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Essays on market competition and law enforcement

Yanchen WANG

ESSAYS ON MARKET COMPETITION AND LAW ENFORCEMENT

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PHD

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ESSAYS ON MARKET COMPETITION AND LAW ENFORCEMENT

by

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ABSTRACT

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My Ph.D. dissertation contains both theoretical and empirical studies on market competition and law enforcement.

The first study, entitled "Piracy, Counterfeiting, and Market Competition", is a theoretical study and investigates the economic consequences of intellectual property law enforcement by looking at two types of intellectual property infringement, piracy and counterfeiting. To investigate how the market power changes in the presence of piracy, we start with a static model made up of two horizontally and vertically differentiated goods, genuine product and pirated product. The representative consumer's utility is a function of the consumption of the two goods. The consumer can choose to buy one out of the two differentiated goods but faces a potential legal cost if he purchases the pirated product. The legal cost is exogenous and decided by the policy maker. We show that, as the level of law enforcement enhances, the substitutability between genuine product and pirated product decreases, and the market power of the genuine product producer increases. This makes the two products less likely to belong to the same antitrust relevant market, confirming the conjecture raised by Lin (2018). Next, we explore how anti-counterfeiting efforts under the intellectual property law affect market competition, by setting up a two-stage game made up of four firms: two branded firms and two counterfeiters. In the first stage, each branded firm can take anti-counterfeiting effort independently and simultaneously, which only affects its corresponding counterfeiter. In the second stage, four firms compete in the Cournot's framework. We show that two branded firms' decision variables are strategic substitutes, and the negative externality exists for branded firm to take anti-counterfeiting efforts. Due to the negative externalities, we confirm that the private anti-counterfeiting efforts chosen by branded-good producers are higher than the industrial optimum.

The second study, entitled "The Volcker Rule, Bank Stability and Bank Liquidity", is an empirical study and focuses on the latest bank regulation, the Dodd-Frank Wall Street Reform and Consumer Protection Act. Specifically, we focus on section 619 of Dodd-Frank Act, which is commonly known as "Volcker Rule" and imposes restrictions on banks' ability to engage in proprietary trading activities. Using the passage of the Volcker Rule as an exogenous shock, we employ the difference-in-differences analysis to investigate the effect of Volcker Rule on bank risk and liquidity creation. We find a significant reduction on proprietary trading among regulated bank holding companies (BHCs). In the meantime, we find that the enforcement of Volcker Rule induces a significant increase in liability-side liquidity creation and a decrease in the off-balance sheet liquidity creation. Our findings shed light on the trade-off of Volker Rule implementation in the United States.

DECLARATION

I declare that this is an original work based primarily on my own research, and I warrant that all citations of previous research, published or unpublished, have been duly acknowledged.

SIGNED

(WANG Yanchen)

2018/8/31

Date

CERTIFICATE OF APPROVAL OF THESIS

ESSAYS ON MARKET COMPETITION AND LAW ENFORCEMENT

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Doctor of Philosophy

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CHAPTER 1

Piracy, Counterfeiting, and Market Competition

1.1. Introduction

Since the 1980s, intellectual property rights (hereafter, IPR) protection has become much more extensive around the world. However, after over 30 years, intellectual property infringement still occurs in many countries, regardless of whether the country has strong or weak IPR protections. This chapter investigates the economic consequences of intellectual property law enforcement by looking at two types of intellectual property infringement: piracy and counterfeiting.

Piracy is defined as the unauthorized reproduction of intellectual property, which has long been a concern for consumers, producers, and policy-makers. Even though some agencies, like the European Commission, have stepped up the fight against piracy, the situation has not changed.[1] One reason for this lack of progress is that products such as software, video and audio tapes, and books have high fixed costs of development and very low marginal costs of reproduction; in addition, the advent of digital technology makes it easy to create illegal high-quality copies. This problem becomes even more severe if we take online infringement into consideration.[2] Through visiting the pirating firm's website, consumers can download the pirated product directly, thus leading to financial harm to the genuine firm. However, the consumption of pirated products increases consumer welfare, leading to a higher level of social welfare. Therefore, the degree of law enforcement become a serious policy question. We

[1] According to a global software piracy report from the Business Software Alliance, the global piracy rate for computer software has decreased slightly, from 42 to 39 percent, over the past seven years.
[2] According to MUSO global piracy report, for instance, total visits to piracy sites were approximately 191 billion in 2017, and the average number of visits to piracy sites per internet user was about 54.

consider a two-firm industry for a specific copyrightable product, which can be produced by a genuine firm and a pirating firm. Two firms compete within a Bertrand framework. In our model, we follow Lin (2018) and endogenize the legal cost of using the pirated product in the demand function. Specifically, we consider the effective price of the pirated product as the sum of the price charged by the pirating firm and the legal cost, which can be decomposed into two parts: the probability of being detected and punished, and the damage compensation that consumers must pay to the victim, namely the genuine firm. Based on our results, we find that a higher level of law enforcement leads to a lower level of consumer welfare. However, the genuine firm can benefit from a higher level of law enforcement. Therefore, the social welfare is an inverse U-shaped function of law enforcement. With an increase in law enforcement, specifically when law enforcement reaches a certain level, the substitutability between the genuine product and pirated product decreases, and the market power of the genuine firm increases. The two products are thus less likely to belong to the same antitrust relevant market, confirming the conjecture raised by Lin (2018).

In the second section, we explore how anti-counterfeiting efforts under the intellectual property law affect market competition. Counterfeits are illegal imitations of branded goods. Counterfeits in this paper refer to non-deceptive counterfeit goods that consumers can distinguish from branded goods either by close inspection or by distribution channels (Grossman and Shapiro, 1988 a, b). We set up a two-stage game made up of four firms: two branded firms and two counterfeiters. In the first stage, each branded firm can take anti-counterfeiting efforts independently and simultaneously, which only affects its corresponding counterfeiter. In the second stage, four firms compete in a Cournot framework. We examine the private incentives of branded-good producers for curbing counterfeits of their products. We find that two branded firms' decision variables are strategic substitutes, and negative externality exists for branded firms to take anti-counterfeiting efforts. Due to negative externalities, we confirm that private anti-counterfeiting efforts chosen by branded-good producers are higher than the industrial optimum. At both the firm and industry levels, the marginal profit of taking anti-counterfeiting efforts for branded firms increases with vertical differentiation.

1.2. Literature review

Our study contributes to the existing literature in several ways. First, our study adds to a vast body of literature on piracy. In a seminal paper, Reavis Conner and Rumelt (1991) examine software piracy protection policies and find that piracy can increase the size of the user base and induce positive network externality. They argue that consumers are motivated to economize on post-purchase learning and customization costs due to network externality. In a similar vein, Takeyama (1994) shows that, in the presence of demand network externality, piracy can not only induce greater firm profits relative to the case where there is no unauthorized reproduction, but also lead to a Pareto improvement in social welfare. Regarding piracy as a form of price discrimination, Slive and Bernhardt (1998) state that software manufacturers may tolerate piracy by home consumers that can induce positive network externality, and benefit from business consumers who have a high willingness to pay. Shy and Thisse (1999) point out the trade-off between the network effect and competitive effect deriving from piracy. Increasing network effects caused by piracy make software attractive to consumers, and thus enable firms to raise prices. However, they also lead to intensive competition for market share. In addition to network models, earlier papers directly concerned with intellectual property rights protection include Novos and Waldman (1984), Yoon (2002), Bae and Choi (2006), and Harbaugh and Khemka (2010). To solve the underproduction-underutilization problem of copyright protection, Novos and Waldman (1984) construct a model in which consumers vary only in terms of the cost of their obtaining a copy. They argue that an increase in copyright protection decreases the social welfare loss due to underproduction. Yoon (2002) considers the situation where consumers vary in terms of their valuations of the quality of software, rather than the quantity. He finds that an increase in copyright protection may increase or decrease the social welfare loss due to underutilization by introducing the valuation model. Bae and Choi (2006) improve the model by introducing two types of costs associated with piracy (type-independent reproduction cost and type-dependent degradation cost) and accordingly show that the effects of piracy depend on the nature of piracy costs. Focusing on the extension of copyright law in 1998, Hui and Png (2002) investigate the impact of economic incentives on the international supply of big-screen movies. They find strong evidence that the supply of creative work did respond to economic incentives. Chen and Png (2003) conduct a welfare analysis by considering how the government should set fines for copying, taxes on copying media, and subsidies for legitimate purchases. They find that increases in detection affect welfare more negatively than price cuts and that government policies that focus on penalties alone will miss the social welfare optimum. We add to this list by exploring the effect of law enforcement on substitutability and market power in the presence of piracy.

In addition to piracy, our study is associated with the ongoing research interest in counterfeiting. Conventional wisdom suggests that counterfeits can damage sales of branded goods and have a negative influence on innovation. However, a growing literature challenges the assumed negative effect of counterfeits. Among the very few papers that have directly examined the impact of counterfeits, Grossman and Shapiro (1988a, b) theorize about the positive and normative effects of counterfeiting in international trade. Several recent papers show that branded firms can benefit from counterfeiters via spillover effects. Qian (2008) uses data from shoe companies in China and shows that prices of branded goods increase on average after the entry of counterfeiters. In a subsequent study, Qian (2014) documents that the impact of counterfeiting on sales differs for branded goods of various quality tiers. She finds a positive impact on high-end goods but a negative impact on low-end goods. In a recent paper, Wu, Gong, and Chiu (2016) consider two branded firms competing in Hotelling's framework in the presence of outside competition from non-deceptive counterfeiters. They find that the presence of counterfeit goods gives rise to two effects on branded firms' profit: a substitution effect and price increasing effect. In this paper, we explore how anti-counterfeiting efforts engaged in by producers affect market competition between branded goods and counterfeits. We contribute to this stream of the literature by considering both inter-brand competition and competition between branded goods and counterfeits.

1.3. Market power in the presence of piracy

1.3.1. Theoretical framework

This section investigates how intellectual property law enforcement affects the competition constraint from piracy. We consider a two-firm industry for a specific copyrightable product (computer software, for example), which can be produced by a genuine firm G and a pirating firm X. Two firms compete in price and sell the product by providing a download website to customers. Production involves zero marginal cost, due to the nature of the copyrightable product, and no fixed cost in the production stage.

We assume that each customer can consume the product by one of the following two methods. The first is to purchase the genuine product from the official website. In this case, the consumer pays the price p_G. The second is for the consumer to purchase the product directly from the piracy site, or indirectly from an online shopping website (e.g., Taobao). When consumers purchase the pirated product, they have to pay the price p_X, which is charged by the pirating firm and is lower than p_G.

In addition to the price p_X, consumers who download and use the pirated product will face a legal cost. Therefore, the effective price of the pirated product equals the sum of the price and legal cost, $p_X + \tau p_G$. The legal cost can be decomposed into two parts: the probability of being detected and punished, and the damage compensation that consumers must pay to the victim, namely the genuine firm. The probability denoted by τ is exogenous and decided by the law enforcement agency. The probability τ is $0 < \tau < 1$. A smaller τ means weaker IPR protection, and τ becomes larger if the level of law enforcement increases. The compensation depends on the value of the product that has been pirated. Thus, we simply assume that the compensation equals the price of the genuine product. Eventually, the law enforcement agency will transfer the compensation paid by consumers to the genuine firm. Obviously, the effective price of the pirated product should not be larger than the price of the genuine product. That is, $p_X + \tau p_G \leq p_G$. Otherwise, consumers have no incentive to download the product from the piracy site.

The pirated product is not a perfect substitute for the genuine product. We assume that two products obtained from different websites are horizontally and vertically differentiated. We introduce a parameter θ to indicate the degree of vertical differentiation between the genuine and pirated products. The parameter θ is $0 < \theta < 1$, because the pirated product is not as good as the genuine product. A higher value of θ indicates a larger quality difference between the two products. The quality difference is due to quality degradation, lack of manuals, lack of technical support, etc. Furthermore, we use a parameter δ to represent the degree of horizontal differentiation between the genuine and pirated products. δ approaches 1 if the two products are almost homogeneous, and δ approaches 0 as the two products become differentiated.

A higher value of δ indicates a higher substitute effect between the two products.

Vertical differentiation is far more important than horizontal differentiation, because in most real-life situations, the quality of pirated products is indeed lower than that of the genuine products. If we take computer software as an example, the variations in advanced functions or timely updates constitute vertical differentiation. Specifically, the pirated software includes only basic functions, whereas the genuine software provides many advanced functions for users. Consumers who use the genuine products will receive reminders of necessary updates, while the pirated software will not provide update services. In addition, genuine products are usually faster and yield a better user experience.

We also allow for horizontal differentiation between the genuine product and the pirated product. While computer software may exhibit vertical differentiation, there are situations where the overall quality difference between the genuine product and the pirated product may not be significant. For example, in the case of movies, consumers can watch pirated movies on DVD players at home, in a more relaxed environment and at flexible times, and perhaps more than once. This may represent horizontally differentiated products to the genuine movies which are shown in movie theaters and strictly adhere to the show times. Similarly, the pirated books in electronic version are easier to carry around or store, and may be considered as horizontally differentiated products with respect to original hard copies of the book.

1.3.2. The consumer

Based on the product differentiation literature (see, e.g., Dixit and Stiglitz, 1977), we consider the representative consumer's utility as a function of the consumption of the two goods:

$$u(q_G, q_X) = \alpha[q_G + (1-\theta)q_X] - \frac{1}{2}(q_G^2 + q_X^2) - \delta q_G q_X \tag{1}$$

Utility maximization gives rise to the following demand structure, which is formulated as a system of inverse demand functions.

$$p_G = \alpha - q_G - \delta q_X \tag{2}$$

$$p_X + \tau p_G = \alpha(1-\theta) - q_X - \delta q_G \tag{3}$$

where p_G and p_X are the prices of the genuine product and pirated product, respectively, q_G and q_X are the quantities of the genuine product and pirated product, respectively, θ is the quality difference between the two products, δ measures the differentiation between the two products, and τ is the probability of being detected and punished if the consumer uses the pirated product.

The direct demand functions can be obtained by inverting the demand structure exhibited in (2) and (3).

$$q_G = \frac{1-\delta(1-\theta)}{1-\delta^2}\alpha - \frac{1-\delta\tau}{1-\delta^2}p_G + \frac{\delta}{1-\delta^2}p_X \tag{4}$$

$$q_X = \frac{1-\theta-\delta}{1-\delta^2}\alpha - \frac{1}{1-\delta^2}p_X + \frac{\delta-\tau}{1-\delta^2}p_G \tag{5}$$

Assumption 1. $\boldsymbol{1-\theta > \delta}$.

To ensure that the coefficient $\frac{1-\theta-\delta}{1-\delta^2}$ in (5) is positive, we assume that $1-\theta$ is larger than δ. $1-\theta$ denotes the quality of the pirated product, and δ measures the substitute effect between the genuine and pirated products. $1-\theta > \delta$ means that consumers prefer the pirated product to the genuine product if the quality of the pirated product is larger than the substitute effect of the pirated product.

Assumption 2. $\delta > \tau$.

To ensure that the coefficient $\frac{\delta-\tau}{1-\delta^2}$ in (5) is positive, we assume that δ is larger than τ. δ measures the substitute effect between genuine and pirated products, and τ denotes the level of law enforcement. Consumers who choose a pirated product face a trade-off problem between the substitute effect measured by δ and the punishment effect measured by τ. When the substitute effect is larger than the punishment effect, some consumers are willing to choose the pirated product. Otherwise, consumers will only choose to purchase the genuine product to avoid the legal cost.

1.3.3. The firm

Denote firm i's profit function as a Bertrand competitor by $\pi_i^B(p_i, p_j)$, where p_i and p_j represent the two firms' price levels. Firm i chooses p_i, taking p_j as given. The profit of the genuine firm is determined by sales and damage compensation obtained. Thus, the genuine firm needs to maximize the profit function described in (6).

$$\begin{aligned}\pi_G^B &= p_G q_G + \tau p_G q_X \\ &= -\frac{\tau^2 - 2\delta\tau + 1}{1-\delta^2} p_G^2 + \left[\frac{(1-\theta-\delta)\tau + (\theta-1)\delta + 1}{1-\delta^2}\alpha + \frac{\delta-\tau}{1-\delta^2} p_X\right] p_G\end{aligned} \tag{6}$$

The first-order condition is $-\frac{2(\tau^2-2\delta\tau+1)}{1-\delta^2} p_G + \frac{(1-\theta-\delta)\tau+(\theta-1)\delta+1}{1-\delta^2}\alpha + \frac{\delta-\tau}{1-\delta^2} p_X = 0$, yielding a best-response function given by

$$p_G(p_X) = \frac{(1-\theta-\delta)\tau + (\theta-1)\delta + 1}{2(\tau^2 - 2\delta\tau + 1)}\alpha + \frac{\delta-\tau}{2(\tau^2 - 2\delta\tau + 1)} p_X \tag{7}$$

The genuine firm's profit function is strictly concave, because the second-order condition for the maximization problem is satisfied: $\frac{\partial^2 \pi_G^B}{\partial p_G^2} = -\frac{2(\tau^2-2\delta\tau+1)}{1-\delta^2} < 0$.

The profit of the pirating firm is determined only by sales. Thus, the pirating firm needs to maximize the profit function described in (8).

$$\begin{aligned}\pi_X^B &= p_X q_X \\ &= -\frac{1}{1-\delta^2} p_X^2 + \left(\frac{1-\theta-\delta}{1-\delta^2}\alpha + \frac{\delta-\tau}{1-\delta^2} p_G\right) p_X\end{aligned} \tag{8}$$

The first-order condition is $-\frac{2}{1-\delta^2} p_X + \frac{1-\theta-\delta}{1-\delta^2}\alpha + \frac{\delta-\tau}{1-\delta^2} p_G = 0$, yielding a best-response function given by

$$p_X(p_G) = \frac{1-\theta-\delta}{2}\alpha + \frac{\delta-\tau}{2} p_G \tag{9}$$

The pirating firm's profit function is strictly concave because the second-order condition for the maximization problem is satisfied: $\frac{\partial^2 \pi_X^B}{\partial p_X^2} = -\frac{2}{1-\delta^2} < 0$.

Based on the two best-response functions, we have our first result.

Proposition 1. The two firms' decision variables are strategic complements. As the level of law enforcement τ increases, ceteris paribus, the best-response function for the genuine firm shifts to the right.

Proof.

In Figure 1, we draw two full lines to represent the best-response function for the genuine firm, $p_G(p_X)$, and the best-response function for the pirating firm, $p_X(p_G)$, respectively. Both lines are upward sloping because their slopes are positive. Therefore, the two best-response functions are strategic complements. The best-response function of the genuine firm is steeper than that of the pirating firm because $\frac{2(\tau^2-2\delta\tau+1)}{\delta-\tau} - \frac{\delta-\tau}{2} = \frac{3(\delta-\tau)^2+4(1-\delta^2)}{2(\delta-\tau)} > 0$.

[Insert Figure 1 here]

In addition, we draw two dotted lines to represent new best-response functions when the level of law enforcement increases. As τ increases, $p_X(p_G)$ rotates clockwise because the slope of $p_X(p_G)$ decreases with τ such that $\frac{\partial[(\delta-\tau)/2]}{\partial\tau} < 0$, and $p_G(p_X)$ shifts to the right because the intercept of $p_G(p_X)$ decreases with τ such that $\frac{\partial\{-[(1-\theta-\delta)\tau+(\theta-1)\delta+1]/(\delta-\tau)\}}{\partial\tau} < 0$.

As the level of law enforcement increases, the demand for genuine product increases and thus the genuine firm will increase the price of the genuine product. Accordingly, the pirating firm will also increase the price of pirated products, because their decision variables are strategic complements. However, increased law enforcement will decrease the demand for the pirated product and accordingly decrease the price of pirated products. Therefore, how the price of the pirated product changes with law enforcement depends on the two opposite effects: the increasing effect derived from p_G and the decreasing effect derived from τ.

1.3.4. Equilibrium

Using two best-response functions, we obtain equilibrium prices and quantities for the genuine and pirated products, respectively.

$$p_G^* = \frac{(1-\theta-\delta)\tau-\delta^2+(\theta-1)\delta+2}{3\tau^2-\delta^2-6\delta\tau+4}\alpha \tag{10}$$

$$p_X^* = \frac{(1-\theta-\delta)\tau^2+[3\delta^2+2(\theta-1)\delta-1]\tau+(\theta-1)\delta^2-\delta+2(1-\theta)}{3\tau^2-\delta^2-6\delta\tau+4}\alpha \tag{11}$$

$$q_G^* = \frac{[-2\delta^2 + (\theta-1)\delta + 3]\tau^2}{(1-\delta^2)(3\tau^2 - \delta^2 - 6\delta\tau + 4)}\alpha + \frac{[2\delta^3 + 3(1-\theta)\delta^2 - 4\delta + \theta - 1]\tau}{(1-\delta^2)(3\tau^2 - \delta^2 - 6\delta\tau + 4)}\alpha + \frac{-\delta^2 + (\theta-1)\delta + 2}{(1-\delta^2)(3\tau^2 - \delta^2 - 6\delta\tau + 4)}\alpha \quad (12)$$

$$q_X^* = \frac{(1-\theta-\delta)\tau^2}{(1-\delta^2)(3\tau^2 - \delta^2 - 6\delta\tau + 4)}\alpha + \frac{[3\delta^2 + 2(\theta-1)\delta - 1]\tau}{(1-\delta^2)(3\tau^2 - \delta^2 - 6\delta\tau + 4)}\alpha + \frac{(\theta-1)\delta^2 - \delta + 2(1-\theta)}{(1-\delta^2)(3\tau^2 - \delta^2 - 6\delta\tau + 4)}\alpha \quad (13)$$

As the effective price of the pirated product should not be larger than the price of the genuine product, we hereby verify whether the equilibrium prices satisfy the condition.

$$p_X^* + \tau p_G^* \leq p_G^*$$

$$\frac{[2(\delta-\tau)^2 + (\delta-\tau)(1-\delta) + 2(1-\delta^2)]\theta + 2\tau(1-\delta)(\delta-\tau)}{3(\delta-\tau)^2 + 4(1-\delta^2)}\alpha \geq 0 \quad (14)$$

Proposition 2. As the level of law enforcement τ increases, ceteris paribus, the equilibrium price of the genuine product and the equilibrium effective price of the pirated product increase, whereas the equilibrium price of the pirated product increases under weak IPR protection and decreases under strong IPR protection.

Proof.

$$\frac{\partial p_G^*}{\partial \tau} = \frac{3(\theta+\delta-1)\tau^2}{(3\tau^2 - \delta^2 - 6\delta\tau + 4)^2}\alpha + \frac{6[\delta^2 + (1-\theta)\delta - 2]\tau}{(3\tau^2 - \delta^2 - 6\delta\tau + 4)^2}\alpha + \frac{-5\delta^3 + 7(\theta-1)\delta^2 + 8\delta + 4(1-\theta)}{(3\tau^2 - \delta^2 - 6\delta\tau + 4)^2}\alpha \quad (15)$$

$$\frac{\partial(p_X^* + \tau p_G^*)}{\partial\tau} = \frac{3[2\delta^2 + (\theta - 1)\delta - 1]\tau^2}{(3\tau^2 - \delta^2 - 6\delta\tau + 4)^2}\alpha + \frac{[4\delta^3 + 2(1-\theta)\delta^2 - 10\delta + 4(1-\theta)]\tau}{(3\tau^2 - \delta^2 - 6\delta\tau + 4)^2}\alpha + \frac{-2\delta^4 + 3\delta^3(\theta - 1) + \delta^2 + 4}{(3\tau^2 - \delta^2 - 6\delta\tau + 4)^2}\alpha \tag{16}$$

$$\frac{\partial p_X^*}{\partial\tau} = \frac{(1-\delta^2)\{3\tau^2 + 2[2(\theta-1) - \delta]\tau\}}{(3\tau^2 - \delta^2 - 6\delta\tau + 4)^2}\alpha + \frac{(1-\delta^2)[3\delta^2 + 4(1-\theta)\delta - 4]}{(3\tau^2 - \delta^2 - 6\delta\tau + 4)^2}\alpha \tag{17}$$

$$\frac{\partial(p_G^*/p_X^*)}{\partial\tau} = \frac{-(\theta+\delta-1)^2\tau^2}{F^2} + \frac{(2\theta^2\delta - 4\theta\delta + 4\theta - 2\delta^3 + 6\delta - 4)\tau}{F^2} + \frac{3\delta^4 + 6\theta\delta^2 + 2\delta^3 + 2\theta^2 + 4}{F^2} - \frac{3\theta^2\delta^2 + 2\theta\delta^3 + 9\delta^2 + 4\theta}{F^2} \tag{18}$$

where $F = (\theta + \delta - 1)\tau^2 + [1 + 2(1-\theta)\delta - 3\delta^2]\tau + (1-\theta)\delta^2 + \delta + 2(\theta - 1)$.

We define the numerator of $\frac{\partial p_G^*}{\partial\tau}$ as new function $f(\tau)$, which is a strictly concave function because its second-order condition is negative, $6(\theta + \delta - 1) < 0$. As $f(0) = -5\delta^3 + 7(\theta-1)\delta^2 + 8\delta + 4(1-\theta) > 0$ and $f(\delta) = 4(1-\delta^2)(1-\theta-\delta) > 0$, we can state that $f(\tau) > 0$ and thus $\frac{\partial p_G^*}{\partial\tau} > 0$. Therefore, we confirm that the equilibrium price of the genuine product increases with the level of law enforcement.

We define the numerator of $\frac{\partial(p_X^* + \tau p_G^*)}{\partial\tau}$ as new function $g(\tau)$, which is a strictly concave function because its second-order condition is negative, $6[2\delta^2 + (\theta-1)\delta - 1] < 0$. As $g(0) = -2\delta^4 + 3\delta^3(\theta - 1) + \delta^2 + 4 > 0$ and $g(\delta) = 4(1-\delta^2)[-2\delta^2 +$

$\delta(1-\theta)+1] > 0$, we can state that $g(\tau) > 0$ and thus $\frac{\partial(p_X^* + \tau p_G^*)}{\partial \tau} > 0$. Therefore, we confirm that the equilibrium effective price of the pirated product increases with the level of law enforcement.

We define the second term of the numerator of $\frac{\partial p_X^*}{\partial \tau}$ as a new function $h(\tau) = 3\tau^2 + 2[2(\theta-1)-\delta]\tau + 3\delta^2 + 4(1-\theta)\delta - 4$, which is a strictly convex function because its second-order condition is positive, $6 > 0$. As $h(0) = 3\delta^2 + 4(1-\theta)\delta - 4 > 0$ and $h(\delta) = -4(1-\delta^2) < 0$, we can state that $\frac{\partial p_X^*}{\partial \tau} > 0$ when $\tau \to 0$ and $\frac{\partial p_X^*}{\partial \tau} < 0$ when $\tau \to \delta$. Therefore, we confirm that the equilibrium price of pirated product increases with the level of law enforcement under weak IPR protection, and decreases with the level of law enforcement under strong IPR protection.

We define the numerator of $\frac{\partial(p_G^*/p_X^*)}{\partial \tau}$ as new function $j(\tau)$, which is a strictly concave function because its second-order condition is negative, $-2(\theta+\delta-1)^2 < 0$. As $j(0) = 3\delta^4 + 6\theta\delta^2 + 2\delta^3 + 2\theta^2 + 4 - (3\theta^2\delta^2 + 2\theta\delta^3 + 9\delta^2 + 4\theta) > 0$ and $j(\delta) = 2(1-\delta^2)[\theta^2 + 2(1-\theta)(1-\delta)] > 0$, we can state that $j(\tau) > 0$ and thus $\frac{\partial(p_G^*/p_X^*)}{\partial \tau} > 0$. Therefore, we confirm that the price ratio between the genuine and pirated products increases with the level of law enforcement.

As the level of law enforcement increases, consumers who choose to download the product from piracy sites are more likely to be punished. This increased likelihood leads them to choose the genuine product, rather than the pirated product. Therefore, the market power of the genuine firm increases, and the equilibrium price chosen by the genuine firm increases. The increase in law enforcement and higher equilibrium price of the genuine product will jointly increase the equilibrium effective price of the pirated product. Regarding the equilibrium price of the pirated product, the analysis becomes complex due to two opposite effects. As the equilibrium price of the genuine product increases, the pirating firm will accordingly increase the equilibrium price, because the two firms are strategic complements. Meanwhile, the increased level of law enforcement will decrease the equilibrium price of the pirated product. We can see that these two effects, separately from increasing p_G^* and increasing τ^*, are in opposite directions. Under weak IPR protection, the increasing effect derived from p_G^* dominates the decreasing effect derived from τ^*, and thus the equilibrium price of the pirated product increases with τ. However, under strong IPR protection, the decreasing effect derived from τ^* dominates the increasing effect, and thus the equilibrium price of the pirated product decreases with τ.

Proposition 3. As the vertical differentiation parameter θ increases, ceteris paribus, the difference in equilibrium prices between genuine and pirated products increases.

Proof.

$$\frac{\partial(p_G^* - p_X^*)}{\partial\theta} = \frac{2(1-\delta^2) + (\delta-\tau)^2 + \delta - \tau}{3(\delta-\tau)^2 + 4(1-\delta^2)}\alpha > 0 \qquad (19)$$

We differentiate the difference in equilibrium price between genuine and pirated products with respect to vertical differentiation and find that $(p_G^* - p_X^*)$ is an increasing function of θ. This result indicates that the difference in equilibrium prices depends on the quality difference between the two products. The larger the quality difference, the larger the difference in equilibrium prices between genuine and pirated products.

Proposition 4. The equilibrium quantity of the genuine product is a U-shaped function of τ, whereas the equilibrium quantity of the pirated product is an inverse U-shaped function of τ.

Proof.

$$\frac{\partial q_G^*}{\partial \tau} = \frac{3(1-\theta-2\delta)\tau^2}{(3\tau^2-\delta^2-6\delta\tau+4)^2}\alpha + \frac{2[-2\delta^2+(\theta-1)\delta+6]\tau}{(3\tau^2-\delta^2-6\delta\tau+4)^2}\alpha + \frac{2\delta^3+3(1-\theta)\delta^2-4\delta+4(\theta-1)}{(3\tau^2-\delta^2-6\delta\tau+4)^2}\alpha \tag{20}$$

$$\frac{\partial q_X^*}{\partial \tau} = \frac{3\tau^2+2[2(\theta-1)-\delta]\tau+3\delta^2+4(1-\theta)\delta-4}{(3\tau^2-\delta^2-6\delta\tau+4)^2}\alpha \tag{21}$$

We find that the equilibrium quantities are not monotonic functions of law enforcement. Essentially, the equilibrium quantity of the genuine product is a U-shaped function of τ, whereas the equilibrium quantity of the pirated product is an inverse U-shaped function of τ. We derive Figure 2 to show how the equilibrium quantities are affected by law enforcement. As the level of law enforcement increases from zero, the genuine firm increases the equilibrium price, thus leading to a decrease in equilibrium quantity. When the law enforcement increases to a certain level, IPR protection becomes stronger and the legal cost is high enough to prevent consumers from choosing the pirated product. The result is an increase in equilibrium quantity of the genuine product, because consumers have no outside options and can only choose the genuine product regardless of its price. In contrast, the equilibrium quantity of the pirated product is non-decreasing when the level of law enforcement increases from zero. Even though the equilibrium price of the pirated product increases, its effective price is still low enough to attract consumers. When law enforcement increases to a certain level, the equilibrium price of the pirated product starts to decrease. However, at this moment, the effective price is high enough, and consumers can only choose the genuine product to avoid the high legal cost. Therefore, we see that the equilibrium quantity of the pirated product decreases dramatically at a high level of law enforcement.

[Insert Figure 2 here]

Proposition 5. As the level of law enforcement τ increases, ceteris paribus, the profit of the genuine product producer increases, whereas the profit of the pirating firm first increases and then decreases.

$$\begin{aligned}\pi_G^{B*} &= p_G^* q_G^* + \tau p_G^* q_X^* \\ &= \frac{(\tau^2 - 2\delta\tau + 1)[(\delta - \tau)(1-\theta) + \delta^2 + \delta\tau - 2]^2}{(1-\delta^2)(3\tau^2 - \delta^2 - 6\delta\tau + 4)^2}\alpha^2\end{aligned} \tag{22}$$

$$\pi_X^{B*} = p_X^* q_X^* \tag{23}$$

$$= \frac{\{(\theta + \delta - 1)\tau^2 + [-3\delta^2 + 2(1-\theta)\delta + 1]\tau + (1-\theta)\delta^2 + \delta + 2(\theta - 1)\}^2}{(1-\delta^2)(3\tau^2 - \delta^2 - 6\delta\tau + 4)^2}\alpha^2$$

We derive Figure 3 to show how the equilibrium profits are affected by law enforcement. As the level of law enforcement increases from zero, the profit of the pirating firm is non-decreasing because its equilibrium price and quantity are non-decreasing at this stage. When law enforcement increases to a certain level, the equilibrium price and quantity of the pirated product decreases, and thus the profit of the pirating firm decreases. The profit of the genuine firm includes two parts: sales and damage compensation. Law enforcement will boost the profit of the genuine firm.

[Insert Figure 3 here]

1.3.5. Consumer welfare

We next study how the increase in IPR protection affects consumer welfare. To do so, we plug the equilibrium quantities into the consumer's utility function described in (24). Due to algebraic complexity, it is difficult to obtain analytic results. Accordingly, we plot consumer welfare with respect to law enforcement in Figure 4, for a certain set of parameter values.

$$u(q_G^*, q_X^*) = \alpha[q_G^* + (1-\theta)q_X^*] - \frac{1}{2}(q_G^{*2} + q_X^{*2}) - \delta q_G^* q_X^* \tag{24}$$

Proposition 6. A higher level of law enforcement leads to a lower level of consumer welfare.

The consumer welfare derives from the consumption of both the genuine and pirated products. As the level of law enforcement increases, the genuine firm increases the price of the genuine product, thus leading to a decreasing consumption of genuine products. Meanwhile, consumers can choose the pirated product, but the effective price also goes up, due to the increase in both τ and p_G. Therefore, the consumption of pirated products decreases. Overall, the consumption of both genuine and pirated products reduces with the increasing level of law enforcement, leading to a lower level of consumer welfare.

[Insert Figure 4 here]

We obtain this proposition without taking the ex-ante innovation incentive into consideration. According to Gilbert and Shapiro (1990), Klemperer (1990), and Gallini (1992), stronger IPR protection encourages innovation by protecting the genuine firm's profits against potential imitation. Such innovation will enhance consumer welfare in the long run. Eventually, the innovation encouraged by stronger IPR protection will increase consumer welfare. This increase may offset the decrease in consumer welfare caused by the higher level of IPR law enforcement. It is worth conducting future research that extends the current model to include the innovation incentive.

1.3.6. Social welfare

To investigate how the increase in IPR protection affects social welfare, we sum up the consumer welfare and producer surplus as described in (25). We follow Novos and

Waldman (1984) and Chen and Png (2003) and include consumer surplus from consuming the pirated product in social welfare. In terms of producer surplus, we consider the profit of both the genuine firm and the pirating firm. We plot social welfare with respect to law enforcement in Figure 5, for certain set of parameter values.

$$\text{Social Welfare} = u(q_G^*, q_X^*) + \pi_G^{B*} + \pi_X^{B*} \tag{25}$$

Proposition 7. The social welfare is an inverse U-shaped function of law enforcement.

In Figure 5, we see that social welfare first increases with law enforcement and eventually decreases with law enforcement. The increase in social welfare is caused by the increasing producer surplus. As the level of law enforcement increases, the genuine firm receives damage compensation from consumers punished for using pirated products. In addition, as law enforcement becomes stronger, demand for the genuine product increases, enabling the genuine firm to increase the product's price and quantity, and thus increase the firm's profit. These two factors lead to a higher producer surplus. When law enforcement reaches a certain level, social welfare will decrease due to the decreasing profit of the pirating firm and the decreasing consumer surplus from consuming the pirated product. At this moment, the legal cost is high enough to prevent consumers from using pirated products. Consumers can only choose the genuine product to avoid the legal cost, which leads to lower consumer welfare. Overall, these findings suggest that there may exist an optimal level of IPR law enforcement in the current model. In the current static setting, an increase in the level of IPR protection necessarily lowers consumer surplus as a result of increases in the price of the genuine product, in addition to the effective price of the pirated product. Social welfare may also decline, despite the increase in the profitability of the genuine product, as is shown in Proposition 5. However, in a dynamic setting where innovation decisions are included, a stronger protection of IPR will certainly stimulate greater innovation effort, leading to an increase in both consumer surplus and social welfare. It would be worth extending the current setting to a dynamic model in future research.

[Insert Figure 5 here]

1.3.7. Demand substitutability and market power

Finally, we investigate substitutability and market power in the presence of piracy. Following Lin (2018), we describe the substitutability between the genuine product and the pirated product using the cross-price elasticity between the two products. We describe the cross-price elasticity in (26) and derive Figure 6 to show how substitutability is affected by law enforcement. Furthermore, we use the Lerner Index to measure how law enforcement affects the market power of the genuine firm. We describe the Lerner Index in (27) and derive Figure 7 to show how market power is affected by law enforcement.

$$\begin{aligned} &\frac{dq_X}{dp_G}\cdot\frac{p_G^*}{q_X^*} \\ &= \frac{\delta-\tau}{\delta-\tau+\frac{(1-\theta-\delta)\alpha}{p_G^*}-\frac{p_X^*}{p_G^*}} \\ &= \frac{(\delta-\tau)[(1-\theta-\delta)\tau-\delta^2+(\theta-1)\delta+2]}{(1-\theta-\delta)\tau^2+[3\delta^2+2(\theta-1)\delta-1]\tau+(\theta-1)\delta^2-\delta+2(1-\theta)} \end{aligned} \tag{26}$$

$$\begin{aligned} &Lerner\ Index_G^B \\ &= \frac{p_G^*-c_G}{p_G^*} \\ &= \frac{[(1-\theta-\delta)\tau-\delta^2+(\theta-1)\delta+2]\alpha+[-3\tau^2+(4\delta-1)\tau+\delta^2+\delta-2]c_G}{[(1-\theta-\delta)\tau-\delta^2+(\theta-1)\delta+2]\alpha+[2(1-\delta\tau)+\delta-\tau]c_G} \end{aligned} \tag{27}$$

Lin (2018) conjectures that IPR protection enhances the market power of the genuine firm and reduces the demand substitutability of the two goods, hence making the two products less likely to belong to the same antitrust relevant market. Using this model, we are able to endogenize the effective price of the pirated product and that of the genuine product, and express the cross-price elasticity between the two products and the Lerner Index as a function of all exogenous model parameters. However, due to algebraic complexity, we are unable to obtain analytic results on how the level of IPR protection affects cross-price elasticity and the Lerner Index. We plot the cross-price elasticity and Lerner Index for different sets of parameter values, and the results are consistent with expectations.

Proposition 8. The cross-price elasticity between genuine and pirated products decreases with law enforcement, while the market power of the genuine firm increases with law enforcement.

In Figure 6, we see that the substitutability decreases with law enforcement, especially when law enforcement attains a certain level. As the level of law enforcement increases, the genuine firm will keep increasing the price of genuine product. However, the pirating firm will increase the price when the law enforcement level is low and decrease it when law enforcement reaches a certain level. In this case, the price ratio between the genuine and pirated products will determine the substitutability between the two products. When law enforcement attains a certain level, the price ratio starts to decrease and accordingly the substitutability decreases significantly. We therefore conclude that the enforcement of intellectual property law will protect the genuine firm and reduce the competition constraint from piracy only under strong IPR protection.

[Insert Figure 6 here]

In Figure 7, we see that the market power of the genuine firm increases with law enforcement. As the level of law enforcement increases, the legal cost keeps increasing and thus prevents consumers from downloading the product from a piracy site.

Therefore, consumers can only choose the genuine product to avoid the legal cost. In this case, the market power of the genuine firm increases when the level of law enforcement increases.

[Insert Figure 7 here]

In addition, we confirm that substitutability decreases with vertical differentiation. As shown in proposition 3, the difference in equilibrium prices between genuine and pirated products increases with the vertical differentiation parameter θ. Together with the fact that the cross-price elasticity decreases with the price ratio between genuine and pirated products, we therefore confirm that the cross-price elasticity should decrease with θ, meaning that the larger the quality difference between the genuine product and the pirated product, the more likely that the two products will not be in the same relevant market.

1.4. Counterfeiting and market competition

1.4.1. Theoretical framework

In this section, we analyze another practice that violates IPR laws, namely counterfeiting. This practice is also commonly observed around the world, especially in developing economies. Similar to the analysis in the previous section, this section explores how anti-counterfeiting efforts affect market competition. We set up a two-stage game made up of four firms: two branded firms and two counterfeiters. The branded firm i produces the branded good G_i, and the counterfeiter i infringes the brand and produces the counterfeit X_i. Likewise, the branded firm j produces the branded good G_j, and the counterfeiter j infringes the brand and produces the counterfeit X_j. We assume that the counterfeits, X_i and X_j, are non-deceptive counterfeit goods.

We consider the case of non-deceptive counterfeiting. In the terminology of Grossman and Shapiro (1988a, 1988b), a non-deceptive counterfeit good is a counterfeit good that consumers can distinguish from the branded good by, for example, close inspection or distribution channels.

The counterfeit is not a perfect substitute for the branded good. We assume that the branded good and its counterfeit are horizontally and vertically differentiated. We introduce a parameter θ to indicate the degree of vertical differentiation between branded and counterfeit goods. The parameter θ is $0 < \theta < 1$ due to quality degradation. A higher value of θ indicates a larger quality difference between the branded and counterfeit goods. Furthermore, we use a parameter δ to represent the degree of horizontal differentiation between branded and counterfeit goods. δ is close to 1 if the two products are almost homogeneous, and δ approaches 0 if the two products become differentiated. In addition, we use a parameter γ to represent the interbrand differentiation between brand i and brand j. γ is close to 1 if the two brands are almost homogeneous, and γ approaches 0 if the two brands become differentiated.

1.4.2. The consumer

The inverse demand system is as follows:

$$p_{G_i} = \alpha - q_{G_i} - \delta q_{X_i} - \gamma q_{G_j} - \delta\gamma q_{X_j} \tag{28}$$

$$p_{X_i} = \alpha(1 - \theta) - q_{X_i} - \delta q_{G_i} - \gamma q_{X_j} - \delta\gamma q_{G_j} \tag{29}$$

where p_{G_i} and p_{X_i} are the prices for branded good i and counterfeit i, respectively; q_{G_i}, q_{G_j}, q_{X_i}, and q_{X_j} are the quantities for branded good i, branded good j, counterfeit i, and counterfeit j, respectively; θ is the quality difference between branded and counterfeit goods; δ measures the differentiation between branded and counterfeit goods; and γ represents the interbrand differentiation between brand i and brand j.

1.4.3. The firms

Counterfeiters face the possibility of being caught and punished. This probability is endogenously determined by each branded firm. The anti-counterfeiting effort determined by branded firm i is τ_i and the effort determined by branded firm j is τ_j. The probabilities, τ_i and τ_j, belong to $(0, 1)$. We use the parameter λ to measure the degree of penalty specified by the protection policy. The parameter λ is a positive integer. The penalty costs faced by counterfeiters are $\tau_i \lambda p_{X_i} q_{X_i}$ and $\tau_j \lambda p_{X_j} q_{X_j}$, respectively. In the first stage, branded firms choose their anti-counterfeiting efforts independently and simultaneously. In the second stage, four firms compete in a Cournot framework. We assume that all firms have same marginal cost, which is constant and equals to $c > 0$. There is no fixed cost in the model.

Denote branded firm i 's profit function as a Cournot competitor by $\pi_{G_i}^C\left(q_{G_i}, q_{G_j}, q_{X_i}, q_{X_j}\right)$, where q_{G_i} and q_{G_j} represent the two branded firms' output levels and q_{X_i} and q_{X_j} represent the two counterfeiters' output levels. Branded firm i chooses q_{G_i}, taking q_{G_j}, q_{X_i}, and q_{X_j} as given. Thus, the branded firm needs to maximize the profit function described in (30).

$$\begin{aligned}\pi_{G_i}^C &= (p_{G_i} - c) q_{G_i} \\ &= -q_{G_i}^2 + \left(\alpha - \delta q_{X_i} - \gamma q_{G_j} - \delta\gamma q_{X_j} - c\right) q_{G_i}\end{aligned} \tag{30}$$

The first-order condition is $-2q_{G_i} + \alpha - \delta q_{X_i} - \gamma q_{G_j} - \delta\gamma q_{X_j} - c = 0$, yielding a best-response function given by

$$q_{G_i}\left(q_{X_i}, q_{G_j}, q_{X_j}\right) = \frac{1}{2}\alpha - \frac{\delta}{2}q_{X_i} - \frac{\gamma}{2}q_{G_j} - \frac{\delta\gamma}{2}q_{X_j} - \frac{1}{2}c \tag{31}$$

The branded firm's profit function is strictly concave, because the second-order condition for the maximization problem is satisfied: $\frac{\partial^2 \pi_{G_i}^C}{\partial q_{G_i}^2} = -2 < 0$.

Denote counterfeiter i 's profit function as a Cournot competitor by $\pi_{X_i}^C\left(q_{X_i}, q_{X_j}, q_{G_i}, q_{G_j}\right)$, where q_{X_i} and q_{X_j} represent the two counterfeiters' output levels and q_{G_i} and q_{G_j} represent the two branded firms' output levels. Counterfeiter i chooses q_{X_i}, taking q_{X_j}, q_{G_i}, and q_{G_j} as given. Thus, the counterfeiter needs to maximize the profit function described in (32).

$$\begin{aligned} \pi_{X_i}^C &= \left(p_{X_i} - c\right)q_{X_i} - \tau_i\lambda p_{X_i}q_{X_i} \\ &= -(1-\tau_i\lambda)q_{X_i}^2 + (1-\tau_i\lambda)\left[\alpha(1-\theta) - \delta q_{G_i} - \gamma q_{X_j} - \delta\gamma q_{G_j}\right]q_{X_i} - cq_{X_i} \end{aligned} \tag{32}$$

The first-order condition is $-2(1-\tau_i\lambda)q_{X_i} + (1-\tau_i\lambda)\left[\alpha(1-\theta) - \delta q_{G_i} - \gamma q_{X_j} - \delta\gamma q_{G_j}\right] - c = 0$, yielding the best-response function given by

$$q_{X_i}\left(q_{G_i}, q_{X_j}, q_{G_j}\right) = \frac{1-\theta}{2}\alpha - \frac{\delta}{2}q_{G_i} - \frac{\gamma}{2}q_{X_j} - \frac{\delta\gamma}{2}q_{G_j} - \frac{1}{2(1-\tau_i\lambda)}c \tag{33}$$

Assumption 3. $\tau_i\lambda < 1$ and $\tau_j\lambda < 1$.

To ensure that the counterfeiter's profit function is strictly concave, we assume that $\tau_i\lambda < 1$ and $\tau_j\lambda < 1$. In this case, the second-order condition for the maximization problem is satisfied: $\frac{\partial^2 \pi_{X_i}^C}{\partial q_{X_i}^2} = -2(1-\tau_i\lambda) < 0$.

1.4.4. Second stage - product competition

We use the standard backward induction procedure to derive the equilibrium. We start with the second stage and obtain equilibrium quantities under the Cournot competition for the branded firm and counterfeiter, respectively, for any given $\{\tau_i, \tau_j\}$.

$$q_{G_i}^* = \frac{2+\gamma-(1-\theta)(1+\gamma)\delta}{(2+\gamma)^2-\delta^2(1+\gamma)^2}\alpha + \frac{-A_1^{G_i}(1-\tau_i\lambda)(1-\tau_j\lambda)-A_2^{G_i}(1-\tau_i\lambda)+A_3^{G_i}(1-\tau_j\lambda)}{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)(1-\tau_j\lambda)}c \tag{34}$$

where $A_1^{G_i} = (2+\gamma)(4-\gamma^2)[(2-\gamma)^2-\delta^2(1-\gamma)^2]$, $A_2^{G_i} = 2\delta\gamma(1-\gamma^2)(4+\delta^2\gamma^2-\gamma^2-3\delta^2)$, and $A_3^{G_i} = 4\delta(1-\gamma^2)(4-\gamma^2-\delta^2)$.

$$q_{X_i}^* = \frac{(2+\gamma)(1-\theta)-(1+\gamma)\delta}{(2+\gamma)^2-\delta^2(1+\gamma)^2}\alpha + \frac{A_1^{X_i}(1-\tau_i\lambda)(1-\tau_j\lambda)+A_2^{X_i}(1-\tau_i\lambda)-A_3^{X_i}(1-\tau_j\lambda)}{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)(1-\tau_j\lambda)}c \tag{35}$$

where $A_1^{X_i} = \delta(1+\gamma)(4-\gamma^2)[(2-\gamma)^2-\delta^2(1-\gamma)^2]$, $A_2^{X_i} = 2\gamma(16+5\delta^2\gamma^2+\gamma^4-\delta^2\gamma^4-8\gamma^2-8\delta^2)$, and $A_3^{X_i} = 2(16+\delta^2\gamma^4+\gamma^4-\delta^2\gamma^2-8\gamma^2-4\delta^2)$.

Proposition 9. As the branded firm *i* increases its anti-counterfeiting efforts, ceteris paribus, the branded firm *i* and counterfeiter *j* will increase their output, whereas the branded firm *j* and counterfeiter *i* will decrease their output. That is, $\frac{\partial q_{G_i}^*}{\partial \tau_i} > 0$, $\frac{\partial q_{G_j}^*}{\partial \tau_i} < 0$, $\frac{\partial q_{X_i}^*}{\partial \tau_i} < 0$, and $\frac{\partial q_{X_j}^*}{\partial \tau_i} > 0$.

Proof.

$$\frac{\partial q_{G_i}^*}{\partial \tau_i} = \frac{4\delta\lambda(1-\gamma^2)(4-\gamma^2-\delta^2)}{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)^2}c$$

$$\frac{\partial q_{G_j}^*}{\partial \tau_i} = \frac{-2\delta\gamma\lambda(1-\gamma^2)(4+\delta^2\gamma^2-\gamma^2-3\delta^2)}{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)^2}c$$

$$\frac{\partial q_{X_i}^*}{\partial \tau_i} = \frac{-2\lambda(16+\delta^2\gamma^4+\gamma^4-\delta^2\gamma^2-8\gamma^2-4\delta^2)}{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)^2}c$$

$$\frac{\partial q_{X_j}^*}{\partial \tau_i} = \frac{2\gamma\lambda(16+\gamma^4+5\delta^2\gamma^2-\delta^2\gamma^4-8\gamma^2-8\delta^2)}{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)^2}c$$

If the branded firm i increases its anti-counterfeiting efforts, the counterfeiter i will face a higher probability of being punished. Counterfeiter i's profit function can be written as $(1-\tau_i\lambda)p_{X_i}q_{X_i} - cq_{X_i}$. The expected revenue, $(1-\tau_i\lambda)p_{X_i}q_{X_i}$, will decrease due to a higher τ_i. Thus, counterfeiter i will save costs by decreasing output. In this case, consumers who used to purchase the counterfeit i will turn to its close substitutes, branded good i and counterfeit j. Therefore, the outputs of branded firm i and counterfeiter j will increase, which will lead to increasingly severe market competition for branded firm j. Therefore, branded firm j will decrease its output.

Next, we obtain the equilibrium prices under Cournot competition for the branded firm and counterfeiter, respectively, for any given $\{\tau_i, \tau_j\}$.

$$\begin{aligned} p_{G_i}^* = {} & \frac{2+\gamma-(1-\theta)(1+\gamma)\delta}{(2+\gamma)^2-\delta^2(1+\gamma)^2}\alpha \\ & + \frac{B_1^{G_i}(1-\tau_i\lambda)(1-\tau_j\lambda) - B_2^{G_i}(1-\tau_i\lambda) + B_3^{G_i}(1-\tau_j\lambda)}{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)(1-\tau_j\lambda)}c \end{aligned} \quad (36)$$

where $B_1^{G_i} = (1+\gamma)(4-\gamma^2)[2+\gamma-\delta^2(1+\gamma)][(2-\gamma)^2-\delta^2(1-\gamma)^2]$, $B_2^{G_i} = 2\delta\gamma(1-\gamma^2)(4+\delta^2\gamma^2-\gamma^2-3\delta^2)$, and $B_3^{G_i} = 4\delta(1-\gamma^2)(4-\gamma^2-\delta^2)$.

$$p_{X_i}^* = \frac{(2+\gamma)(1-\theta)-(1+\gamma)\delta}{(2+\gamma)^2-\delta^2(1+\gamma)^2}\alpha + \frac{B_1^{X_i}(1-\tau_i\lambda)(1-\tau_j\lambda)-B_2^{X_i}(1-\tau_i\lambda)+B_3^{X_i}(1-\tau_j\lambda)}{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)(1-\tau_j\lambda)}c \tag{37}$$

where $B_1^{X_i} = \delta(1+\gamma)(4-\gamma^2)[(2-\gamma)^2-\delta^2(1-\gamma)^2]$, $B_2^{X_i} = 2\delta^2\gamma(1-\gamma^2)(\gamma^2+\delta^2-\delta^2\gamma^2)$, and $B_3^{X_i} = 2(1-\gamma^2)(16+\delta^4\gamma^4+\gamma^4+2\delta^4+9\delta^2\gamma^2-2\delta^2\gamma^4-3\delta^4\gamma^2-8\gamma^2-12\delta^2)$.

Firm profits can be derived accordingly, based on the preceding equilibrium quantities and prices.

Proposition 10. As the branded firm *i* increases its anti-counterfeiting efforts, ceteris paribus, the branded firm *i* and counterfeiter *i* will charge a higher price, whereas the branded firm *j* and counterfeiter *j* will charge a lower price. That is, $\boldsymbol{\frac{\partial p_{G_i}^*}{\partial \tau_i} > 0, \frac{\partial p_{G_j}^*}{\partial \tau_i} < 0, \frac{\partial p_{X_i}^*}{\partial \tau_i} > 0}$**, and** $\boldsymbol{\frac{\partial p_{X_j}^*}{\partial \tau_i} < 0}$**.**

Proof.

$$\frac{\partial p_{G_i}^*}{\partial \tau_i} = \frac{4\delta\lambda(1-\gamma^2)(4-\gamma^2-\delta^2)}{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)^2}c$$

$$\frac{\partial p_{G_j}^*}{\partial \tau_i} = \frac{-2\delta\gamma\lambda(1-\gamma^2)(4+\delta^2\gamma^2-\gamma^2-3\delta^2)}{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)^2}c$$

$$\frac{\partial p_{X_i}^*}{\partial \tau_i}$$

$$= \frac{2\lambda(1-\gamma^2)(16+\delta^4\gamma^4+\gamma^4+2\delta^4+9\delta^2\gamma^2-2\delta^2\gamma^4-3\delta^4\gamma^2-8\gamma^2-12\delta^2)}{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)^2}c$$

$$\frac{\partial p_{X_j}^*}{\partial \tau_i} = \frac{-2\delta^2\gamma\lambda(1-\gamma^2)(\gamma^2+\delta^2-\delta^2\gamma^2)}{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)^2}c$$

If the branded firm i increases its anti-counterfeiting efforts, the counterfeiter i will face a higher probability of being punished. To maintain the expected revenue, $(1-\tau_i\lambda)p_{X_i}q_{X_i}$, counterfeiter i will charge a higher price for counterfeit good i, which will lead to a higher price for branded good i. As τ_i increases, the output of counterfeiter j increases. Accordingly, the price of counterfeit good j will decrease, which will lead to a lower price for branded good j.

1.4.5. First stage – anti-counterfeiting efforts

In the first stage, two branded firms choose their anti-counterfeiting efforts independently and simultaneously. Specifically, the branded firms choose to pay an anti-counterfeiting company a fixed cost, $\mathrm{c}(\tau_i) = \frac{1}{2}\beta\tau_i^2$ and $\mathrm{c}(\tau_j) = \frac{1}{2}\beta\tau_j^2$, where $\beta > 0$. τ_i is the anti-counterfeiting level that branded firm i expects, and τ_j is the anti-counterfeiting level that branded firm j expects. In this case, branded firms need to pay anti-counterfeiting costs no matter whether counterfeiters exist in the second stage. Denote branded firm i's total profit function including the cost of the anti-counterfeiting effort by $\Pi_{G_i}(\tau_i, \tau_j)$, which is increasing and concave in τ_i. Given τ_j, the profit maximization problem for branded firm i is:

$$\Pi_{G_i} = \left(p_{G_i}^* - c\right)q_{G_i}^* - \mathrm{c}(\tau_i) \quad (38)$$

The first-order condition is:

$$\frac{\partial\left[\left(p_{G_i}^* - c\right)q_{G_i}^*\right]}{\partial\tau_i} - \beta\tau_i = 0 \quad (39)$$

The second-order condition requires that the anti-counterfeiting cost parameter, β, is sufficiently large, i.e., the cost function is sufficiently convex.

$$\frac{\partial^2\left[\left(p_{G_i}^* - c\right)q_{G_i}^*\right]}{\partial{\tau_i}^2} - \beta < 0 \quad (40)$$

The equilibrium anti-counterfeiting effort levels are given by the preceding two first-order conditions. Due to algebraic complexity, we are unable to obtain the subgame perfect Nash equilibrium (SPE), $\left\{\tau_i^* q_{G_i}^*, \tau_j^* q_{G_j}^*, q_{X_i}^*, q_{X_j}^*\right\}$. However, we are able to obtain the following properties of the SPE.

Proposition 11. The two branded firms' decision variables are strategic substitutes. The negative externality exists for the branded firms to take anti-counterfeiting efforts.

Proof.

$$\frac{\partial^2\Pi_{G_i}}{\partial\tau_i\partial\tau_j}$$

$$= \frac{-16\delta^2\gamma\lambda^2(1-\gamma^2)^2(4-\gamma^2-\delta^2)(4+\delta^2\gamma^2-\gamma^2-3\delta^2)c^2}{\left\{(4-\gamma^2)[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)\left(1-\tau_j\lambda\right)\right\}^2}$$

As $\Pi_{G_i}^*$ is increasing and concave in τ_i and $\frac{\partial^2\Pi_{G_i}^*}{\partial\tau_i\partial\tau_j}$ is negative, two anti-counterfeiting efforts are strategic substitutes. As $\frac{\partial^2 \Pi^*_{G_i}}{\partial \tau_i \partial \tau_j}$ is negative, we can state that the marginal benefit of the anti-counterfeiting effort for branded firm i will decrease with the anti-counterfeiting effort from branded firm j. The consequence is negative externality, which means that one branded firm's anti-counterfeiting effort is harmful to another branded firm. The negative externality comes from both severe interbrand competition and intensive competition with the corresponding counterfeit good.

In the given setting, the branded firms choose their anti-counterfeiting efforts in the first stage of the game before the counterfeiters make their illegal production and sale decisions. There may be a commitment issue here. In particular, it has been implicitly assumed that the branded firms in the second stage of the game will stick to their anti-counterfeiting efforts chosen in the first stage of the game. One way to commit to the chosen anti-counterfeiting level is through outsourcing, whereby each branded firm signs a contract with an independent third party that specializes in anti-counterfeiting activity. Such for-profit organizations have existed in China since the 1990s, when counterfeiting started to soar in China.[3]

Next, we consider the case in which two branded firms cooperate with each other and choose to engage in a collective anti-counterfeiting effort, that is $\tau_i = \tau_j = \tau_{ind}$. Therefore, the profit maximization problem for the whole industry is:

$$\Pi_{ind} = \left(p^*_{G_i} - c\right) q^*_{G_i} + \left(p^*_{G_j} - c\right) q^*_{G_j} - 2\mathrm{c}(\tau_{ind}) \tag{41}$$

[3] For example, Wang Hai, known as China's first professional fraud fighter, started his professional fraud-fighting career in March 1995, when he earned double indemnity from intentionally purchased fake Sony earplugs. Subsequently, he founded Beijing Dahai Business Consultancy and has operated businesses in three areas: earning indemnity from intentionally purchased counterfeited goods, and providing anti-counterfeiting and rights-protection services for individuals and companies. His fraud-fighting business was first operated by his own team, but is now more involved with governmental supports and cooperation (Gu, 2015).

The first-order condition is $\frac{\partial\left[\left(p^*_{G_i}-c\right)q^*_{G_i}+\left(p^*_{G_j}-c\right)q^*_{G_j}\right]}{\partial\tau_{ind}} - 2\beta\tau_{ind} = 0$, where

$$\frac{\partial\left[\left(p^*_{G_i}-c\right)q^*_{G_i}+\left(p^*_{G_j}-c\right)q^*_{G_j}\right]}{\partial\tau_{ind}} = \frac{8\delta\lambda(1-\gamma^2)c}{(2-\gamma)^2[(2+\gamma)^2-\delta^2(1+\gamma)^2]^2(1-\tau_{ind}\lambda)^3} \cdot \frac{\{(2-\gamma)(1-\tau_{ind}\lambda)[(2+\gamma)(\alpha-c)-\delta\alpha(1+\gamma)(1-\theta)]+2\delta c(1-\gamma^2)\}}{(2-\gamma)^2[(2+\gamma)^2-\delta^2(1+\gamma)^2]^2(1-\tau_{ind}\lambda)^3}$$

Due to algebraic complexity, we are unable to obtain the industrial optimum, τ^*_{ind}. However, we are able to identify the relationship between the SPE anti-counterfeiting effort and industrial optimum.

Proposition 12. The SPE anti-counterfeiting effort chosen by an individual branded firm is higher than the industrial optimum. That is, $\boldsymbol{\tau^*_i > \tau^*_{ind}}$.

As the two branded firms' decision variables are strategic substitutes, their anti-counterfeiting efforts will offset each other. We therefore conclude that the SPE anti-counterfeiting effort chosen by an individual branded firm is higher than the industrial optimum.

In addition, we find that vertical differentiation is one determinant of marginal profit for branded firms. As the vertical differentiation increases, branded firms will take more anti-counterfeiting efforts, whether individually or collectively.

Proposition 13. At both the firm and industry levels, the marginal profit of anti-counterfeiting effort for a branded firm increases with vertical differentiation.

Proof.

$$\frac{\partial^2\Pi_{G_i}}{\partial\tau_i\partial\theta} = \frac{8\delta^2\lambda(1+\gamma)(1-\gamma^2)(4-\gamma^2-\delta^2)[(2-\gamma)^2-\delta^2(1-\gamma)^2]\alpha c}{(4-\gamma^2)\{[(2+\gamma)^2-\delta^2(1+\gamma)^2][(2-\gamma)^2-\delta^2(1-\gamma)^2](1-\tau_i\lambda)\}^2}$$

$$\frac{\partial^2 \Pi_{ind}}{\partial \tau_{ind} \partial \theta} = \frac{8\delta^2 \lambda (1+\gamma)(1-\gamma^2)\alpha c}{(2-\gamma)[(2+\gamma)^2 - \delta^2 (1+\gamma)^2]^2 (1-\tau_{ind}\lambda)^2}$$

The parameter θ indicates the degree of vertical differentiation between branded and counterfeit goods. As the vertical differentiation parameter θ increases, the quality difference between branded and counterfeit goods is more apparent. As the branded firm increases its anti-counterfeiting effort, consumers who used to purchase the counterfeit are more likely to turn to the branded good, which makes the anti-counterfeiting effort more profitable.

1.5. Concluding remarks

In this chapter, we investigated the economic consequences of intellectual property law enforcement by looking at two types of intellectual property infringement: piracy and counterfeiting. We first considered a two-firm industry producing a specific copyrightable product, which can be made by a genuine firm and a pirating firm in Bertrand competition. We followed Lin (2018) and endogenized the legal cost of using the pirated product in the demand function. Specifically, the effective price of pirated product was calculated as the sum of the price charged by the pirating firm and the legal cost, which can be decomposed into two parts: the probability of being punished, and the damage compensation. We found that the social welfare is an inverse U-shaped function of law enforcement. As law enforcement increases, the substitutability between the genuine product and pirated product decreases, and the market power of the genuine firm increases. This proposition can be used to define antitrust relevant markets, which is an important step in the enforcement of antitrust law. The cross-price demand elasticity is also used to delineate the boundary of a relevant market.

Following Lin (2018), we provided some preliminary results from defining relevant markets in the presence of piracy. As IPR law enforcement increases, cross-price demand elasticity between genuine and pirated products decreases, indicating that the pirated product should be excluded from the relevant market of the genuine product.

In the second section, we explored how anti-counterfeiting efforts under the intellectual property law affect market competition, by setting up a two-stage game made up of two branded firms and two counterfeiters. In the first stage, each branded firm can take anti-counterfeiting efforts independently and simultaneously, which only affect its corresponding counterfeiter. In the second stage, four firms compete in a Cournot framework. We found that anti-counterfeiting efforts are strategic substitutes, and negative externality exists for branded firms that take anti-counterfeiting efforts. We confirmed that, due to negative externalities, the equilibrium anti-counterfeiting effort is higher than the industrial optimum. At both firm- and industry-level, the marginal profit for a branded firm of engaging in anti-counterfeiting efforts increases with vertical differentiation. As a future extension, we will take deceptive counterfeit goods into consideration and investigate whether the same propositions hold.

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Tables and Figures

Figure 1. Reaction functions.

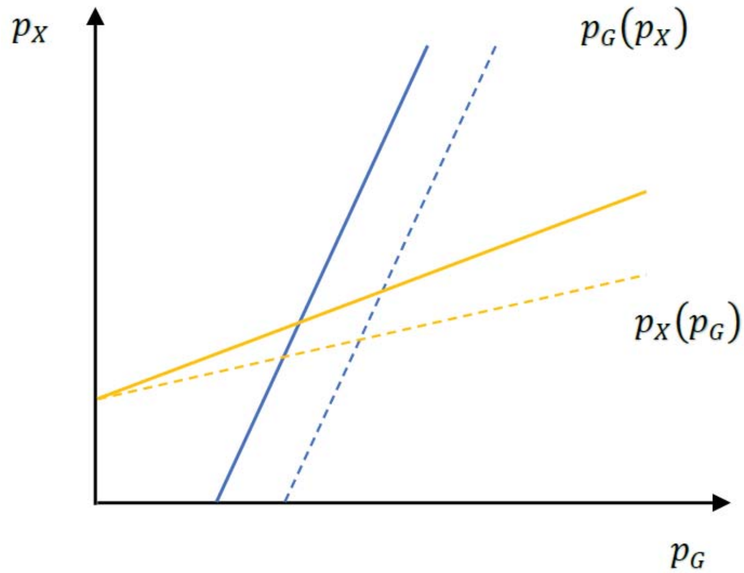


Figure 2. Equilibrium quantities of the genuine product and the pirated product.

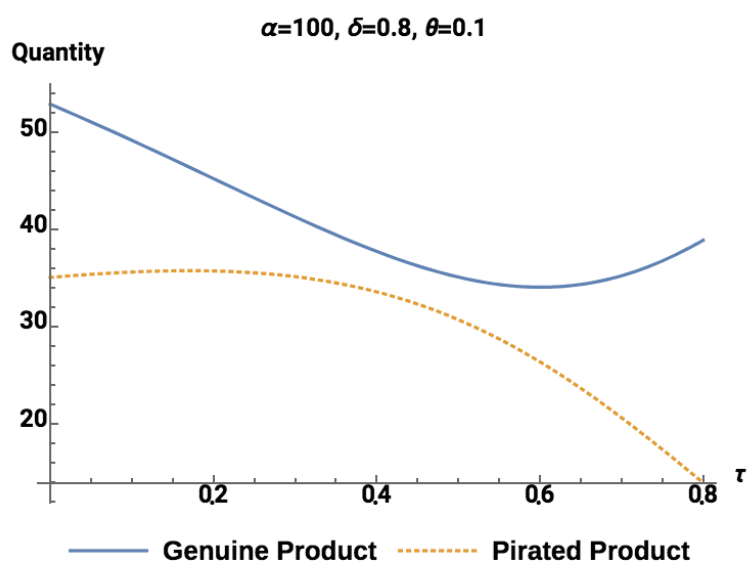


Figure 3. Equilibrium profits of the genuine firm and the pirating firm.

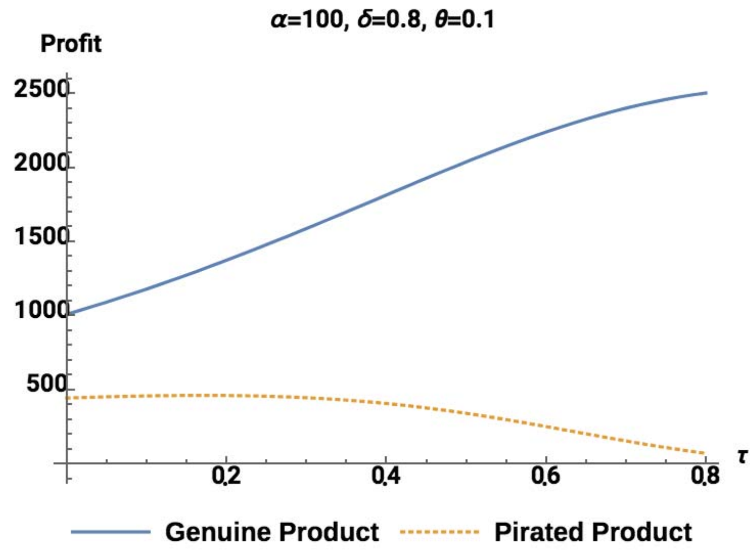


Figure 4. Consumer welfare.

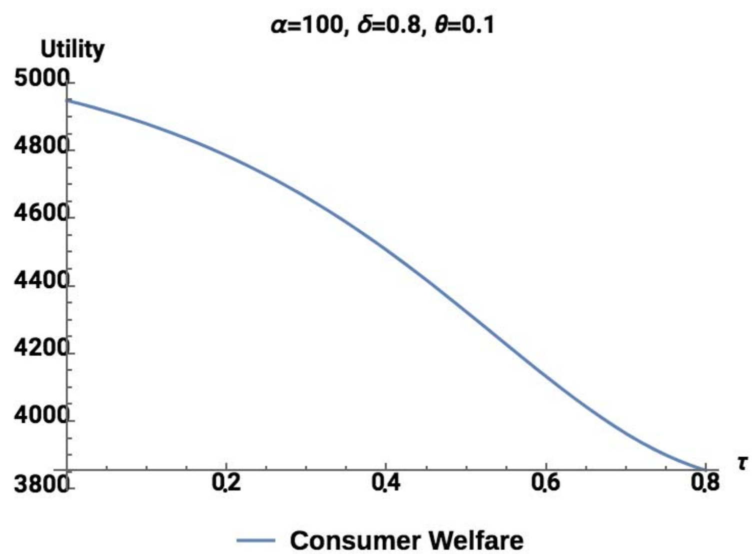


Figure 5. Social welfare.

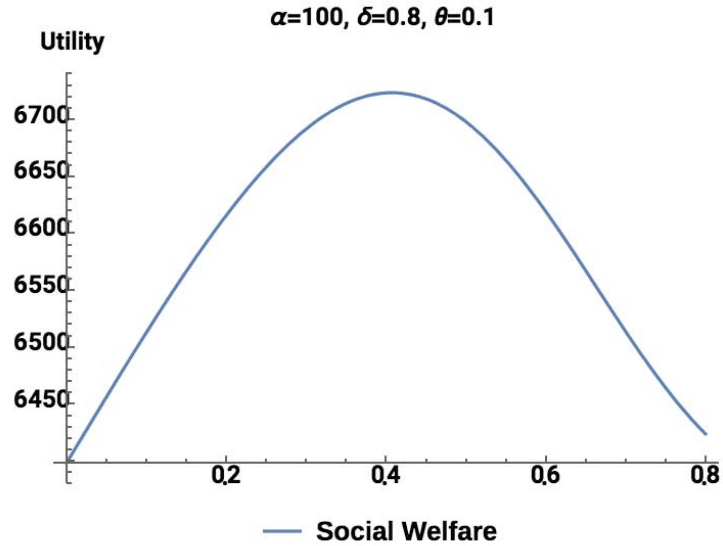


Figure 6. Cross-price elasticity between the genuine product and the pirated product.

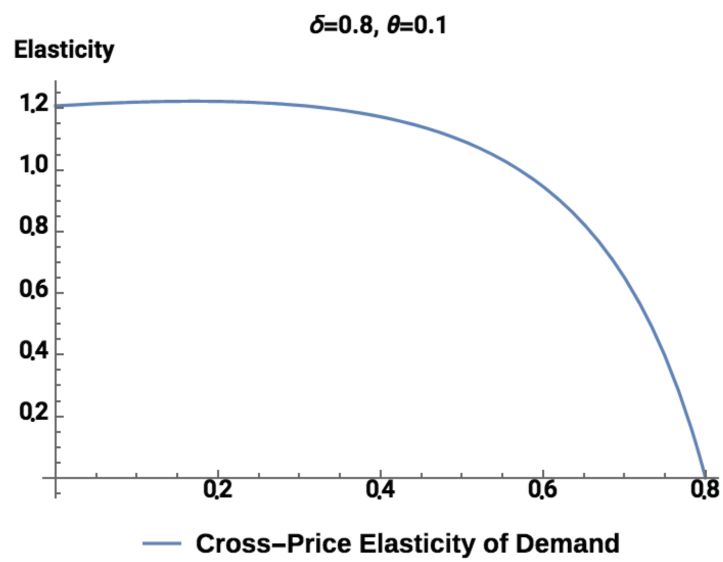
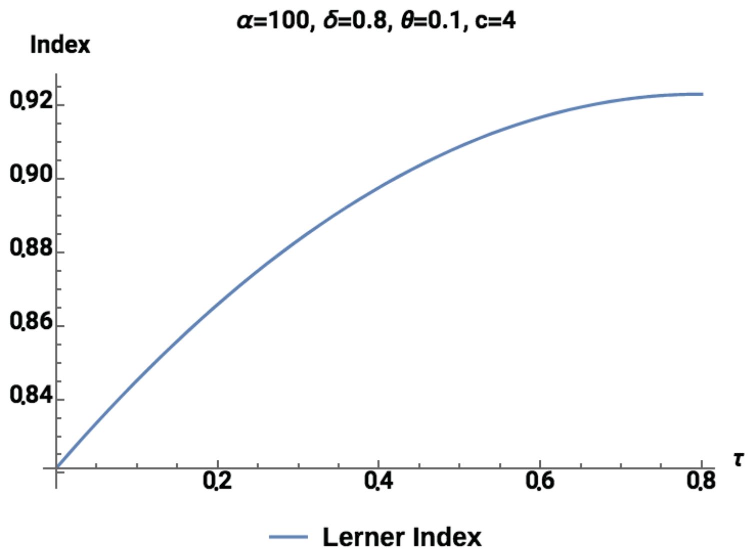


Figure 7. The Lerner Index of the genuine firm.



CHAPTER 2

The Volcker Rule, Bank Stability, and Bank Liquidity

2.1. Introduction

In response to the financial crisis, the Dodd-Frank Wall Street Reform and Consumer Protection Act (hereinafter, Dodd-Frank Act) was passed by the United States Congress on July 21, 2010, with the aim of regulating the financial market in the wake of the subprime mortgage crisis. One important part of the Dodd-Frank Act, section 619, commonly known as the "Volcker Rule", imposes restrictions on banks' ability to engage in proprietary trading activities. Specifically, the Volcker Rule prohibits any banking entity from two types of nonbanking activities: sponsoring, or investing in, specific types of funds[1] and engaging in proprietary trading. Regarding proprietary trading, the Volcker Rule prohibits engaging as a principal for short-term trading with the intent to profit from price movements. Since then, whether the Volcker Rule can remedy the problems that gave birth to the financial crisis has been the subject of intensive debate in academia (see, e.g., Richardson, 2012; and Thakor, 2012). According to Thakor (2012), the Volcker Rule will have negative effects on market making and liquidity provision, leading to higher costs of capital and riskier investments. In contrast, Richardson (2012) argues that the Volcker Rule is an economically sensible way to mitigate moral hazard and to manage systemic risk. Motivated by this debate, we provide an empirical analysis of whether and how the passage of the Volcker Rule has affected bank stability. Serving as a financial intermediary in the economy, banks perform two central roles: risk transformation and liquidity creation. These two roles are highly related to bank stability. Risk transformation and liquidity creation may coincide with each other, but may not move in perfect tandem, given that the amount of liquidity created may vary considerably for a given amount of

[1] These include hedge funds, private equity funds, venture capital funds, real estate funds, structured finance vehicles, and some special-purpose vehicles used in project financing.

risk transformed (Berger and Bouwman, 2009). Therefore, in our analysis, we distinguish these two roles of banks and separately study the effect of the Volcker Rule on risk transformation and liquidity creation.

To maximize profit, banks have an incentive to undertake excessive risk using their funds that are guaranteed by federal deposit insurance. Banks usually engage in proprietary trading for their own direct gain instead of earning commission fees by trading on behalf of their customers, leading to a notable increase in profit. As a high-risk form of trading, proprietary trading is speculative in nature and was responsible for some large losses during the financial crisis. By prohibiting this kind of trading, the Volcker Rule can address the moral hazard problem in the banking industry and accordingly affect bank risk-taking. As banks that engage in proprietary trading need to stockpile an inventory of securities, the prohibition on proprietary trading leads to a decrease in inventory and therefore affects the liquidity created by banks. In addition, banks can create liquidity in the market by engaging in market making, which is a permitted activity. However, the enforcement of the Volcker Rule can also influence market makers and accordingly affect liquidity creation, due to the difficulty of differentiating between prohibited proprietary trading and permitted market making.

We base our analysis on the population of all bank holding companies (BHCs) in the United States covering the period from 2006 through 2015. We consider BHCs with trading assets that used to engage in proprietary trading as treated banks; we consider BHCs without trading assets as the control group, because they are exempted from the Volcker Rule. Using the passage of the Volcker Rule as an exogenous shock, we use the difference-in-differences (DID) method to separately investigate the effect of the Volcker Rule on bank risk-taking and liquidity creation. To evaluate bank risk-taking, we use the time-varying Z-score as our primary measure, which equals the sum of asset return and capital asset ratio over the rolling four-quarter standard deviation of asset return. Following Berger and Bouwman (2009), we construct four BHC-level category-based measures of liquidity creation: total liquidity creation and its three components (asset-side liquidity creation, liability-side liquidity creation, and off-balance sheet liquidity creation).

Our results show that prohibition of proprietary trading decreases the level of risk-taking for regulated BHCs. More specifically, the Z-score of regulated BHCs increases by 42.2% on average, compared with BHCs exempted from the Volcker Rule. Regarding liquidity creation, we find that the enforcement of the Volcker Rule induces a significant increase in liability-side liquidity creation and a decrease in liquidity creation off the balance sheet. Regulated BHCs create $35.7 million more liquidity on the liability side and destroy $13.4 million more liquidity off the balance sheet, compared with exempted BHCs. Relative to the sample mean, the effect is not only statistically significant but also economically significant.

Next, we examine whether the Volcker Rule has heterogeneous effects on liquidity creation across BHCs with different business models (i.e., commercial banking and investment banking). Following Laeven and Levine (2007), we introduce the indicator of diversification to determine where each BHC lies along the spectrum from pure commercial banking to specialized investment banking. Specifically, we construct the indicator as an index of diversification across different types of assets, including net loans and other earning assets. Using a triple-differences methodology, we find that the passage of the Volcker Rule imposes a significantly positive effect on total liquidity creation for regulated commercial BHCs. For regulated investment BHCs, the effect on total liquidity creation becomes negative. Specifically, an increase in the degree of diversification by one standard deviation is associated with a drop of $24.1 million in total liquidity creation. Moreover, we find that the heterogeneous effects of the Volcker Rule on total liquidity creation primarily derives from the liability side. In addition, we find that commercial BHCs destroy liquidity off the balance sheet, whereas investment BHCs create liquidity off the balance sheet after the enforcement of the Volcker Rule. Our findings suggest that the Volcker Rule has reestablished the regulatory boundary between commercial and investment banking.

2.2. Literature review

Our study contributes to the existing literature in several ways. First, our study adds to the ongoing research on the Dodd-Frank Act. In a recent influential paper, Dimitrov et al. (2015) show that credit rating agencies issued lower ratings, gave more false warnings, and issued downgrades that were less informative after the enactment of the Dodd-Frank Act. Using secondary market subordinated debt transactions, Balasubramnian and Cyree (2014) find that the Dodd-Frank Act has statistically and economically improved market discipline, particularly for banks identified as too-big-to-fail. However, Gao, Liao, and Wang (2016), who examine stock and bond market reactions to the enactment of Dodd-Frank Act, argue that markets have been doubtful about the effectiveness of the Dodd-Frank Act in putting an end to too-big-to-fail status. Recently, Loon and Zhong (2016) have examined transaction costs and liquidity in the index credit default swap, finding that the Dodd-Frank Act decreases trading costs and hence improves liquidity in the over-the-counter derivatives market. Moreover, Keppo and Korte (2016) analyze the effects of the Volcker Rule's announcement on BHCs and find that banks affected by the Volcker Rule had already reduced their trading books but did not reduce overall risk-taking. In this paper, we focus on the enforcement of the Volcker Rule and provide a comprehensive understanding of its effectiveness, in terms of risk-taking and liquidity creation.

Second, we add to the vast body of literature on bank regulation and risk-taking, such as work by Esty (1998), who studies the impact of contingent liability on risk-taking, Houston et al. (2010), who find that stronger creditor rights tend to promote higher bank risk-taking and accordingly increase the likelihood of financial crisis, and Black and Hazelwood (2013), who focus on the adverse effect of the Troubled Asset Relief Program on risk-taking due to the moral hazard problem caused by government support. Our paper contributes to this strand of the literature by investigating the impact of the latest bank regulation, the Volcker Rule of the Dodd-Frank Act, on bank risk-taking.

Finally, we contribute to research on the effect of bank regulation on liquidity creation. Berger and Bouwman (2009) were the first to develop a comprehensive measurement of liquidity creation. Based on this measure, Berger et al. (2016) study the effects of regulatory interventions and capital support on banks' liquidity creation and find that liquidity creation decreases after regulatory interventions but does not change after capital support. Using a dataset of Czech banks, Horvath et al. (2016) find a negative relationship between competition and liquidity creation. Following Berger and Bouwman (2009), we construct four BHC-level category-based measures of liquidity creation and document the effect of the Volcker Rule on liquidity creation.

2.3. Institutional background

In assessing the Volcker Rule of the Dodd-Frank Act, it is essential to understand the historical roots of this prescription and why the Dodd-Frank Act, specifically the Volcker Rule, was proposed after the subprime mortgage crisis.

With the passage of the Glass-Steagall Act in 1933, commercial banking was legally separated from investment banking. Commercial banks were only allowed to originate loans, whereas investment banks could underwrite securities, serve as market makers, and participate in other capital market activities. The Glass-Steagall Act aimed to ensure that the United States banking industry remained safe and sound, as commercial banking guaranteed by federal deposit insurance was protected from "non-banking" capital market risk. Because all risk-taking activities were rejected by the Glass-Steagall Act, the problem of moral hazard in the banking industry was effectively restrained. In 1999, the separation between commercial and investment banking broke down due to the passage of the Gramm-Leach-Bliley Act. This new regulation authorized BHCs that met its eligibility criteria to engage in a broad range of financially related activities.

The Dodd-Frank Act reestablished the regulatory boundary between commercial and investment banking that was lost when parts of the Glass-Steagall Act were repealed by the Gramm-Leach-Bliley Act. More specifically, the Volcker Rule of the Dodd-Frank Act prohibits any banking entity, including bank affiliates and subsidiaries, from sponsoring or investing in hedge funds, private equity funds, venture capital funds, real estate funds, structured finance vehicles, and some special purpose vehicles used in project financing;

and from engaging in proprietary trading, which is defined as short-term trading with the intent to profit from the difference between the purchase and sale prices. By prohibiting banks from engaging in short-term proprietary trading of certain securities, derivatives, commodity futures, and options on these instruments on their own account, the Volcker Rule aims to segregate nonbanking risk-taking businesses and ensure that core banking activities under government guarantees are fundamentally sound and in the public interest. In addition, the Dodd-Frank Act stipulates a long list of exemptions from the Volcker Rule. First, sponsorship of, or equity investment into, a fund is permitted if the banking entity owns no more than 3 percent of the fund or invests no more than 3 percent of Tier-One capital into the fund. Second, trading on behalf of customers, market making, or hedging are permitted activities. Even though the Dodd-Frank Act exempts market-making activities, enforcement of the Volcker Rule will affect market makers, because it is difficult to distinguish between trading activities that aim to profit from the price difference and those intended to serve market-making purposes.

2.4. Data and methodology

In this section, we first describe the data sources and explain how we construct the key variables, then introduce the econometric methodology.

2.4.1. Data

We start our analysis with the population of BHCs in the United States covering the period from 2006 through 2015 on a quarterly basis, by utilizing the Federal Reserve Consolidated Financial Statements for Holding Companies (namely, the Y-9C Report) from the Federal Reserve Bank of Chicago. As the most comprehensive and representative BHC-level dataset in the United States, these reports provide us with the complete balance sheets, income statements, and detailed supporting schedules. We exclude a BHC if it is majority-owned outside the United States; if it is a non-holding company or a non-bank structure; and if it is held by other institutions. We also exclude BHCs that appear to be thrift holding companies. We further exclude a BHC if it has negative trading assets or negative equity capital in the current quarter. To be included in the sample, each BHC should provide the necessary financial data available in the Y-9C Report. Our final sample contains 32,519 BHC-quarter observations, from 1,315 BHCs[2] during the period from 2006 to 2015. We discuss the main dependent variables, explanatory variables, and control variables below.

2.4.2. Risk measures

Our primary measure of risk-taking is the time-varying *Z-score* for each BHC. As a measure of a bank's distance from insolvency (Roy, 1952), the *Z-score* has been widely used in empirical studies (e.g., Boyd et al., 2006; Yeyati and Micco, 2007; Laeven and Levine, 2009; and Houston et al., 2010). We follow Boyd et al. (2006) and measure the *Z-score* using the current period value of asset return and capital asset ratio divided by the rolling four-quarter standard deviation of asset return. To be precise, the formula equals the sum of asset return and capital asset ratio over the rolling four-quarter standard deviation of asset return. That is,

$$\text{Z-score} = \frac{(\text{ROA} + \text{CAR})}{\sigma(\text{ROA})}, \tag{1}$$

where *ROA* denotes the asset return, *CAR* indicates the capital asset ratio, and $\sigma(ROA)$ is an estimate of the standard deviation of asset return using a four-quarter window. A higher value of *Z-score* implies less risk-taking and more stability. As the *Z-score* is highly skewed, we take the natural logarithm of the *Z-score* to explain our regression results.

As a further robustness test, we also use the ratio of loan loss provisions over total loans as an alternative risk measure for all BHCs. It is calculated as loan loss provisions divided

[2] In our sample, there are 529 publicly listed BHCs and 786 non-listed BHCs. We identify publicly listed BHCs by checking whether a BHC has provided information on PERMCO-RSSD links, which can be obtained from the Federal Reserve Bank of New York.

by total loans, in percentage, averaged quarterly over 2006-2015. A lower value of this ratio is associated with less risk-taking and vice versa.

2.4.3. Liquidity creation measures

In addition to risk measures, measures of liquidity creation constitute another group of dependent variables. Following Berger and Bouwman (2009), we construct four BHC-level category-based measures of liquidity creation using the Y-9C Report. First, we only retain on- and off-balance sheet items that were classified as either liquid or illiquid. Second, we assign a weight of 0.5 to illiquid assets, liquid liabilities, and illiquid guarantees and a weight of -0.5 to liquid assets, illiquid liabilities plus equity, liquid guarantees, and liquid derivatives. Finally, we compute each BHC-level measure of liquidity creation, and calculate *Total Liquidity Creation* as the weighted sum of the following items:

$$\begin{aligned}\text{Total Liquidity Creation} = {} & \text{Asset-side Liquidity Creation} + \\ & \text{Liability-side Liquidity Creation} + \\ & \text{Off-balance Sheet Liquidity Creation}\end{aligned} \tag{2}$$

where

$$\text{Asset-side Liquidity Creation} = 0.5(\text{illiquid assets} - \text{liquid assets})/\ \text{total assets}$$

$$\begin{aligned}\text{Liability-side Liquidity Creation} = 0.5(&\text{liquid liabilities} - \text{illiquid liabilities plus} \\ &\text{equity})/\ \text{total assets}\end{aligned}$$

$$\begin{aligned}\text{Off-balance Sheet Liquidity Creation} = 0.5(&\text{illiquid guarantees} - \text{liquid guarantees} \\ &-\text{liquid derivatives})/\ \text{total assets}\end{aligned}$$

To make each variable comparable across BHCs of different sizes, we normalize BHC-level measures of liquidity creation by a BHC’s total assets. For brevity, we define “liquidity creation” as liquidity creation per bank asset in the remainder of this chapter.

2.4.4. BHCs regulated by the Volcker Rule

To identify when the Volcker Rule began to regulate BHCs, we define two separate periods, the pre-DFA period and post-DFA period, based on the passing of the Dodd-Frank Act. Specifically, the pre-DFA period is from the first quarter of 2006 to the third quarter of 2010 and the post-DFA period is from the fourth quarter of 2010 to the last quarter of 2015.

Given that BHCs with trading assets used to engage in proprietary trading, we consider these BHCs as treated banks; BHCs without trading assets are used as the control group, as they are exempted from the Volcker Rule. Accordingly, we refer to regulated BHCs as any BHCs with a positive trading asset ratio during the pre-DFA period. Based on this criterion and the time break between two separate periods, we create an interaction term, *Volcker Rule*, that takes a value of one if the BHC has a positive trading asset ratio during the pre-DFA period at a time after the enforcement of the Volcker Rule, and zero otherwise.

2.4.5. BHCs with different business models

Next, we examine whether the Volcker Rule has heterogeneous effects on liquidity creation across BHCs with different business models, such as commercial banking and investment banking. Following Laeven and Levine (2007), we introduce the indicator of diversification to determine where each BHC lies along the spectrum from pure commercial banking to specialized investment banking. Accordingly, BHCs with low diversification are considered commercial BHCs, while BHCs with high diversification are more likely to pursue an investment banking model. Specifically, we construct the indicator *Asset Diversity* as an index of diversification across different types of assets. It can be calculated as

$$\text{Asset Diversity} = 1 - \left|\frac{\text{Net Loans} - \text{Other Earning Assets}}{\text{Total Assets}}\right| \tag{3}$$

where *Other Earning Assets* includes securities and investments, and *Total Assets* is the sum of *Net Loans* and *Other Earning Assets*. *Asset Diversity* takes values between zero and one, with higher values indicating higher diversification.

2.4.6. Control variables

Our regressions include a set of time-varying bank characteristics, controlling for other factors that might influence bank risk-taking and liquidity creation. In the case where the dependent variables are risk measures, we control for *Bank Size*, *Deposit Asset Ratio*, and *Loan Asset Ratio*. In addition to *Bank Size* and *Capital Asset Ratio*, we follow Berger et al. (2016) and include *ROE* in our regressions, controlling for profitability, when we examine the effect of the Volcker Rule on liquidity creation. In addition, we control for both BHC and state-quarter fixed effects, given that the unit of analysis is at the BHC-quarter level. The BHC fixed effects capture all time-invariant BHC characteristics, and the state-quarter fixed effects capture all time-varying state influences.

[Insert Table 1 here]

In Table 1 we report summary statistics by BHC-quarter for variables used in the study, including statistical information on all components used to calculate the variables.

2.4.7. Empirical methodology

We first evaluate the impact of the Volcker Rule on risk-taking and liquidity creation using the following regression specification as our core analysis:

$$\mathrm{Y_{ijt}} = \alpha_{\mathrm{i}} + \alpha_{\mathrm{jt}} + \beta' \cdot \text{Volcker Rule}_{\mathrm{ijt}} + \gamma' \cdot \mathrm{X_{ijt}} + \varepsilon_{\mathrm{ijt}} \tag{4}$$

where i indexes BHCs, j indexes states, t indexes time, Y_{ijt} is the dependent variable of interest (i.e., measures of risk-taking and liquidity creation), α_i is BHC fixed effects, α_{jt} is state-quarter fixed effects, $Volcker\ Rule_{ijt}$ is a dummy variable that equals one if the BHC i in state j has a positive trading asset ratio during the pre-DFA period at time t after the enforcement of the Volcker Rule and zero otherwise, X_{ijt} is a vector of controls, and ε_{ijt} is the error term. We cluster the standard errors at BHC-level to account for possible autocorrelation.

We estimate equation (4) using a DID approach. The coefficient β on the *Volcker Rule* dummy measures the effect of the Volcker Rule on risk-taking and liquidity creation. In the case where the dependent variable is *Z-score*, the conjecture is that regulated BHCs undertake less risk after the enforcement of the Volcker Rule, implying that the coefficient β should be positive. In the case where the dependent variable is *Total Liquidity Creation*, the conjecture is that regulated BHCs create more liquidity, implying that the coefficient β should be positive.

Next, we move forward to examine whether the Volcker Rule has heterogeneous effects on liquidity creation across BHCs with different business models. We follow Giroud and Mueller (2010) and estimate the following model:

$$\begin{gathered} \mathrm{Y_{ijt}} = \alpha_{\mathrm{i}} + \alpha_{\mathrm{jt}} + \beta_1{}' \cdot \mathrm{Volcker\ Rule_{ijt}} + \beta_2{}' \cdot \mathrm{Asset\ Diversity_{ijt}} + \\ \beta_3{}' \cdot (\mathrm{Volcker\ Rule_{ijt}} \cdot \mathrm{Asset\ Diversity_{ijt}}) + \gamma' \cdot \mathrm{X_{ijt}} + \varepsilon_{\mathrm{ijt}} \end{gathered} \tag{5}$$

where i indexes BHCs, j indexes states, t indexes time, Y_{ijt} is the dependent variable of interest (i.e., measures of liquidity creation), α_i is BHC fixed effects, α_{jt} is state-quarter fixed effects, $Volcker\ Rule_{ijt}$ is a dummy variable that equals one if the BHC i in state j has a positive trading asset ratio during the pre-DFA period at time t after the enforcement of the Volcker Rule and zero otherwise, $Asset\ Diversity_{ijt}$ is an index of diversification across different types of assets, X_{ijt} is a vector of controls, and ε_{ijt} is the error term. We cluster the standard errors at BHC-level to account for possible autocorrelation.

We estimate equation (5) using a triple-differences approach. The coefficient β_1 on the $Volcker\ Rule$ dummy measures the limit effect of the Volcker Rule on liquidity creation as diversification approaches zero. In other words, it measures the effect on liquidity creation for commercial BHCs regulated by the Volcker Rule. The coefficient β_2 measures the effect of diversification on liquidity creation. The coefficient β_3 on the interaction term measures how the effect of the Volcker Rule varies with the degree of diversification. For any given degree of diversification, we can compute the total effect of the Volcker Rule on liquidity creation as $(\beta_1 + \beta_3 \cdot Asset\ Diversity)$. In the case where the dependent variable is $Total\ Liquidity\ Creation$, the conjecture is that regulated BHCs with a higher degree of diversification create more liquidity, implying that the coefficient β_3 should be positive.

2.5. Empirical results

This section presents our empirical results. As our core analysis, we first separately evaluate the effect of the Volcker Rule on risk-taking and liquidity creation, using the methodology described in equation (4). Using the triple-differences methodology in equation (5), we conclude this section by examining the heterogenous effect to reveal how the degree of diversification influences the impact of the Volcker Rule on liquidity creation.

2.5.1. The effect of the Volcker Rule on risk-taking

2.5.1.1. Graphical result

In Figure 1, we plot the time trends of risk-taking (measured by *Z-score*) for the treatment group (i.e., BHCs regulated by the Volcker Rule) and control group (i.e., BHCs exempted from the Volcker Rule). The red vertical line indicates the passage of the Dodd-Frank Act in the third quarter of 2010.

[Insert Figure 1 here]

Clearly, the two groups have quite similar trends in the pre-DFA period. This parallel pretreatment trend in risk-taking between the treatment and control groups alleviates the concern that two groups are *ex-ante* incomparable, and lends support to our DID identifying assumption. However, there is a clear divergence between treatment and control groups in trends of risk-taking right after the third quarter of 2010, when the Volcker Rule was enforced. The consistency in timing between the divergence in risk-taking and enforcement of the Volcker Rule indicates that prohibition of proprietary trading reduces bank risk-taking.

2.5.1.2. Regression results

We provide primary results regarding the effect of the Volcker Rule on risk-taking in Table 2. Based on equation (4), we start with a simple DID specification that includes only BHC and state-quarter fixed effects in column 1. Our regressor of interest, *Volcker Rule*, is statistically significant and positive, suggesting that regulated BHCs undertake less risk after the enforcement of the Volcker Rule. In column 2, we add a set of time-varying bank characteristics, such as *Bank Size*, *Deposit Asset Ratio*, and *Loan Asset Ratio*. Our results are found to be robust to these additional controls. More specifically, the coefficient of 0.422 in the second column indicates that the *Z-score* of regulated BHCs increases by 42.2% on average, compared with BHCs exempted from the Volcker Rule.

[Insert Table 2 here]

Decomposing *Z-score*, we know that all else being equal, higher asset return and higher capital asset ratio translate into a higher *Z-score*, while a higher level of standard deviation of asset return translates into a lower *Z-score*. To further explore how the components of *Z-score* change in response to the enforcement of the Volcker Rule, we run regressions treating each of these *Z-score* components as a separate dependent variable. From columns 3 to 5, we see that enforcement of the Volcker Rule is significantly associated with a higher level of ROA and lower standard deviation of ROA. These results suggest that the higher *Z-score* results primarily from BHCs investing in better-performing assets at a lower level of risk-taking. One possible reason for this finding is that enforcement of the Volcker Rule restricts BHCs from undertaking more risk by limiting proprietary trading, but does not decrease their profitability.

2.5.1.3. Robustness checks

In Table 3, we test the robustness of the main result in three ways. First, we exclude non-listed BHCs and only consider the 529 publicly listed BHCs in the baseline regression. Doing so reduces the sample size from 32,519 to nearly 13,000 observations, but allows us to show that the effect of the Volcker Rule on risk-taking is influential in the banking sector. In column 1, we find that the result is highly consistent with our previous finding and the estimated coefficient of *Volcker Rule* is 0.432, which is larger than in the main result. This finding indicates that the effect of the Volcker Rule on risk-taking is even stronger for listed BHCs.

[Insert Table 3 here]

Second, we use the ratio of loan loss provisions over total loans as an alternative risk-taking measure and re-run our baseline regression. As reported in column 2, the estimated coefficient of *Volcker Rule* is negative and statistically significant at the 1% level. As a lower value of *Loan Loss Provisions (%)* indicates less risk-taking and more stability, the negative coefficient suggests the same conclusion: the enforcement of the Volcker Rule restricts bank risk-taking.

Lastly, we consider the time lag effect of the Volcker Rule and change the cutoff time from the third quarter to the fourth quarter of 2010. Specifically, we create a new dummy variable, *Volcker Rule (lag one period)*, that takes a value of one if the BHC has a positive trading asset ratio during the pre-DFA period at a time after the fourth quarter of 2010, and zero otherwise. We provide the result in column 3 and find that the estimated coefficient remains significant, but the magnitude reduces to 0.402.

2.5.2. The effect of the Volcker Rule on liquidity creation

We have established that the enforcement of the Volcker Rule reduces bank risk-taking, which is the first step in our core analysis. Here, we move further to investigate whether the Volcker Rule has any impact on liquidity creation.

Table 4 presents regression results based on equation (4), where dependent variables are *Total Liquidity Creation* and its three components. Our regressions include three time-varying bank characteristics, i.e. *Bank Size*, *Capital Asset Ratio*, and *ROE*. To capture both time-invariant BHC characteristics and time-varying state influences, we condition on BHC and state-quarter fixed effects. As shown in columns 2 and 4, enforcement of the

Volcker Rule induces a significant increase in liability-side liquidity creation and a decrease in liquidity creation off the balance sheet. More specifically, regulated BHCs create 0.8 percentage point more liability-side liquidity and destroy 0.3 percentage point more liquidity off the balance sheet, compared with exempted BHCs. When applying these estimates to the average (median) BHC in our sample, which has total assets of $4,461 million ($966 million), the positive 0.8 percentage point implies an increase of $35.7 million ($7.7 million) in liability-side liquidity creation and the negative 0.3 percentage point indicates a decrease of $13.4 million ($2.9 million) in off-balance sheet liquidity creation. Relative to the sample mean of *Liability-side Liquidity Creation* and *Off-balance Sheet Liquidity Creation*, the effect of the Volcker Rule on liquidity creation is also meaningful.

[Insert Table 4 here]

At the BHC level, the enforcement of the Volcker Rule induces a significant increase in liability-side liquidity creation, which suggests that the Volcker Rule may expose regulated BHCs to liquidity risk, which is not captured in the credit-risk-taking measure Z-score. In addition, the Volcker Rule triggers the unintended consequence of a noticeable drop in liquidity creation off the balance sheet. Thus the passage of the Volcker Rule may adversely affect certain financial services provided by BHCs, such as loan commitments and letters of credit. According to Boot et al. (1993), Holmstrom and Tirole (1998), and Kashyap et al. (2002), loan commitments and letters of credit, as key functions of financial intermediaries in providing liquidity, enable firms to change long-run investment strategies efficiently. The negative influences on off-balance sheet liquidity creation may further affect the cost of capital for firms.

2.5.3. The heterogeneous effects of the Volcker Rule

Our aforementioned analysis estimates the effect of the Volcker Rule on risk-taking and liquidity creation. In this subsection, we investigate the heterogeneous effects of the Volcker Rule on liquidity creation across BHCs with different business models to shed further light on how its passage affects liquidity creation. We use the triple-differences specification in equation (5), and condition on BHC and state-quarter fixed effects to capture both time-invariant BHC characteristics and time-varying state influences.

[Insert Table 5 here]

In column 1 of Table 5, we investigate the heterogeneous effects on total liquidity creation across BHCs. First, the *Volcker Rule* dummy captures the limit effect of the Volcker Rule on total liquidity creation as the degree of diversification approaches zero. The significantly positive coefficient confirms that the passage of the Volcker Rule has a positive effect on total liquidity creation for regulated BHCs with only lending activities. Furthermore, the negative coefficient on *Asset Diversity* suggests that total liquidity creation decreases with the degree of diversification. Finally, the interaction term $Volcker\ Rule \times Asset\ Diversity$ has a significant coefficient of -0.049, which implies that passage of the Volcker Rule has an adverse effect on total liquidity creation for regulated BHCs with diversified activities. As for the economic magnitude of the effect, a one-standard-deviation increase in the degree of diversification induces a reduction in total liquidity creation of 0.00539 ($= 0.049 \times 0.11$), or 0.539 percentage point. When applying this estimate to the average (median) BHC in our sample, the negative 0.539 percentage point implies that an increase in the degree of diversification by one standard deviation is associated with a drop of $24.1 million ($5.2 million) in total liquidity creation.

Given that *Asset Diversity* can be used to determine where each BHC lies along the spectrum from pure commercial banking to specialized investment banking, we can explain these findings as heterogeneous effects across BHCs (i.e., commercial BHCs versus investment BHCs). That is, the passage of the Volcker Rule motivates commercial BHCs to create liquidity and meanwhile induces investment BHCs to destroy liquidity. According to Allen and Santomero (1998) and Allen and Gale (2004), liquidity creation exposes banks to liquidity risk. The more liquidity that is created, the more significant the likelihood and severity of losses associated with banks. Therefore, the significant increase in liquidity creation may expose commercial BHCs to liquidity risk, because they may have to dispose of illiquid assets to meet the liquidity demands of customers. Meanwhile, the passage of the Volcker Rule may restrict some activities for regulated investment BHCs, given that liquidity creation is negatively associated with the degree of diversification.

In column 2, we find a positive effect on liquidity creation off the balance sheet for investment BHCs regulated by the Volcker Rule. The interaction term between the *Volcker Rule* dummy and *Asset Diversity* has a significant coefficient of 0.007, which suggests that an increase in the degree of diversification by one standard deviation is associated with an increase in liquidity creation off the balance sheet of 0.007 ($0.007 \times 0.01 = 0.00007$) percentage point. Together with the negative coefficient on the *Volcker Rule* dummy in the same column, we argue that commercial BHCs destroy liquidity off the balance sheet and investment BHCs create liquidity off the balance sheet after the enforcement of the Volcker Rule. In addition, the result in column 4 suggests that the heterogeneous effects of the Volcker Rule on total liquidity creation is mostly accounted for by *Liability-side Liquidity Creation*. It can be seen that the interaction term between *Volcker Rule* dummy and *Asset Diversity* has a significant coefficient of -0.043, which suggests that an increase in the degree of diversification by one standard deviation is associated with a decrease in liquidity creation on the liability side of 0.301 ($0.043 \times 0.07 = 0.00301$) percentage point. This finding indicates that regulated investment BHCs decrease total liquidity creation by destroying liquidity on the liability side. Similarly, the positive coefficient on the *Volcker Rule* dummy in the same column tells us that the positive effect of the Volcker Rule on total liquidity creation for commercial BHCs derives from the liability side.

Under the regulation, commercial BHCs create liquidity on the balance sheet and destroy liquidity off the balance sheet. In contrast, investment BHCs regulated by the Volcker Rule pay more attention to off-balance sheet activities and provide less liquidity on the balance sheet. This finding to some extent shows that the Volcker Rule reestablishes the regulation boundary between commercial and investment banking. Commercial BHCs ensure the safety of core banking activities, and investment BHCs can focus on nonbanking risk-taking businesses.

2.6. Conclusion

In response to the financial crisis, the Dodd-Frank Act was passed on July 21, 2010. In section 619 of the Dodd-Frank Act, commonly known as the Volcker Rule, the United States Congress imposes restrictions on banks' ability to engage in proprietary trading activities. Using the passage of the Volcker Rule as an exogenous shock, we used the DID methodology to separately examine the effect of the Volcker Rule on risk-taking and liquidity creation. Based on our results, we confirmed that prohibition of proprietary trading decreases bank risk-taking for regulated BHCs. However, the trade-off of the Volcker Rule is that it may over-regulate banks that hinder the market-making activities, especially market-making and proprietary trading are in practice hard to completely differentiate from each other. The market-making activities are important for the over-the-counter market, since market makers provide "immediacy" to investors. Banks with market-making activities normally hold some trading assets and therefore are easily to be classified as regulated banks under the Volcker Rule. The enforcement of Volcker Rule may restrict these banks' willingness to serve as market makers and therefore limit their ability of absorbing supply and demand imbalances in the market.

In terms of liquidity creation, we find that enforcement of the Volcker Rule induces a significant increase in liability-side liquidity creation and a decrease in liquidity creation off the balance sheet. This finding suggests that the Volcker Rule may expose regulated BHCs to liquidity risk, which is not captured in the credit-risk-taking measure Z-score. This finding also implies that passage of the Volcker Rule may have adversely affected certain financial services provided by BHCs, such as loan commitments and letters of credit.

We also investigated the heterogeneous effects of the Volcker Rule on liquidity creation across BHCs with different business models. According to the definition of *Asset Diversity*, investment BHCs may hold other earning assets such as trading assets. Therefore, investment BHCs are more likely to be identified as regulated BHCs, leading to the self-selection problem. In our triple-differences regression model, the interaction term evaluates how liquidity creation changes with the degree of diversification, *Asset Diversity*, only for the regulated BHCs. In this case, the self-selection will not affect our result and conclusion. We find that the passage of the Volcker Rule has a significantly positive effect on total liquidity creation for regulated commercial BHCs. For regulated investment BHCs, the effect on total liquidity creation becomes negative. Moreover, we find that the heterogeneous effects of the Volcker Rule on total liquidity creation derives from the liability side. In addition, we find that commercial BHCs destroy liquidity off the balance sheet, whereas investment BHCs create liquidity off the balance sheet after enforcement of the Volcker Rule. This finding to some extent suggests that the Volcker Rule has reestablished the regulatory boundary between commercial and investment banking.

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Tables and Figures

Figure 1

Changes of Z-score for BHCs regulated by Volcker Rule vs BHCs exempted from Volcker Rule.

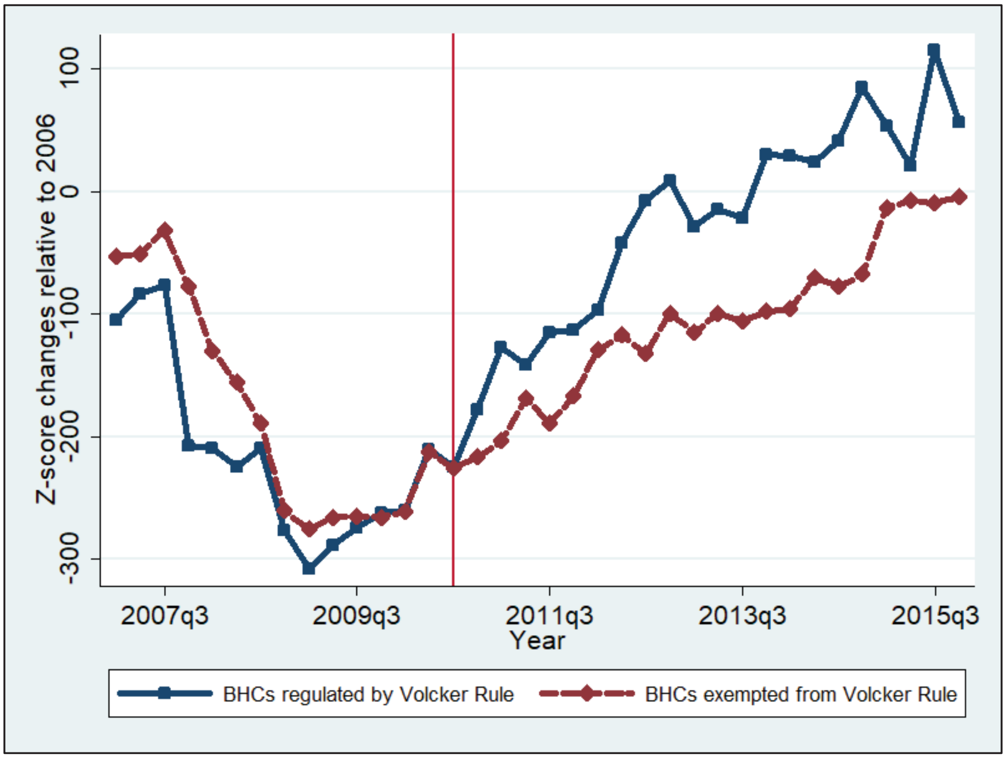

Table 1
Summary statistics for bank holding companies.
All variables have been winsorized at 1% level.

	(1) Mean	(2) Std.dev	(3) Min	(4) Median	(5) Max	(6) No. of obs.
Risk Measures						
Log Z-score	4.99	1.38	1.21	5.22	7.75	32,519
Z-score	296.2	356.8	3.4	184.8	2312.0	32,519
- ROA	0.15	0.29	-1.02	0.20	0.78	32,519
- CAR	9.36	2.94	3.23	9.15	19.96	32,519
- σ(ROA)	0.15	0.26	0.00	0.05	1.33	32,519
Loan Loss Provisions (%)	0.20	0.32	-0.10	0.08	1.65	32,519
Liquidity Measures						
Total Liquidity Creation	0.18	0.11	-0.14	0.18	0.43	32,519
Off-balance Sheet Liquidity Creation	0.02	0.01	0.00	0.01	0.07	32,519
Asset-side Liquidity Creation	0.00	0.07	-0.22	0.01	0.19	32,519
Liability-side Liquidity Creation	0.17	0.07	-0.04	0.16	0.34	32,519
Explanatory Variables						
Volcker Rule	0.07	0.26	0.00	0.00	1.00	32,519
Trading Asset Ratio	0.16	1.10	0.00	0.00	24.62	32,519
Asset Diversity	0.50	0.22	0.08	0.48	0.98	32,519
- Gross Loans	2571.0	8741.0	137.3	633.7	72539.0	32,519
- Other Earning Assets	421.9	504.0	2.5	222.4	1815.0	32,519
Control Variables						
Bank Size	7.18	1.11	5.51	6.86	11.85	32,519
- Total Asset	4461	16645	248	966	140085	32,519
Deposit Asset Ratio	0.80	0.08	0.48	0.81	0.92	32,519
Loan Asset Ratio	0.67	0.12	0.29	0.69	0.90	32,519
Capital Asset Ratio	0.09	0.03	0.03	0.09	0.20	32,519
ROE	0.01	0.04	-0.20	0.02	0.09	32,519

Table 2

Risk-taking and Volcker Rule: BHC-level DID OLS regressions.

This table presents results of the effect of Volcker Rule on risk-taking. The sample consists of BHC-quarter observations from 2006 through 2015. The dependent variables in columns (1) and (2) are Log Z-score. Z-score = (ROA+CAR)/σ(ROA). Higher Z-score implies less risk-taking and more stability. In columns (3) - (5), we use three components of Z-score as separate dependent variables. In this specification, Volcker Rule is a dummy variable that takes a value of one if BHC's trading asset ratio during the pre-DFA period was greater than 0% at a time after the enforcement of Volcker Rule and zero otherwise. All control variables are lagged by one quarter. Standard errors are adjusted for BHC-level clustering and appear in parentheses. *, **, and *** indicate significant at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)
Dependent Variables	Log Z-score		ROA	CAR	σ(ROA)
Volcker Rule	0.393***	0.422***	0.046***	0.362**	-0.051***
	(0.070)	(0.070)	(0.014)	(0.180)	(0.013)
Bank Size		-0.073	-0.075***	-0.345	0.012
		(0.073)	(0.017)	(0.219)	(0.015)
Deposit Asset Ratio		-3.124***	-0.367***	-11.217***	0.514***
		(0.376)	(0.077)	(1.091)	(0.080)
Loan Asset Ratio		0.588**	0.175***	0.086	-0.063
		(0.267)	(0.049)	(0.622)	(0.054)
Observations	32,519	32,519	32,519	32,519	32,519
R-squared	0.608	0.612	0.534	0.831	0.482
Number of BHCs	1,315	1,315	1,315	1,315	1,315
BHC fixed effects	Yes	Yes	Yes	Yes	Yes
State-Quarter fixed effects	Yes	Yes	Yes	Yes	Yes

Table 3

Risk-taking and Volcker Rule: Robustness checks.

This table presents results of robustness checks. The sample consists of BHC-quarter observations from 2006 through 2015. In column (1), the sample only includes 529 public-listed BHCs. In column (2), the dependent variable is Loan Loss Provisions (%), the ratio of loan loss provisions over total loans. A lower value of this ratio is associated with less risk-taking and vice versa. In column (3), the cutoff time of policy enforcement is lagged one quarter. In this specification, Volcker Rule is a dummy variable that takes a value of one if BHC's trading asset ratio during the pre-DFA period was greater than 0% at a time after the enforcement of Volcker Rule and zero otherwise. All control variables are lagged by one quarter. Standard errors are adjusted for BHC-level clustering and appear in parentheses. *, **, and *** indicate significant at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)
Dependent Variables	Log Z-score	Loan Loss Provisions (%)	Log Z-score
Volcker Rule	0.432***	-0.089***	
	(0.102)	(0.016)	
Volcker Rule (lag one period)			0.402***
			(0.069)
Bank Size	-0.264**	0.182***	-0.072
	(0.114)	(0.018)	(0.073)
Deposit Asset Ratio	-4.270***	0.116	-3.128***
	(0.603)	(0.078)	(0.377)
Loan Asset Ratio	0.523	0.214***	0.582**
	(0.519)	(0.051)	(0.267)
Observations	13,079	32,519	32,519
R-squared	0.608	0.521	0.612
Number of BHCs	529	1,315	1,315
BHC fixed effects	Yes	Yes	Yes
State-Quarter fixed effects	Yes	Yes	Yes

Table 4

Liquidity Creation and Volcker Rule: BHC-level DID OLS regressions.

This table presents results of the effect of Volcker Rule on liquidity creation. The sample consists of BHC-quarter observations from 2006 through 2015. Following Berger and Bouwman (2009), we construct four BHC-level category-based measures of liquidity creation. In column (1), the dependent variable is Total Liquidity Creation. In columns (2) - (4), we use three components of Total Liquidity Creation as separate dependent variables. In this specification, Volcker Rule is a dummy variable that takes a value of one if BHC's trading asset ratio during the pre-DFA period was greater than 0% at a time after the enforcement of Volcker Rule and zero otherwise. All control variables are lagged by one quarter. Standard errors are adjusted for BHC-level clustering and appear in parentheses. *, **, and *** indicate significant at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
Dependent Variables	Total Liquidity Creation	Off-balance Sheet Liquidity Creation	Asset-side Liquidity Creation	Liability-side Liquidity Creation
Volcker Rule	-0.001	-0.003***	-0.004	0.008**
	(0.007)	(0.001)	(0.005)	(0.004)
Bank Size	-0.010	-0.002**	0.001	-0.010***
	(0.006)	(0.001)	(0.004)	(0.004)
Capital Asset Ratio	-0.312***	-0.013*	0.171***	-0.451***
	(0.071)	(0.007)	(0.056)	(0.040)
ROE	0.012	0.003*	-0.027**	0.036***
	(0.015)	(0.002)	(0.011)	(0.008)
Observations	32,519	32,519	32,519	32,519
R-squared	0.849	0.859	0.815	0.893
Number of BHCs	1,315	1,315	1,315	1,315
BHC fixed effects	Yes	Yes	Yes	Yes
State-Quarter fixed effects	Yes	Yes	Yes	Yes

Table 5

Liquidity Creation and Volcker Rule: BHC-level triple differences OLS regressions.

This table presents results of heterogeneous effects of Volcker Rule on liquidity creation. The sample consists of BHC-quarter observations from 2006 through 2015. Following Berger and Bouwman (2009), we construct four BHC-level category-based measures of liquidity creation. In column (1), the dependent variable is Total Liquidity Creation. In columns (2) - (4), we use three components of Total Liquidity Creation as separate dependent variables. In this specification, Volcker Rule is a dummy variable that takes a value of one if BHC's trading asset ratio during the pre-DFA period was greater than 0% at a time after the enforcement of Volcker Rule and zero otherwise. Following Laeven and Levine (2007), we construct Asset Diversity as one minus the absolute value of the difference between net loans and other earning assets divided by total assets. It takes values between zero and one with higher values indicating greater diversification. All control variables are lagged by one quarter. Standard errors are adjusted for BHC-level clustering and appear in parentheses. *, **, and *** indicate significant at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
Dependent Variables	Total Liquidity Creation	Off-balance Sheet Liquidity Creation	Asset-side Liquidity Creation	Liability-side Liquidity Creation
Volcker Rule	0.032**	-0.007***	0.007	0.034***
	(0.014)	(0.002)	(0.011)	(0.009)
Asset Diversity	-0.168***	-0.009***	-0.152***	-0.008
	(0.010)	(0.001)	(0.007)	(0.006)
Volcker Rule × Asset Diversity	-0.049**	0.007**	-0.013	-0.043***
	(0.021)	(0.003)	(0.015)	(0.015)
Bank Size	-0.018***	-0.002***	-0.006*	-0.011***
	(0.005)	(0.001)	(0.004)	(0.004)
Capital Asset Ratio	-0.385***	-0.016**	0.109**	-0.459***
	(0.062)	(0.008)	(0.047)	(0.040)
ROE	0.015	0.003*	-0.025**	0.036***
	(0.013)	(0.002)	(0.010)	(0.008)
Observations	32,519	32,519	32,519	32,519
R-squared	0.869	0.862	0.847	0.894
Number of BHCs	1,315	1,315	1,315	1,315
BHC fixed effects	Yes	Yes	Yes	Yes
State-Quarter fixed effects	Yes	Yes	Yes	Yes