Internet taxation, and so on.

In particular, focusing on online market competition for price and content differentiation, Bakos [1] and Harrington [9] analyzed the relationship between search costs and product price in online marketplaces and compared prices of online and offline purchases. Oh and Chang [18] and Lee [15] developed an online content differentiation model and examined the welfare effect of strategic alliances between content and network providers. Chun and Kim [6] examined the relative efficiency of transaction costs between offline and online purchases using a game model of price equilibrium. Cho and Lee [4, 5] extended their model into the pricing strategies of online and offline firms with or without multiple (hybrid) channels in a vertical structure and compared the social costs in an equilibrium model.

Some public policy issues of Internet taxation

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2) The discussion on economic and business strategies for digitized information goods is provided in Shapiro and Varian [19] and Sohn and Lee [20].

and e-commerce have also been examined.[3] Goolsbee and Zittrain [7] investigated where tax revenues come from and how the Internet is likely to affect them, and Goolsbee [8] examined the effect of local sales taxes on e-commerce. Lee [16, 17] analyzed the effect of Internet taxation using a price competition model between online and offline firms and suggested a discriminatory optimal tax. However, as far as the author is aware, no work has been done on the optimal taxation issue for e-commerce and environmental problems.

In order to examine the taxation issue on environmental welfare in the e-commerce market, this article formulates an equilibrium model for analyzing price competition between offline and online firms when taxes are imposed on consumption which results in environmental pollution. In particular, considering the conventional linear city model of product differentiation developed by Hotelling [10], we analyze an e-commerce market where a monopolistic offline firm competes against an online firm. We then investigate the prices between the two transactions at the coexistence equilibrium and show how the price equilibrium depends on offline/online transportation costs and differential tax treatment. We then demonstrate that there is an optimal difference between the two types of taxation, depending upon not only the transaction cost between offline and online consumption, but also the environmental damage cost. We also examine the effect of tax-free online transactions on tax revenues and the financial feasibility of optimal taxation.[4]

The organization of this paper is as follows : In the next section, we formulate the basic e-commerce market model between offline and online firms and explore the properties of equilibrium prices and taxes. In Section 3, we examine environmental welfare and tax revenues and provide the optimal tax difference between online and offline consumption. A conclusion is provided in the final section.

2. Offline vs. Online Transactions

Based on the linear city model of product differentiation by Hotelling [10], we consider a linear city of unit length where consumers are uniformly distributed on this interval. Each consumer is indexed by $x \in [0, 1]$, so x is a location from the origin. Suppose that there is one local monopolistic offline firm at the origin, which sells its product with zero production cost. Each consumer decides whether to buy one unit of the product from the offline firm by paying the price of p_f and transportation cost of τ per unit of distance. We assume that the government im-

3) The subject of Internet taxation is at the forefront of recent public policy debates over e-commerce in response to the Internet Tax Freedom Act (ITFA) in the United States, which was first passed in 1998 and extended in 2006. Goolsbee and Zittrain [8], Watanabe [22], and Lee [16, 17] provided some important discussion of this matter, including tax evasion behavior for tax-free online transactions and optimal taxation.

4) Our approach is not a general Ramsey rule in public taxation, in which the optimal taxation reflects the situation in which the tax/price ratio is proportional to the inverse of the elasticity of demand. See Varian [19], p.432. Notice that the optimal tax does not require uniform tax rates for the two types of commerce unless the utility function is homothetic and there is separability between leisure and consumption.

poses a consumption tax of t_f per unit product of consumption for the offline firm. Then, we can define total payment of the consumer located at point x by $p_f + t_f + \tau x$.

On the other hand, an online firm, which has no specific location in the city, sells the same good as the offline firm, having the price of p_n and zero production cost.5) We assume that every consumer at each location point has access to the Internet and that consumers may buy goods from either the offline or online firm. If the consumer buys the good from the online firm, irrespective of the location point of the consumer, he or she incurs an online access cost of *a*, which includes search cost, uncertainty cost, security cost, order tracking cost, and delivery cost. We also assume that the government imposes a consumption tax of t_n per unit product of consumption for the online firm.6) Then, if a consumer buys one unit of the product from the online firm, he or she has to pay $p_n + t_n + a$.

Finally, we consider the environmental pollution problem of the two transaction behaviors for consumption. In the offline transaction, the consumer's transportation activity produces pollution, which depends upon the distance traveled. We assume that pollution causes (social) marginal environmental damage cost e per unit of distance. Then, the social damage cost from the consumer who locates at x is ex if that consumer buys the product from the offline firm. Thus, total environmental damage from the offline purchase will be represented by the integral of marginal damage cost per distance. For the online transaction, however, the delivery system of the online firm, which conveys the ordered product to the consumer, incurs pollution proportional to the total distance. If we denote the total distance of its delivery system as g, then we assume that total social damage cost of keg arises from the total amount of online consumption, where k $(0 < k < 1)$7) is the adjustment factor of marginal damage from the online delivery system. This implies that the online consumption of any consumer causes adjusted environmental damage per unit product in the delivery system; thus, total environmental damage from the online purchase will be proportional to the average damage cost per distance.8)

5) This is for comparison purposes; the location of the online firm and its production cost do not affect the main results of this model. Instead, we focus on the relative magnitude of transportation cost between offline and online transactions. Bakos [1] and Brynjolfsson and Smith [3] provided some discussions of the transaction cost of the online channel in an e-commerce market.

6) If the government imposes the same rate of consumption tax for offline consumption of the online transaction, the tax does not affect the consumption decision of consumers under the market-covered assumption since they are indifferent between the two tax rates; that is, the tax will be cancelled out from the comparisons between total payments in (1).

7) The adjustment factor represents a trade-off between the positive and negative effects of e-commerce on the environment. In particular, if k = 0.5, the offline and online channels result in symmetric social damage in the model, i.e., the online consumption without the offline channel yields the same social damage as the offline consumption without the online channel. For example, total social damage of the offline channel is $\int_0^1 esds = \frac{e}{2}$, while that of the online channel is *ke*. Thus, compared to the offline consumption, k < 0.5 indicates online consumption improves the environment, while k > 0.5 indicates online consumption degrades the environment.

8) Cho and Lee [5] specifically described the properties of transaction costs between offline and online transactions and pointed out that the offline trans-

Let x_A be the market divide, which denotes the critical consumer who is indifferent to whether he or she purchases the product from the offline or online firm; that is, $p_f + t_f + \tau x = p_n + t_n + a$ yields the following market divide between offline and online markets :

$$x_A = \frac{p_n - p_f + t_n - t_f + a}{\tau} \tag{1}$$

We will restrict our analysis to the coexistence equilibrium in which both offline and online firms cover the full market and sell the product in equilibrium,[9] i.e., $0 < x_A < 1$. Specifically, we assume that $-\tau - a < \Delta < 2\tau - a$, where $\Delta \equiv t_n - t_f$. Then, demand functions for each firm are given by :

$$D_f = x_A = \frac{p_n - p_f + \Delta + a}{\tau} \quad \text{and}$$
$$D_n = 1 - x_A = \frac{\tau - (p_n - p_f + \Delta + a)}{\tau} \tag{2}$$

From the first-order conditions of the profit functions of offline firm, $\pi_f = p_f D_f$, and that of the online firm, $\pi_n = p_n D_n$, we have the following positive equilibrium prices :

$$p_f^* = \frac{\tau + \Delta + a}{3} \quad \text{and} \quad p_n^* = \frac{2\tau - \Delta - a}{3}. \tag{3}$$

Comparing the properties of equilibrium prices in (3), we show that the difference of the equilibrium prices between offline and online firms depends on the parameters in the model as follows :

$$p_f^* - p_n^* = \frac{2\Delta - \tau + 2a}{3} \tag{4}$$

A few comments are in order. First, p_n^* might be larger (smaller) than p_f^* when t_n is sufficiently smaller (larger) than t_f; that is, $p_f^* \gtrless p_n^*$ when $\Delta \gtrless \frac{\tau}{2} - a$. Second, the differences in prices are dependent on two transaction costs. As the online access cost increases, consumers prefer to buy products from offline firms; thus, the price of offline firms increases while that of the online firm decreases; that is, $\frac{\partial p_n^*}{\partial a} < 0 < \frac{\partial p_f^*}{\partial a}$. As the offline transportation cost increases, the prices of both offline and online firms increase because of the product differentiation effect, but the upward pressure is stronger on the online firm; that is, $0 < \frac{\partial p_f^*}{\partial \tau} < \frac{\partial p_n^*}{\partial \tau}$. Third, the offline tax will reduce the price for the offline firm, but will raise that for the online firms, while the online tax will reduce the price for the online firm, but will raise that of the offline firms; that is, $\frac{\partial p_f^*}{\partial t_f} < 0 < \frac{\partial p_n^*}{\partial t_f}$ and $\frac{\partial p_n^*}{\partial t_n} < 0 < \frac{\partial p_f^*}{\partial t_n}$.

From the equilibrium prices in (3), we have

$$D_f^* = x_A^* = \frac{1}{3} + \frac{\Delta + a}{3\tau} \quad \text{and}$$
$$D_n^* = 1 - x_A^* = \frac{2}{3} - \frac{\Delta + a}{3\tau} \tag{5}$$

action cost is marginally increasing for individual transportation distance, while the online transaction cost can be proportional to the total delivery distance.

9) A lot of empirical research has analyzed the competition between offline and online markets and yielded conflicting results about the relative prices between the two markets according to the product types, order placement, payment system, and market-coverage. See, for example, Lee [14], Chun and Kim [6], and Lee [16].

A few comments are in order. First, D_f^* might be larger (smaller) than D_n^* when t_n is sufficiently smaller (larger) than t_f; that is, $D_f^* \gtrless D_n^*$ when $\Delta \gtrless \frac{\tau}{2} - a$. Second, as the online access cost increases or as the offline transportation cost decreases, the market size of offline firms increases, while that of the online firm decreases; that is, $\frac{\partial D_f^*}{\partial \tau} < 0 < \frac{\partial D_f^*}{\partial a}$ and $\frac{\partial D_n^*}{\partial a} < 0 < \frac{\partial D_n^*}{\partial \tau}$. Third, as the online tax decreases or as the offline tax increases, the market size of the offline firms decreases, while that of the online firm increases; that is, $\frac{\partial D_f^*}{\partial t_f} < 0 < \frac{\partial D_f^*}{\partial t_n}$ and $\frac{\partial D_n^*}{\partial t_n} < 0 < \frac{\partial D_n^*}{\partial t_f}$. Finally, the total distance of the online delivery system is represented by the demand for the online firm at equilibrium, i.e., $g = D_n = 1 - x_A$.

Then, we can define environmental damage from these two consumption behaviors as follows :

$$E = \int_0^{x_A} esds + keg = \frac{ex_A^2}{2} + ke(1 - x_A)$$
$$= \frac{e}{2}\left(\frac{\tau + a + \Delta}{3\tau}\right)^2 + ke\left(\frac{2\tau - a - \Delta}{3\tau}\right) \quad (6)$$

Note that $\frac{\partial E}{\partial x_A} = e(x_A - k) \gtrless 0$ if $x_A \gtrless k$. Thus, if $0 < x_A < k < 1$ at the coexistence equilibrium, we have (i) as the online access cost increases or as offline transportation cost decreases, environmental damage decreases, i.e., $\frac{\partial E}{\partial a} < 0 < \frac{\partial E}{\partial \tau}$, and (ii) as the online tax increases or as the offline tax decreases, environmental damage decreases, i.e., $\frac{\partial E}{\partial t_n} < 0 < \frac{\partial E}{\partial t_f}$. Otherwise, the results are reversed.

3. Optimal Taxation for Offline/Online Transactions

We investigate the optimal taxes for offline and online consumption, which maximizes environmental welfare, defined as the sum of profits, consumer surplus, loss of environmental damages, and tax revenues :

$$W = \pi_f + \pi_n + S - E + G, \quad (7)$$

where $S = \int_0^{x_A} (V - p_f - t_f - \tau s)ds + \int_{x_A}^1 (V - p_n - t_n - a)ds$ is the consumer surplus incurred from offline and online consumption of the product, which gives the same product value of V, and $G = \int_0^{x_A} t_f ds + \int_{x_A}^0 t_n ds$ is the government's tax revenue. Then, environmental welfare can be rewritten as follows :

$$W = \int_0^x (V - \tau s - es)ds + \int_x^1 (V - a - ke)ds \quad (8)$$

We need to decide the optimal market divide x_A^o, which maximizes the above environmental social welfare function. Then, it should satisfy the following first-order condition :

$$\frac{\partial W}{\partial x_A} = (V - \tau x_A - ex_A) + (V - a - ke) = 0, \quad (9)$$

which yields the optimal market divide :

$$x_A^0 = \frac{a+ke}{\tau+e}. \tag{10}$$

This optimal condition requires the marginal social cost of the offline transaction, $(\tau+e)x_A$, which is variable with the travel distance of consumers, to be equal to the marginal social cost of the online transaction $a+ke$. Notice also that $\frac{\partial x_A^o}{\partial a} > 0 > \frac{\partial x_A^o}{\partial \tau}$ and $\frac{\partial x_A^o}{\partial e} \underset{<}{>} 0$ if $k \underset{<}{>} \frac{a}{\tau}$

Therefore, in order to make the market divide in the equilibrium in (5) be the optimal market divide in (10), the government should impose the following optimal tax difference on offline and online market transactions :

$$\Delta^o = \frac{3\tau(a+ke)-(\tau+a)(\tau+e)}{\tau+e}. \tag{11}$$

A few remarks are in order. First, the same tax rate between offline and online transactions, i.e., $\Delta^o = 0$, will not be the optimum unless $3\tau(a+ke) = (\tau+a)(\tau+e)$. Therefore, the optimal online tax might be greater or less than the offline tax depending not only on the relative size of the transportation cost and access cost, but also on the environmental damage cost.

Second, if there is no pollution problem, i.e., $e=0$, the optimal tax difference is $\Delta^o = 2a-\tau$ and thus $t_n^o \underset{<}{>} t_f^o$ if $a \underset{<}{>} \frac{\tau}{2}$.

Third, if the government imposes zero tax on the online transaction, i.e., $t_n = 0$, the optimal offline tax should be $t_f^o = \frac{3\tau(a+ke)-(\tau+a)(\tau+e)}{\tau+e}$; that is, under moderate conditions, zero online tax would not be the optimum.[10)]

Fourth, comparative statics gives : (i) $\frac{\partial \Delta^o}{\partial e} \underset{<}{>} 0$ if $k \underset{<}{>} \frac{a}{\tau}$, (ii) $\frac{\partial \Delta^o}{\partial a} \underset{<}{>} 0$ if $e \underset{<}{>} 2\tau$, and (iii) $\frac{\partial \Delta^o}{\partial \tau} \underset{<}{>} 0$ if $e \underset{<}{>} \frac{(\tau+e)^2}{3(a+ke)}$.

Finally, we examine how the tax revenues depend on the tax difference between offline and online taxes in the model. The tax revenues for the product at market equilibrium are as follows :

$$\begin{aligned} G &= \int_0^{X_A} t_f ds + \int_{X_A}^0 t_n ds \\ &= \frac{t_f(\tau+a+\Delta)+t_n(2\tau-a-\Delta)}{3\tau} \end{aligned} \tag{12}$$

A few remarks are in order. First, $\partial G/\partial \tau \underset{<}{>} 0$ and $\partial G/\partial a \underset{>}{<} 0$ if $t_n \underset{<}{>} t_f$. Second, if we consider zero online tax, where $t_n = 0$, G becomes $t_f(\tau+a-t_f)/3\tau$. Then, G will be positive only when $0 < t_f < \tau+a$.[11)] Third, imposing the optimal tax gives the following tax revenues :

$$\begin{aligned} G^o &= t_f^o x_A^o + t_n^o(1-x_A^o) = t_n^o - \Delta^o\left(\frac{a+ke}{\tau+e}\right) \\ &= t_f^o + \Delta^o\left(\frac{\tau-a+e(1-k)}{\tau+e}\right) \end{aligned} \tag{13}$$

Finally, optimal taxation is financially feasible only when $G^o \geq E^o$, where the environmental damage is covered by the tax revenue. Specifically,

10) The recent public policy debate over the ITFA has placed the onus on academic scholars to establish why e-commerce should, or should not, be taxed. On this point, Lee [16, 17] analyzed the effect of ITFA on social welfare and tax revenue.

11) For the coexistence equilibrium at the optimum in (9), we assume that $-\tau-a < \Delta^o < 2\tau-a$, which assures $0 < x_A^o < 1$. In particular, if $t_n = 0$, it becomes $a-2\tau < t_f < \tau+a$.

$$t_f^o \geq \frac{e}{2}x_A^o - (t_n^o - ke)\frac{(1-x_A^o)}{x_A^o}$$
$$= \frac{e}{2}\left(\frac{a+ke}{\tau+e}\right) - (t_n^o - ke)\left(\frac{\tau - a + e(1-k)}{a+ke}\right) \quad (14)$$

Note that a sufficient condition for the financial feasibility of optimal taxation is $t_n^o \geq ke$ and $t_f^o \geq \frac{e}{2}\left(\frac{a+ke}{\tau+e}\right)$. For example, if $t_n = 0$, for the financial feasibility of optimal taxation, offline tax should be increasing so that

$$t_f^o \geq \frac{e}{2}\left(\frac{a+ke}{\tau+e}\right) + ke\left(\frac{\tau - a + e(1-k)}{a+ke}\right).$$

4. Concluding Remarks

This paper has analyzed the impact of offline and online taxes on the price equilibrium in an e-commerce market and the properties of optimum taxation when environmental pollution is considered. We have demonstrated that there is an optimal difference between the two taxes, depending upon not only the transaction cost between online and offline consumption, but also the environmental damage cost. We also have shown that, under moderate conditions, zero tax on online transaction would not be the optimum and a zero online tax requires a higher offline tax for financial feasibility.

The implication of this article relates to the current debate over taxing e-commerce, whether e-commerce should or should not be taxed, in response to the Internet Tax Freedom Act in the United States. The conventional "infant industry" argument supports a moratorium on online taxation until e-commerce channels are mature. However, this paper argues that e-commerce must be taxed to level the playing field between offline and online firms to improve market efficiency and to address tax evasion for offline taxation in order to support government revenues. In addition, concerning the sustainable development of e-commerce, we include the environmental pollution problem into our examination of e-commerce policy and conclude that the environmental damage cost should be involved in the calculation of optimal taxation.

Some promising business economic issues should be examined for future research. For instance, it is worthwhile to analyze the competition effect among multiple (online or hybrid) channels with retailers in a vertical structure. In that case, e-commerce practices such as product-process design for green management could be incorporated. In particular, it would be interesting to consider the case in which economic agents such as consumers and producers take into account the environmental quality of the transaction process in e-commerce. It would be also challenging to investigate the dynamic interactions between the growth of e-commerce and the long-term impact on environmental welfare.

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