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ABSTRACT

Crime and the durability of goods are strongly connected issues. However, surprisingly, they have been studied separately. This paper explores the relationship between the production of durable goods and crime from a theoretical perspective and draws important conclusions for both topics. Crime affects the consumer and producer surplus and thus the behavior of consumers, firms, the market equilibrium, and, in turn, the social optimum. Lower durability of goods reduces the incentive to steal those goods, thus reducing crime. When crime is included in the standard framework of durable goods, even without considering the negative externalities of crime, perfect competition does not provide the optimal durability level. When considering different stealing technologies, perfect competition either over-produces durability or produces zero (minimum) durability. The monopolist under-produces durability regardless of the stealing technology considered. If crime externalities are taken into account, the socially optimal durability level is reduced and gets closer to that which prevails under monopoly. The model presented in this paper implies that the durability of goods, and the market structure for those goods, can be an effective instrument to reduce crime. In particular, making the durability of a good contingent upon that good being stolen is likely to increase welfare.

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1. Introduction

Crime and the durability of goods are strongly connected issues. However, surprisingly, they have been studied separately and there has not been any link between the literature on modelling the production of durable goods and the literature on crime. This paper explores the relationship between crime and the durability of goods from a theoretical perspective and draws important conclusions for both topics from the interaction between them.

On the one hand, since Gary Becker's seminal paper in 1968, there has been remarkable progress in the analysis of crime from the criminology and crime economics perspectives. Studies focusing on factors that increase the expected costs or reduce the expected benefits of committing crimes led to important, mainly empirical, contributions to the crime-reducing impact of different law enforcement, education, and employment policies. On the other hand, microeconomic theory has studied the optimal durability of goods to disentangle whether, under the monopoly market structure, social optimum durability is achieved. This literature, which has evolved since the 1960s, has found that under reasonable assumptions a monopolist under-produces durability, as this feature of the goods links the production of present and future periods and thus lowers the durability of goods, which in turn allows for higher prices in the future periods.

The literature on crime has not addressed the producer side as an important determinant of the features of goods that affect their prices, such as their durability. In this paper we develop a theoretical model to study the connection between durability and crime. Our model implies that the durability of goods, and the market structure under which goods are produced, can affect crime. Interventions that attempt to reduce the level of durability of goods make stealing less profitable, which leads to a reduction in the incidence of acquisitive crimes. Additionally, making the durability of goods contingent on those goods being stolen would also likely increase welfare by diminishing the future utility or resale value of those goods if they are stolen. Moreover, traditional policy recommendations to reduce crime, such as an increase in the severity or celerity of sanctions, probably have a lower impact in the long run through the equilibrium effect that the reduction of crime have on the durability of the goods.

In order to formally assess the link between crime and the optimal level of durability, we develop a model that adds crime to the standard framework of the production of durable goods. Crime produces externalities because the losses and damages it causes go beyond the stolen objects and can lead to long-lasting negative consequences, even death. The model shows that perfect competition does not provide the optimal durability level, even if we do not consider the externalities caused by crime. Two technologies for stealing are studied: the random stealing technology in which all types of goods have the same probability of being stolen; and the selective stealing technology, which targets durable goods. Perfect competition sets a durability level that is higher than the social optimum, i.e., it over-produces durability under the random stealing technology and produces zero durability under selective stealing. The monopoly market structure sets a durability level that is lower than the social optimum, i.e., it under-produces durability, regardless of the stealing technology. If we also consider the externalities caused by crime, the optimal social level of durability gets closer to the one that prevails under monopoly. We find that if this externality is big enough, even the monopoly market structure could over-produce durability.

Advancing the understanding of the causes of crime and of policies that could reduce crime rates is very important both for developed and developing countries. Crime has negative effects on the welfare of individuals and societies. Crime and the threat of crime distort the allocation of resources from governments, households, and firms (Sah 1991; Jaitman 2015). Most of the crimes recorded by the police are property crimes. In the United States, property crime represented 87 percent of total crime in 2014, and financial losses suffered by victims of these crimes totaled approximately $14.3 billion (FBI 2014). In England and Wales, property crime accounted for 70 percent of all crimes recorded by the police in 2013–2014 (UK Office of National Statistics 2014). The consistently high proportion of offenses attributable to property crimes means that acquisitive crimes are important drivers of overall crime trends.[3] Indeed, burglary and vehicle-related theft are considered to be "keystone" crimes that are thought to facilitate and encourage other types of crime (Farrell et al. 2010).

A large component of property crimes worldwide involves durable goods, which are goods that are not consumed or destroyed and can be used for a period of time and are therefore costlier. For example, in the United States there were an estimated 690,000 thefts of motor vehicles in 2014, which accounted for around $4.5 billion in losses (FBI 2014). Of all the motor vehicles stolen in 2014, 74.5 percent were automobiles. In the United Kingdom there were around 32,000 motor vehicle offenses reported to the police in the same year. Another example is smartphones. Official data indicate that in 2013 more than a quarter of all thefts and over half of grand larcenies from a person in New York City involved a smartphone. In 2013–2014 in England and Wales, there were half a million mobile phone theft victims. Most thefts in San Francisco (59 percent) and London (49 percent) in 2013 also involved the theft of a smartphone (Technological Advisory Council 2014). In Latin America, the share of durable goods in thefts and robberies is even greater. According to the national victimization survey in Chile, durable goods represented 96 percent of thefts and robberies in 2013 (Subsecretaria de

[3] These types of crimes are also predominantly reported to the police for insurance reasons. Property crimes are also the most prevalent reported in victimization surveys (Jaitman and Anauati, forthcoming).

Prevención y Delito 2014), while in Colombia, 48 percent of thefts were cellular phones in that year (DANE 2014). Finally, according to the 2013 crime victimization survey in Mexico, 52 percent of total thefts committed on the street or on public transports involved cellular phones (INEGI 2014).

How could the durability of goods affect the equilibrium crime rate? In the crime economics basic framework (Becker 1968; Erlich 1973), durability can be considered one of the characteristics of goods that potential criminals take into account when making their decision to get involved in illegal activities. Under that framework, individuals act rationally and therefore seek to maximize their well-being, comparing the costs and benefits of participating in the legal or illegal sector. The benefits of committing a crime (participating in the illegal sector) can be put into two categories: pecuniary benefits and psychological benefits. An individual who commits a crime also faces the expected costs from enforcement of the law. If individuals are risk-neutral, those costs are equal to the probability of punishment multiplied by the cost of the punishment, which usually refers to sentences handed down to criminals. Therefore, the net expected return from crime, calculated as the difference between the expected benefit and the cost of committing a crime, should be compared with the expected net return obtained from undertaking an activity in the legal sector, which in a simplified form is the salary earned. Thus, an individual will commit a crime only if the net expected return of that activity exceeds the net return that will be obtained through a legal activity.

Under this crime economics framework, criminals can be deterred from committing crimes by policies that either reduce the expected net benefits from crime vis-à-vis legal activities or increase the expected payoff from working legally. For example, increasing the certainty, celerity, and severity of punishment can reduce the net return to crime (by increasing the expected cost of criminal activity), while increases in salaries in the legal sector can reduce the number of criminals. The parallel of that concept for the purpose here is that a reduction in the durability of stolen goods can also reduce crime, since it reduces the pecuniary benefits of crime. This is because it is intuitive to think that the less durable a good, the lower its resale price will be and the lower its consumption value for the thief. Consequently, as the benefits of illegal activities decrease, and as the costs remain the same, criminals will find it less profitable to devote themselves to illegal activities. In an extreme case, if durability is zero and thus goods do not yield services once stolen, criminals would not benefit from stealing goods, and this type of acquisitive crime would not occur.

In fact, there seems to be supportive evidence for the criminological approach outlined by Clarke (1999, 2000), who stressed the role of a range of price and nonprice attributes in determining rates of theft across goods. Durability is one such attribute that translates into prices and may also, depending on the technology, make it impossible or very difficult for the goods to be subject to theft.[4] Indeed, there is empirical evidence of a decrease in car thefts once technologies to deter these crimes were introduced. According to a study by Morgan et al. (2016), vehicle thefts started rising in the 1960s, and steering locks were introduced as a result. The locks did not stop vehicle thefts, leading to a "second wave" of security devices in the 1980s and 1990s that included central locking, car alarms, and – most importantly – electronic immobilizers (devices fitted to vehicles that prevent starting the engine without the key, which contains a microchip uniquely programmed by the dealer to match the car). Vehicle thefts began to fall sharply as many of the second-wave devices spread through the vehicle fleet. Once electronic immobilizers were installed on around half the vehicle fleet in certain nations, those nations saw a sharp decline in vehicle thefts of around 40 percent (see Figure 1). The spread of electronic immobilizers happened more quickly in Europe and Australia than in the United States and Canada due partly to the presence and timing of legislation mandating the installation of such immobilizers in new vehicles by producers (see Table 1 and Figure 2). This was a clear shock to the market of durable goods from the supply side. Legislation was important in putting the burden on producers rather than consumers – according to Morgan et al. (2016) there was little evidence of consumers retrofitting electronic immobilizers to existing vehicles, and installation of immobilizers by suppliers required no knowledge or conscious action by the consumer (most people do not know their car has an electronic immobilizer and do not need to even switch it on). The channel through which this intervention reduced crime was by making theft more difficult, not because it led to more offenders being caught (vehicle crime detection rates changed little during the period of sharp decline in offenses). The introduction of this technology, which mainly reduced the durability of the vehicles once stolen, may have caused crime displacement in the sense of changing targets to older cars that did not have the technology. Had the legislation been applied to all vehicles rather than just new vehicles, even more crime might have been prevented.

This paper also contributes to the literature on durable goods and crime economics. The latter has focused mainly on the deterrence effects of changing the costs of committing crimes, particularly increases in the certainty, celerity, and severity of punishment through criminal justice system reforms or law enforcement interventions (for a review see Chalfin and McCrary, forthcoming, and Nagin, 2013). Another strand of the literature focuses on changes in the incentives to engage in legal activities and explores the relationship between crime and unemployment or crime and education (Bell, Bindler, and Machin 2014; Fougère, Pouget, and Kramarz 2009; Freeman 1999; Gronqvist 2013; Machin and

[4] As we show in the model, what would be optimal is to have a level of durability that is contingent upon the good being stolen. However, when this technology is not available the relevant decision is about average durability.

Meghir 2004). Less studied has been the question of how changes in the benefits from or returns to criminal activity affect observed crime levels. In the case of property theft, a key determinant of the benefits derived from crime is the financial value of stolen property, which is important both in terms of the resale potential of the property and the extent of its utility for the criminal's personal consumption. Thus, changes in these benefits may affect criminal participation decisions. There are a few empirical studies that address the issue of how the economic return of property crime may change crime levels. These include Reilly and Witt (2008) on changes in prices of audio-visual goods, Draca, Koutmeridis, and Machin (2015) on the impact of commodity prices such as gold and copper in the United Kingdom, and D'Este (2014) on the availability in the United States of pawnshops, which are usually associated with increasing opportunities to sell stolen goods. To the best of our knowledge the existing crime economics literature has not studied how the supply of goods may affect crime.

On the other hand, the literature on durable goods has developed along various dimensions since the main contributions in the 1970s, which included Akerlof (1970) on adverse selection, Swan (1970, 1971) on optimal durability, and Coase (1972) on time inconsistency. Although Akerlof's contribution was not on durables, his main application was to the automobile market. In the 1990s, asymmetric information and adverse selection were included in models of durable goods, and the literature initially advanced these models and then turned to other developments more consistent with the real world. There have been important contributions in terms of the choice of the durability level (and we aim to contribute to this literature as well). Studies include Hendel and Lizzeri (1999), Mussa and Rosen (1978), and Waldman (1996a, 1996b), as well as product-line literature on the introduction of new products and research and development, and on leasing markets, especially for cars (Hendel and Lizzeri 2002). However, this literature still does not include any mention to crime and does not address the possibility that reducing the durability of a good could reduce the incentives to steal it.

The next section discusses the literature that deals with the monopoly market structure in the production of durable goods. Section 3 presents the set-up for our analysis, and Section 4 develops the model and studies the results under both monopoly and perfect competition market structures. Section 5 then discusses the main implications derived from the analysis and presents related empirical evidence. Section 6 puts forth our conclusions.

2. Durable Goods: A Literature Review

There is a vast literature that deals with monopoly in the production of durable goods.[5] Durable goods pose a number of questions for microeconomic analysis. One of the most important questions that has been studied is whether a monopolist produces the “optimal” level of durability, or more generally, under which conditions a monopolist reduces the optimal durability level. All the literature either implicitly or explicitly assumes that welfare is the sum of producer and consumer surplus, and perfect competition leads to the optimal level of durability.

The main results in the literature concerning the choice of durability come from Swan (1970, 1971) and Sieper and Swan (1973), who consider a variety of settings in which the socially optimal durability level is that which minimizes the cost of producing the service stream provided by the firm’s output choices. Swan (1971) shows that, as a monopolist has an incentive to minimize the cost of producing whatever service stream it provides, that monopolist will produce output with the socially optimal level of durability. There are three important assumptions that lead to Swan’s results. First, the firm commits to a choice of price and durability for the future at an initial date. Second, the durable product is valued for the services it yields, implying that units of services are perfect substitutes irrespective of the age or the durability of the product from which they are derived. And third, the lifetime distribution of the service stream generated by the durable good is fixed at the date of production.

Bulow (1982, 1986) relaxes the first of the assumptions and allows the monopolist to sell output in two periods. In the second period, output is set to maximize the second-period profits. Bulow shows that in this case the firm faces a time-inconsistency problem due to the durability of the product, so the monopolist has to reduce durability in the first period to mitigate this problem, leading to lower durability choices. Rust (1986) relaxes the second and third assumptions and also finds that the monopolist chooses durability levels that are below the socially optimal level.

Along these lines Waldman (1996a) relaxes the assumption that there is a definition of product service such that units of service are perfect substitutes in consumption (or production) irrespective of the age or durability of the product from which they are derived. Waldman considers that new units of output are of higher quality than old units, and considers that durability choice is the choice of the speed with which the quality of a unit deteriorates. He also assumes that consumers vary in terms of the valuation they place on product quality and that there is an operating secondhand market in which old units are

[5] Waldman (2003) presents an excellent survey.

traded among consumers. One of the main results of his model is that, because of the consumer's ability to substitute between new and old units, the monopolist has an incentive to build less durability into its output than would be the case if this linkage were not present or, equivalently, durability were set below the socially optimal level. The logic is that because new and used units are substitutes, albeit imperfect ones, the price of a used unit on the secondhand market constrains the monopolist in terms of the price it charges for new units. By reducing durability below the efficient level and thus the quality of used units below that level, the monopolist reduces the substitutability between new and used units, which, in turn, allows the firm to increase the price of new units. It is possible, in fact, to generalize the above argument to state that a durable goods seller will have less incentive to reduce durability as market power declines. The logic is as follows. The return to reducing durability is the higher price the firm receives in the future for its new units of output. A reduction in market power should thus decrease the firm's incentive to reduce durability for two reasons. First, similar to the above argument concerning perfect competition, as market power declines, the price for new units will be determined more by the competition between the sellers of new units than by the substitutability between new and old units. Second, there is a public good aspect to the problem that becomes more important as market power declines. That is, the return to reducing durability is the higher price for new units in the future, and as market power declines each seller is a smaller part of the total market and should thus internalize a smaller and smaller proportion of this return (Waldman 1996a). Hendel and Lizzeri (1999) also show that a monopolist does not provide socially optimal durability. Using a model in which output can also be distorted, they show that when this occurs, durability may even be over-provided by the monopolist.

Like Waldman (1996a), Waldman (1996b) also considers a durable goods monopoly model where new units of output are of higher quality than old units. However, in contrast to the first analysis, in Waldman (1996b) the monopolist does not face a durability choice; rather, quality deteriorates at an exogenously fixed speed. The focus in Waldman (1996b) is on the incentive for a durable goods monopolist to eliminate the secondhand market.

The durability choice can also affect technological progress. If products are too durable, potential innovators may lack the incentives to invest in the development of a new technology and the economy may stagnate as a result. Fishman, Gandal, and Shy (1993) show that if development costs are sufficiently low, the only stationary equilibrium involves the continuous introduction of new technologies and the production of nondurable products. Correspondingly, if development costs are sufficiently high, the only equilibrium is one in which technological advancement is arrested and only durables are produced. There is also an intermediate range of development costs in which both outcomes (continuous innovation and technological stagnation) are at equilibrium, but continuous innovation is efficient. In that range, the type of equilibrium obtained depends on whether durables or nondurables are produced. In the former case, the economy stagnates; in the latter case, there is continuous innovation. Thus, excessive product durability may arrest (efficient) technological progress in this setting.

To the best of our knowledge, the literature on durable goods still ignores the relationship between durable goods and crime. Therefore, a novel contribution of this paper is to shed light on this relationship by developing a theoretical model that incorporates the cost of crime, based on the rational model of crime, into the standard framework of durable goods.

3. Introducing the Externality of Durability to Crime

As discussed in Section 2, the threat of property crimes is absent in the literature on durable goods. If we introduce the possibility that goods could be stolen and resold in a secondary market, the results regarding the socially optimal choice of durability may be affected. We begin our theoretical model with the traditional utilitarian welfare function. We assume a simple additive relationship of the form:

$$W = \sum_i CS_i(q_i, D_i) + \sum_j PS_j\,(q_j, D_j) \quad ,$$

where CS stands for consumer surplus and PS for producer surplus, q is the quantity and D the quality of the good, and i indexes consumers while j indexes firms. Quality is positively associated with the durability of the good and in this case the only feature of quality considered is the durability so D will represent the durability in the rest of the paper. Following Waldman (1996a), we will refer to durability as the choice of the speed with which the quality of a unit deteriorates.

It is intuitive to think that the greater the durability of a good, the higher its selling price and the larger the amount of property crimes to which it may be subject. This in turn will reduce welfare, thus the welfare function becomes:

$$W = \left(\sum_i CS_i(q_i, D_i) + \sum_j PS_j\left(q_j, D_j\right), Crime(q, D) \right).$$

It is clear that the cost of crime includes externalities. Apart from the losses and inconveniences of acquisitive crimes, thefts can become violent, producing further physical and psychological injuries. Robbery is in fact an intrinsically violent crime, and, in fact, it is defined as theft accomplished by force or the threat of physical injury. Robbery is mainly of durable goods. In an extreme case, violent robbery proves fatal to the victim. This is a relatively rare event given that there are millions of thefts and robberies annually. Nevertheless, the number of robbery homicides is a major contributor to the public's fear of crime. The costs associated with fatal robberies, the fear of getting robbed, and the psychological traumas caused by being robbed are clearly not included in the traditional welfare (consumer surplus + producer surplus) model. The size of this externality seems to vary across countries. We present empirical support for this point in Figure 3, which shows the percentage of victims of a crime due to armed robbery, and Figure 4, which shows the homicide rate of victims killed during the commission of a robbery per 100,000 population.

More violent acquisitive crimes seem to be common in Latin American and the Caribbean (LAC), but less so in developed countries. According to the United Nations Office on Drugs and Crime, in 2014 approximately 15 percent of robberies led to homicides in LAC, compared to the world average of 9.1 percent (considering a sample of 33 countries). In countries such as Jamaica, 46 percent of homicide victims were killed during the commission of a robbery compared to 5 percent in the United States. This heightened degree of violence is also illustrated in victimization surveys. According to the 2014 Latin American Public Opinion Project, armed robbery accounted on average for 26 percent of total crimes in the region in 2014. In contrast, in the United States, only 5 percent of crimes were armed robberies. Furthermore, in 2014, 13 percent of victims of crime in LAC were victims of unarmed robbery, but which involved assault or physical threat, while in the United States that figure was for only 5 percent of crimes.

As will be shown in the following section, the durability of goods influences the incidence of crime. The choice of a lower level of durability by producers would reduce the amount of robberies and consequently reduce violence and the externality of crime. If our objective is to reduce crime, we need to set D (the durability of goods) low. The optimal action, provided it is cheap enough, is to design a good that once stolen depreciates completely.[6] Unfortunately the technology for achieving this is not cheap enough or even available for all goods.

4. The Model

This section introduces the possibility of the occurrence of crime into the durable goods theoretical framework. We build upon Waldman (1996a), who models a world without crime and shows that a monopolist would produce a durability level lower than that which is socially optimal in a two-period

[6] A proxy of this technology is available for mobile phones. If you call the company they can make the reconnection impossible. Thus, the only possible use of a stolen mobile phone is to dismantle and sell the parts.

model. We first present Waldman's results in order to then develop the model with the introduction of crime. Thus, we take Waldman's model to be our benchmark world without crime.

In our case, in the second period there is a secondhand market for used goods, but there is also a stolen goods market. Two technologies for theft are introduced: "selective stealing," in which the goods are targeted by the thieves and the most valuable goods are stolen first; and "random stealing," in which all the goods have the same probability of being stolen. The social optimum is characterized taking into consideration both the consumer and producer surplus as well as the externality that arises because of crime. Finally, we solve the model for the case of the monopolist.

4.1 The Waldman Model

Waldman's model considers a world without crime and a monopoly that faces pricing problems of what might be a product line: a quality-differentiated spectrum of goods of the same generic type. In this case it is a durable good that yields unit services that are not perfect substitutes in production and in consumption irrespective of the durability of the product. The seller knows the distribution of tastes and demands in the market, but cannot distinguish between buyers so cannot engage in price discrimination.

Waldman (1996a) presents a two-period world in which output lasts for two periods, $t = 1, 2$. In each period the firm chooses how much durability to build into its output, where the durability choice, denoted as D_t in period t, affects both the marginal cost of production and the speed with which quality deteriorates. In each period, the firm faces a constant marginal cost of production $c(D_t)$ where $c'(0) = 0$; $c'(D) > 0$ and $c''(D) > 0$ for all $D > 0$. Waldman (1996a) assumes no fixed costs, although adding small fixed costs does not change his results qualitatively.

In each period t, new units of the product are of quality Q^N, while in the second period units that are one period old are of quality $Q^0(D_1)$, where $Q^0(0) = 0$; $Q^0(\infty) < Q^N; Q^{0\prime}(0) = \infty, Q^{0\prime}(D) > 0$, and $Q^{0\prime\prime}(D) < 0$ for all $D \geq 0$.

There are two types of consumers, and each type lives two periods. There is a mass of size n_1 of type 1 consumers and a mass of size n_2 of type 2 consumers. The gross utility of a representative consumer of type i is $v_i Q$ with $v_2 > v_1 > 0$ when the good is bought legally (in this model, the only possibility because so far we have not incorporated illegal markets). Finally, firms and consumers have a common discount factor $\delta, 0 < \delta < 1$.

The timing is as follows: in the first period, the firm sets the durability choice and price for a new unit output and the consumers decide what to purchase; in the second period, the firm sets the durability choice and price for a new unit of output, consumers decide what to purchase from the firm, and a secondhand market also emerges in which consumers can trade used goods at prices that equate supply and demand.

To reduce the number of cases that need to be considered, Waldman (1996b) assumes the following restrictions on the parameters:

$$n_1 > n_2 \tag{1}$$

$$v_1 Q^N + \delta v_1 Q^0(D) < c(D) \quad \forall D \tag{2}$$

$$v_2\big(Q^N - Q^0(\infty)\big) > c(0), \tag{3}$$

where equation (1) implies that in equilibrium, if there is a market for used goods, as turns out to be the case, the price is positive. Equation (2) states that the valuation of type 1 consumers (v_1) is sufficiently small that the firm does not have an incentive to sell a new unit of output to a type 1 consumer in either period. Finally, the interpretation of equation (3) is that the valuation of type 2 consumers is high enough to ensure that the firm finds it profitable to market new units of output in the second period.

Waldman finds the following equilibrium characterized by $P_t^{N\prime}$, the equilibrium price for a new unit of output in period *t*, and D_t' ,the monopolist's equilibrium durability choice in period *t*. Waldman (1996a) states in his Proposition 2 that there are two possible cases:

If $2v_1 > v_2$ the equilibrium is characterized by[7]:

$$P_1^{N\prime} = v_2 Q^N + \delta v_1 Q^0(D_1'); \;\; 0 < D_1' < D_1^*$$

$$P_2^{N\prime} = v_1 Q^0(D_1') + v_2[Q^N - Q^0(D_1')]; \; D_2' = 0.$$

In *t* = 2, type 2 consumers sell old units to type 1 consumers at price $v_1 Q^0(D_1')$.

If $2v_1 \leq v_2$, the equilibrium is characterized by:

$$P_1^{N\prime} = v_2 Q^N; \; D_1' = 0$$

[7] Where D_1^* is the optimal level of durability.

$$P_2^{N\prime} = v_2 Q^N;\ D_2' = 0.$$

The results show the link between the first and the second period. If the firm produces durable output in $t = 1$, then in $t = 2$ the price of the secondhand market limits what the firm charges for new units, as consumers have old units and otherwise would keep consuming those rather than buy new ones. Given this linkage between periods, the firm has incentives to lower the durability of the first period to be able to charge a higher price in the second period for its new units. Therefore, Waldman (1996a) concludes that the durability in equilibrium is lower than it would be at the socially optimal level in period one (though in the second period it is socially optimal). Finally, Waldman shows that if v_1 is small enough, the firm does not have incentives to produce durable goods in the first period and thus eliminates the secondhand market in the second period.

4.2 The Model with Crime

We now allow for crime to occur in the model. We use a stealing function that could be considered as a reduced form of a crime model. Thus, we now assume that in the second period, goods can be stolen and sold in a secondhand illegal market. So consumers in the second period now have the choice of buying from the producer, buying in the legal secondhand market among consumers, or buying in the secondhand illegal market (stolen goods market). As will become clear below, consumers can distinguish perfectly between used and stolen goods.

More formally, at the beginning of the second period the consumer who owns a good can be victim of a theft or robbery.[8] We assume that there is a cost of stealing a mass of size m goods, given that there is a mass of size h goods that could be stolen. This cost is $s(m;h) = \frac{m^2 k}{h}$ (for example, assume $k \geq v_2 Q^N$).[9] When a good is stolen, the owner loses the good and thus can neither consume nor sell it.

In this setting the utility function of the consumer also changes to incorporate buying from the illegal market. On the demand side, there are still two types of consumers. There is a mass of size n_1 of type 1 consumers, and a mass of size n_2 of type 2 consumers. The gross utility of a representative consumer of type i is $v_i Q$, with $v_2 > v_1 > 0$ when the good is bought legally and $\alpha v_i Q$ when it is bought

[8] We use the terms "theft" and "robbery" interchangeably in this paper to refer to the subtraction of goods from the legal owner. Use of violence is not included in this model, thus there is no difference between theft and robbery here. The externality of crime exists both for thefts and robberies.

[9] To simplify matters, we take this stealing cost function as a reduced form of the crime model à la Becker (1968).

illegally (i.e., if it was stolen) with $0 \leq \alpha < 1$. The three assumptions on the parameters made in the previous section still hold, but equation (1) now means that in equilibrium, if there is a market for used goods, the price is positive and there could be incentives for stealing the good.

The sequence of the game is as follows. In the first period, production takes place and firms market their output. In the second period, goods bought in the first period can be stolen, production takes place, and firms, owners of used goods, and thieves sell their goods.

Note that if a technology were available to make the durability of goods contingent upon the good being stolen, it would be optimal to set durability equal to 0 for the stolen goods. This would reduce the value of the stolen goods to zero and thus, there would be no crime. When such a technology to discriminate durability in the second period is possible, it is similar to setting $\alpha = 0$. Therefore, the model goes back to Waldman (1996a), a world without crime, as stated earlier.[10]

However, such a technology is not available for all goods. Thus, we examine the case where it is not possible to make durability contingent upon being stolen. We implicitly assume that if it is possible to provide a differential durability for goods when they are stolen but the technology cannot make the good completely worthless, this would reduce consumers' valuation of stolen goods but not to zero. We can think that this reduces the valuation to $\alpha < \alpha'$, where $\alpha' v_i Q$ would be the valuation of a stolen good for a consumer of type *i* if there is no reduction in durability when the good is stolen. We analyze the equilibrium of the perfect competition case under two different technologies of stealing goods. In the first one, whenever there is heterogeneity of the goods (i.e., goods with different D), the ones with a higher durability and thus a higher resale value are stolen, which we call selective stealing. In the second one, the thieves are not able to distinguish the quality of goods, or equivalently the stolen good arrives randomly, so any good has the same probability of being stolen. We call this random stealing.

We proceed now to solve the model backwards. Note that when there is a market in the second period for used and stolen goods the price of old used goods with durability $D(P_2^{OD})$ and the price of stolen goods with durability $D(P_2^{SD})$ are characterized by the same functions, regardless of the market structure and stealing technology considered.

Lemma 1. *Whenever there is a market in the second period for used and stolen goods:*

1. *The price of the used goods with durability D is:*

[10] As noted above, a technology close to that described is increasingly being used in new smartphones. For example, there are applications that allow for blocking a lost or stolen iPhones and make these mobile phones worthless in the illegal market.

$$P_2^{OD} = v_1 Q^0(D_1)$$

2. *The price of the stolen goods with durability D is:*

$$P_2^{SD} = \alpha v_1 Q^0(D_1)$$

The intuition of lemma 1 is that, since the quantity of consumers who demand both used and stolen goods is higher than the supply, the equilibrium price is the buyers' reservation price.

4.3 Selective Stealing

Note that under this technology the costs of stealing are independent of the durability of the good, and the price of output depends positively on the durability of the good. Therefore, when there is selective stealing, the goods chosen to be stolen are those with greater durability. Given $F(D)$, the distribution of durability D, when there is selective stealing the thieves' problem is deciding the cutoff point of durability. The gains of stealing are the price of the goods stolen minus the cost of stealing. Thus, the thieves have to solve the following problem:

$$Max_D \int_D^\infty \alpha v_1 Q^0(s) f(s) ds - \frac{(\int_D^\infty f(s) dsh)^2 k}{h}.$$

The first order condition is:

$$-\alpha v_1 Q^0(D^*) f(D^{*SS}) + \frac{2(1 - F(D^{*SS})) f(D^{*SS}) h^2 k}{h} = 0,$$

or similarly:

$$-\alpha v_1 Q^0(D^{*SS}) + 2\big(1 - F(D^{*SS})\big) hk = 0. \tag{4}$$

Therefore, we obtain the following result:

Lemma 2. *Goods of a durability greater than D^{*SS} are stolen, while those of lesser durability are not stolen. Whenever there is a positive mass of goods of durability D^{*SS}, some of the goods of a durability equal to D^{*SS} are stolen and some are not. D^{*SS} is defined implicitly by equation (4).*

Given lemma 2, it is possible to infer that nobody will produce, under perfect competition, a good with durability greater than D^{*SS}, since this good will be stolen with probability one. This is because type 2 consumers are indifferent to buying such a good or buying a good with durability $D = 0$, which is never stolen. Thus, the goods would have the same price, and a good with durability $D = 0$ is cheaper to produce.[11] In addition, if a good of durability D is stolen with positive probability (but smaller than one), it is better to sell a good with durability $D-\varepsilon,$ which is never stolen, since the utility of the consumer is higher and it is cheaper to produce. Thus, we have the following result:

Proposition 1. *Under perfect competition and selective stealing, only goods with durability* $D=0$ *are produced. There is no crime and the price is* $P_{1PC}^{N}=c(0)$ *and* $P_{2PC}^{N}=c(0)$. *Type 1 consumers never consume this good.*

This means that under selective stealing and perfect competition, there are no durable goods. This is because it is not possible to sustain any positive durability for a used good.

4.4 Random Stealing

Given the distribution of durability D $(F(D))$, when there is random stealing the goods that are stolen are randomly "chosen." Thus, the thieves' decision involves the quantity of goods to be stolen and not the cutoff point of durability, as in the previous case. This quantity comes from maximizing the gains of stealing, which are the quantity stolen times the average price, minus the stealing cost. Thus, in order to determine the optimal quantity, thieves have to maximize the following problem:

$$Max_m\left(m\int_0^\infty \alpha v_1 Q^0(s)f(s)ds-\frac{(m)^2k}{h}\right).$$

The solution to this problem is:

$$m^*=\frac{h\int_0^\infty \alpha v_1 Q^0(s)f(s)ds}{2k}.$$

Note that given the assumption about *k*, this value is always smaller than *h*, which represents the mass that can be stolen. When we study the case of perfect competition, we know that the probability that a good is stolen is independent of the durability of the good. Each firm will maximize its profit, taking the probability as given, and produce the quality that maximizes consumers' utility. Competition will drive profits to zero. The durability level that would be produced comes from maximizing the utility of the consumer, taking the probability of stealing as given, minus the production cost. Thus, firms solve the following problem:

$$Max_{D_1=}v_2Q^N+\delta\left\{\left[\left(1-\frac{\int_0^\infty \alpha v_1Q^0(s)f(s)ds}{2k}\right)v_1Q^0(D_1)\right]\right\}-c(D_1), \qquad (5)$$

[11] If there is a cost of being robbed beyond the loss of the good, as happens, the consumer will strictly prefer to buy a good with durability $D\ =0$.

where $\frac{\int_0^\infty \alpha v_1 Q^0(s) f(s) ds}{2k}$ is the probability that a good is stolen and $f(s)$ the distribution of durability.

Proposition 2. *Under perfect competition and random stealing, the durability D_{PC} is given, implicitly, by the following equation:*

$$\delta\left[\left(1-\frac{\alpha v_1 Q^0(D_{PC})}{2k}\right) v_1 Q^{0\prime}(D_{PC})\right]-c'(D_{PC})=0. \qquad (6)$$

Proof: All the firms will set durability that maximizes equation (5). Then, all of them will produce the good with the same durability, that is, D_{PC}, so:

$$\frac{\int_0^\infty \alpha v_1 Q^0(s) f(s) ds}{2k}=\frac{\alpha v_1 Q^0(D_{PC})}{2k}.$$

Note that equation (6) always has a unique solution because:

1. $\delta\left[\left(1-\frac{\alpha v_1 Q^0(0)}{2k}\right) v_1 Q^{0\prime}(0)\right]-c'(0)>0,$
2. $\delta\left[\left(1-\frac{\alpha v_1 Q^0(D\quad)}{2k}\right) v_1 Q^{0\prime\prime}(D)-\frac{\alpha v_1 Q^{0\prime}(D)}{2k}\right]-c''(D)<0 \ \ \forall D$, and
3. $\delta\left[\left(1-\frac{\alpha v_1 Q^0(\infty)}{2k}\right) v_1 Q^{0\prime}(\infty)\right]-c'(\infty)<0.$ ☑

Thus, under random stealing and perfect competition, there are durable goods and there is also crime.

Having determined the levels of durability in perfect competition under both selective stealing (Proposition 1) and random stealing (Proposition 2), we turn now to the social optimum and the monopoly market structure. In both cases we will restrict our analysis to having homogeneity regarding durability. We did not prove that this has to be the case, but neither did we find a case in which this does not hold. We use this assumption for simplicity and also so that we can make comparisons with the perfect competition case. Given this, it is clear that both the social optimum and the monopoly case do not change with the stealing technology. This is because the problem now restricts to set the optimal durability. Note that the goods that can be stolen are random, since they all have the same durability.

4.5 Social Optimum

The social optimum comes from solving the following problem:

$$Max_{D_1} W\left(n_2 \left\{ v_2 Q^N - c(D_1) + \delta \left\{ \begin{array}{c} \left[\left(1-\frac{\alpha v_1 Q^0(D_1)}{2k}\right) v_1 Q^0(D_1)\right] + \; v_2 Q^N - c(0) + \\ \phi \left[\frac{\alpha v_1 Q^0(D_1)}{2k} \alpha v_1 Q^0(D_1) - \left(\frac{n_2 \alpha v_1 Q^0(D_1)}{2k}\right)^2 \frac{k}{n_2^2}\right], \\ \frac{v_1 Q^0(D_1)}{2k} n_2 \end{array} \right\} \right\} \right).$$

Note that the first argument is the total market surplus, and the second term is the externality that derives from crime. The first argument is composed of the consumer surplus plus the producer surplus:

$$n_2 \left\{ v_2 Q^N - c(D_1) + \delta \left\{ \left[\left(1-\frac{\alpha v_1 Q^0(D_1)}{2k}\right) v_1 Q^0(D_1)\right] + v_2 Q^N - c(0) \right\} \right\},$$

where $n_2\{v_2 Q^N - c(D_1)\}$ is the welfare produced by the consumption of the type 2 consumer in the first period minus the cost of producing these goods. $\delta\left\{\left[\left(1-\frac{\alpha v_1 Q^0(D_1)}{2k}\right) v_1 Q^0(D_1)\right]\right\}$ is the welfare of consuming in the second period those goods that are not stolen and are produced in the first period. $\delta\{v_2 Q^N - c(0)\}$ is the welfare produced by the production of goods in the second period that are consumed by type 2 consumers. We also incorporate into the welfare function the welfare obtained by the thieves, $n_2 \delta \phi \left[\frac{\alpha v_1 Q^0(D_1)}{2k} \alpha v_1 Q^0(D_1) - \left(\frac{n_2 v_1 Q^0(D_1)}{2k} 2 \frac{k}{n_2^2}\right)\right]$, where $0 \leq \phi < 1$ is the weight that we give to this welfare. We discount it since it is appropriated by thieves.

Having set the problem, the optimal durability is that which makes:

$$W_1 n_2 \left\{ \delta \left[1 - \frac{\alpha v_1 Q^0(D_{SO})}{k} + \; \phi \left(\frac{\alpha^2 v_1 Q^0(D_{SO})}{k} - \left(\frac{\alpha^2 v_1 Q^0(D_{SO})}{2k} \right) \right) \right] v_1 Q^{0\prime}(D_{SO}) - c'(D_{SO}) \right\}$$
$$+ W_2 \frac{v_1 Q^{0\prime}(D_{SO})}{2k} n_2 = 0.$$

In order to compare the social optimum with the case of perfect competition and monopoly, we will assume away the externality $W_2 = 0$ and we will not consider the welfare appropriated by the thieves, i.e., $\phi = 0$. Note that the first assumption increases the social optimum because the cost caused by the externality is not considered, while the second assumption reduces the social optimum because it reduces the benefits.

Under these assumptions the social optimum satisfies the following equation:

$$\delta\left[1-\frac{\alpha v_1 Q^0(D_{SO})}{k}\right] v_1 Q^{0\prime}(D_{SO}) - c'(D_{SO}) = 0. \tag{7}$$

Note that equation (7) always has a unique solution because:

1. $\delta\left[\left(1-\frac{\alpha v_1 Q^0(0)}{k}\right) v_1 Q^{0\prime}(0)\right] - c'(0) > 0,$
2. $\delta\left[\left(1-\frac{\alpha v_1 Q^0(D\ \ )}{k}\right) v_1 Q^{0\prime\prime}(D) - \frac{\alpha v_1 Q^{0\prime}(D)}{k}\right] - c''(D) < 0\ \ \forall D$, and
3. $\delta\left[\left(1-\frac{\alpha v_1 Q^0(\infty)}{k}\right) v_1 Q^{0\prime}(\infty)\right] - c'(\infty) < 0.$

4.6 Monopoly

We now switch to the case of a monopoly market structure. We will first analyze the case where $2v_1 > v_2$. The monopolist will solve the following problem:[12]

$$Max_{D_1} = v_2 Q^N - c(D_1) + \delta\left\{\left(1-\frac{\alpha v_1 Q^0(D_1)}{2k}\right)\left(v_1 Q^0(D_1) + v_2[Q^N - Q^0(D_1)] + v_1 Q^0(D_1)\right) - c(0)\right\}.$$

The price that the monopolist would charge in the first period for a good with durability D_1 is $v_2 Q^N + \delta\left(1-\frac{\alpha v_1 Q^0(D_1)}{2k}\right) v_1 Q^0(D_1)$, which is the valuation that the type 2 consumer obtains from consuming the good in the first period $v_2 Q^N$ plus the price that he or she gets from selling the good to a type 1 consumer in the second period, $v_1 Q^0(D_1)$, which is discounted by the discount rate δ and the probability of being stolen $\frac{\alpha v_1 Q^0(D_1)}{2k}$. This amount minus the production cost $c(D_1)$ is the monopoly's profit in the first period. In the second period, the monopolist would charge a price of $v_2[Q^N - Q^0(D_1)] + v_1 Q^0(D_1)$ and have a cost of $c(0)$, and these benefits would be discounted by the discount factor.

Therefore, the monopolist would decide on a durability that is defined implicitly by the following equation:

$$\delta\left[1-\frac{\alpha v_1 Q^0(D_M)}{k} - \frac{v_2}{v_1} + 1\right] v_1 Q^{0\prime}(D_M) - c'(D_M) = 0. \tag{8}$$

[12] The Appendix shows that the monopoly will never choose to sell new goods in the second period only to type 2 consumers who have been victims of a robbery.

Note that for the case in which we have assumed $2v_1 > v_2$, equation (8) has a unique solution that comes from the following facts:

1. $\delta\left[1 - \frac{\alpha v_1 Q^0(0)}{k} - \frac{v2}{v1} + 1\right] v_1 Q^{0'}(0) - c'(0) > 0$,
2. $\delta\left[1 - \frac{\alpha v_1 Q^0(\infty)}{k} - \frac{v2}{v1} + 1\right] v_1 Q^{0'}(\infty) - c'(\infty) < 0$,
3. Whenever $\delta\left[1 - \frac{\alpha v_1 Q^0(D_1)}{k} - \frac{v2}{v1} + 1\right] v_1 Q^{0'}(D_1) - c'(D_1) = 0$, $\delta\left[1 - \frac{\alpha v_1 Q^0(D_1)}{k} - \frac{v2}{v1} + 1\right] v_1 Q^{0''}(D_1) - \frac{\alpha v_1^2 Q^{0'}(D_1)}{k} - c''(D_1) < 0$.

In the case where $2v_1 \leq v_2$, the right-hand side of equation (8) is smaller than zero, thus the solution is to set $D = 0$. Therefore, in this case, the monopoly would not be able to provide any durability. Note that this result is similar to that of Waldman (1996a).

4.7 Comparison

Note that Waldman's model can be thought of as a particular case of a more general model, such as the one we introduce in this paper, in which there is no crime and, hence, the social welfare function does not take into account either crime externalities or the transfers associated with crime. Thus, comparing our results with those of Waldman is the same as comparing a world with crime (our model) to a world without crime (Waldman's model).

The monopolist in a world with crime produces less durability than it does if there would not be the possibility of crime occurring (Waldman's model). The level of durability under perfect competition and the social optimum are also smaller than under Waldman's analysis. A big difference is that while under Waldman's model perfect competition and the social optimum are the same, in our model with crime they are not. There is over-production of durability under random stealing and under-production under selective stealing.

From our model it can be easily shown that when there is random stealing if $2v_1 > v_2$, $0 < D_M < D_{SO} < D_{PC}$, and if $2v_1 \leq v_2$, $0 = D_M < D_{SO} < D_{PC}$, which means that there are durable goods under the random stealing and perfect competition scenario, crime can occur. When there is random stealing, the monopolist sets a durability level that is lower than the social optimum, i.e., it under-produces durability, but perfect competition sets a durability level that is higher than the social optimum, i.e., it over-produces durability.

However, when there is selective stealing if $2v_1 > v_2$, $0 < D_M < D_{SO}$, there are durable goods under monopoly so crime can occur, while there is no crime when there is perfect competition. If $2v_1 \leq v_2$, $then\ 0 = D_M < D_{SO}$. In both scenarios, the durability level that prevails with a monopoly is lower than the socially optimal level. Remember that from proposition 1 we know that when there is selective stealing, durability under perfect competition is equal to zero.

If we take into account the externality ($W_2 < 0$), this reduces the socially optimal level of durability. As a consequence, the socially optimal level of durability gets closer to the monopoly level in the case of random stealing as well as the case of selective stealing. Note that if the externality is big enough, even the monopoly will over-produce durability under the random stealing technology (when $2v_1 > v_2$). If we consider the thieves' profits as part of welfare ($0<\phi$), this increases the socially optimal level of durability. Thus in turn increases the difference between the social optimal and the monopoly level of durability.

5 Implications and Evidence

Our model shows that the level of durability affects crime and that crime affects the optimal level of durability. In particular, we show that perfect competition does not lead to the optimal level of durability because there is an externality that emerges when we take into account that greater durability increases the net return of crimes against property, specifically robberies and thefts, which in turn increases crime and reduces social welfare. In view of that, a straightforward implication is that the level of durability of goods can be an effective instrument to reduce crime. In this section we briefly discuss the empirical evidence on this topic, which is mainly focused on security technology applied to vehicles and smartphones.

Ayres and Levitt (1998) were among the first to study the effect of the Lojack car retrieval system on crime. Lojack is a small device hidden in random places inside a vehicle that allows it to be tracked when a theft occurs.[13] Lojack can also disrupt the operation of "chop-shops" where stolen vehicles are disassembled for resale of parts. With this device, police following the radio signal are led directly to the chop-shop. This makes auto theft riskier and less profitable, leading to a probable reduction in the number of such crimes. It is estimated that this security device has an extremely high recovery rate in the United States, with 90 percent of vehicles being recovered within 24 hours of the report (Lojack 2013). All this reduces the durability of the stolen cars. Ayres and Levitt (1998) find strong support for

[13] Lojack uses radio technology to recover stolen vehicles. The system consists of two main components: a radio-frequency transceiver in the protected vehicles and a grid of locality-specific tracking antennas.

the argument that Lojack reduces auto theft, without any evidence of increases in other crime categories. To guarantee that this negative association reflects a causal relationship, the authors use instrumental variables. According to their estimates, one auto theft is eliminated annually for every three Lojacks installed in high-crime cities.

In a similar vein, Gonzalez-Navarro (2013) documents changes in automobile theft risk that were generated by the plausibly exogenous introduction of Lojack into a number of new Ford car models in some Mexican states. The author uses variation over time in theft risk, at the state and car model level, to identify the impact of Lojack in deterring auto theft for Lojack-equipped vehicles. Among other findings, he shows that Lojack was an extremely effective theft deterrence device, generating an estimated reduction in theft risk of 48 percent for vehicles participating in the Ford Lojack program. This device appears to be one of the most cost-effective crime reduction approaches documented in the literature, providing a greater return than increased police, prisons, jobs programs, or early educational interventions (Donohue and Siegelman 1996).

Van Ours and Vollaard (2016) evaluate the crime-reducing effect of mandatory application in new passenger cars in the European Union of a simple, low-cost device to prevent car theft: the electronic engine immobilizer. This security device blocks a vehicle's electrical circuits when the key is not in the ignition; therefore, to steal a car, thieves have to steal the key first. Alternatively, thieves could haul the car away on a flatbed truck. Clearly, that modus operandi involves more time, effort, and risk than simply hot-wiring a car. If the car is eventually stolen, the device reduces its level of durability, since the vehicle only works with the appropriate key. The authors exploit the regulation as a source of exogenous variation in the use of the device by year of manufacture of cars and find that the security device reduced the probability of car theft by an estimated 50 percent on average in the Netherlands during 1995–2008.[14]

The evidence related to cellular phones is less robust but points to promising results. The Home Office and the Behavioral Insights Team (2016) argue that the fall in levels of cellular phone theft – especially during 2013–2015, when the rate fell from 1.7 to 1.2 percent in the United Kingdom – can be related to improvements in cellular phone security introduced by manufacturers during this period. Although the authors do not use a rigorous methodology, they show that the cellular phone industry helps make cellular phones less attractive to thieves by making them harder to use and reducing their value after they have been stolen. These security measures include requiring access control such as a

[14] See Morgan et al. (2016) and Potter and Thomas (2001) for further evidence on electronic engine immobilizers.

unique code (a PIN, password, or some form of pattern) or biometric authentication to be entered onto the handset to unlock it; tracing the location of the handset using a remote service; wiping data from the handset; or locking the handset remotely. All these measures reduce the durability of the stolen cellular phone. However, these features only protect the cellular phone if they are switched on.

In a similar vein, the Technological Advisory Council (2014) shows evidence that industry's effort to develop mechanisms to help smartphone owners reduce the impact of smartphone theft is affecting criminal activity. For instance, in the first five months of 2014, just after Apple introduced Activation Lock, robberies and grand larcenies of Apple products from persons in New York City dropped by 19 percent and 29 percent, respectively, compared to the same time period in the previous year (The Office of the New York State Attorney General 2015). Similarly, in the six months after Apple made Activation Lock available, iPhone robberies declined 38 percent and 24 percent in San Francisco and London, respectively (The Office of the New York State Attorney General 2015).

6 Conclusions

This paper has provided the first theoretical examination of the relationship between crime and the durability of goods, an issue almost nonexistent in the current literature. Therefore, a novel contribution of the paper is that when we incorporate the cost of crime (based on the rational model of crime economics) into the standard framework of durable goods, the traditional results of durable goods are considerably modified.

On the one hand, we show that the level of durability affects crime. The economic analysis of crime supposes that individuals act rationally, i.e., they measure the costs and benefits of their actions. Therefore, a reduction in the durability of stolen goods reduces the pecuniary benefits of crime, as it is intuitive to think that the lower the durability of a good, the lower its selling price will be. Consequently, the level of durability affects the benefits associated with illegal activities, measured in monetary terms. Thus, a decrease in the durability of goods will reduce the benefits of illegal activities relative to legal activities, and as the costs will remain the same, the net expected return from crime will decline and criminals will find it less profitable to devote themselves to illegal activities. In an extreme case, when durability is zero, there are no durable goods, and criminals do not benefit from stealing goods, so this type of crime will not occur.

On the other hand, we show that crime affects the level of durability. In order to study this, we developed a theoretical model that adds the cost of crime to the standard framework of durable goods. Crime affects the consumer and producer surplus and thus the behavior of consumers, firms, the market equilibrium, and, in turn, the social optimum, which is even more distorted given the externalities produced by crime.

The model shows that including the effect of durability on crime considerably modifies the standard results of the literature, even in cases where monopoly and perfect competition market structures produce the same level of durability. We find that perfect competition does not provide optimal durability, even if we do not consider the externalities caused by crime. More specifically, perfect competition sets a durability level that is higher than the social optimum (under random stealing), i.e., it over-produces durability and produces no durable goods when there is selective stealing, while the monopolist sets a durability level that is lower than the social optimum, i.e., it under-produces durability. If we also consider the externality that emerges when firms take into account that higher durability increases crime, and that crime reduces welfare, the socially optimal level of durability declines. As a consequence, the socially optimal level of durability gets closer to the one that prevails under monopoly. We find that if this externality is big enough, even the monopoly will over-produce durability.

The effects of traditional policy recommendations to reduce crime, such as an increase in the celerity or severity of sanctions, are probably in the long run reduced through an increase in the durability of the goods.

Finally, our model implies that less durability is an effective instrument to reduce crime. Therefore, interventions that attempt to reduce the level of durability of goods make stealing less profitable, which leads to a reduction in the number of thefts of such goods. In particular, making the durability of a good contingent upon that good being stolen is likely to increase welfare. This paper discussed empirical evidence that shows that industry's effort to develop mechanisms to increase the security of goods, and at the same time reduce their durability, seems to be promising for reducing crimes against property.

Appendix

This appendix shows that a monopoly market structure will never choose to sell new goods in the second period only to type 2 consumers who have been victims of a robbery. In other words, type 2 consumers who have been victims of a robbery are willing to pay more than consumers who were not victims of a robbery. Thus, the monopolist could decide to sell in the second period only to those who have been victims of a robbery. However, we show that this would never happen in equilibrium.

The proof consists in two steps. First, we show that if there is such an incentive in the second period, it is better for the monopolist to anticipate this in the first period. Second, we show that for the monopolist, it is always better to produce in the first period a good of durability $D = 0$ than to sell in the second period only to consumers who have been victims of a robbery. Thus, all the cases are covered by comparing $D = 0$ with the case of selling new goods to every type 2 consumer in the second period, whether or not the type 2 consumer has been the victim of a robbery.

In the second period, type 2 consumers who have been victims of a robbery are willing to pay $v_2 Q^N$ for a new good. Since there are $\frac{\alpha v_1 Q^0(D_M)}{k} n_2$ type 2 consumers who have been victims of a robbery, the total profit from selling just to these consumers is:

$$\frac{\alpha v_1 Q^0(D_M)}{k} n_2 \big(v_2 Q^N - c(0)\big).$$

If the monopolist wants to sell to all type 2 consumers, the price should be $v_2[Q^N - Q^0(D_M)] + v_1 Q^0(D_M)$, which is the price that consumers who have not been victims of a robbery are willing to pay. In this case the monopoly profit is:

$$n_2[v_2[Q^N - Q^0(D_M)] + v_1 Q^0(D_M) - c(0)].$$

The monopolist prefers to sell in the second period to consumers who have been victims of a robbery whenever:

$$\frac{\alpha v_1 Q^0(D_M)}{k} n_2 \left(v_2 Q^N - c(0)\right) > n_2[v_2[Q^N - Q^0(D_M)] + v_1 Q^0(D_M) - c(0)].$$

If this is the case, “anticipating” this gives to the monopolist a profit of:

$$v_2 Q^N - c(D_M) + \delta\left\{\left(1 - \frac{\alpha v_1 Q^0(D_M)}{2k}\right) v_2 Q^0(D_M) + \frac{\alpha v_1 Q^0(D_M)}{k}\left(v_2 Q^N - c(0)\right)\right\},$$

which is clearly greater than:

$$\mathrm{v}_2\mathrm{Q}^{\mathrm{N}} - \mathrm{c}(D_1) + \delta\left\{\left(1 - \frac{\alpha \mathrm{v}_1 \mathrm{Q}^0(\mathrm{D}_1)}{2k}\right)\left(\mathrm{v}_1\mathrm{Q}^0(\mathrm{D}_1) + \mathrm{v}_2[\mathrm{Q}^{\mathrm{N}} - \mathrm{Q}^0(\mathrm{D}_1)] + \mathrm{v}_1\mathrm{Q}^0(\mathrm{D}_1)\right) - c(0)\right\}.$$

Given that in the second period the monopolist will sell only to consumers who were victims of a robbery in the first period, it is better to sell the goods at $v_2 Q^N + \delta\left\{\left(1 - \frac{\alpha \mathrm{v}_1 \mathrm{Q}^0(\mathrm{D}_\mathrm{M})}{2\mathrm{k}}\right) v_2 Q^0(D_M)\right\}$, which is greater than $v_2 Q^N + \delta\left\{\left(1 - \frac{\alpha \mathrm{v}_1 \mathrm{Q}^0(\mathrm{D}_\mathrm{M})}{2\mathrm{k}}\right) v_1 Q^0(D_M)\right\}$.

We prove that there are no parameter values such that the monopolist wants to sell the goods in the first period, anticipating that in the second period the monopolist will only sell to consumers who have been victims of a robbery. This is because this strategy is dominated by selling a good of quality $D = 0$.

A monopolist when it sells goods anticipating that in the second period it will only sell to consumers who have been victims of a robbery gets profits equal to:

$$Max_{D_1} = \mathrm{v}_2\mathrm{Q}^{\mathrm{N}} - \mathrm{c}(D_1) + \delta\left\{\left(1 - \frac{\alpha \mathrm{v}_1 \mathrm{Q}^0(\mathrm{D}_1)}{2k}\right)\mathrm{v}_2\mathrm{Q}^0(\mathrm{D}_1) + \frac{\alpha \mathrm{v}_1 \mathrm{Q}^0(\mathrm{D}_1)}{k}\left(\mathrm{v}_2\mathrm{Q}^N - c(0)\right)\right\}.$$

If this expression is maximized at D_1^* the value is:

$$\mathrm{v}_2\mathrm{Q}^{\mathrm{N}} - \mathrm{c}(D_1^*) + \delta\left\{\left(1 - \frac{\alpha \mathrm{v}_1 \mathrm{Q}^0(D_1^*)}{2k}\right)\mathrm{v}_2\mathrm{Q}^0(D_1^*) + \frac{\alpha \mathrm{v}_1 \mathrm{Q}^0(D_1^*)}{k}\left(\mathrm{v}_2\mathrm{Q}^N - c(0)\right)\right\}, \tag{9}$$

while producing a good of quality $D = 0$ gives to the monopoly profits equal to:

$$\mathrm{v}_2\mathrm{Q}^{\mathrm{N}} - \mathrm{c}(0) + \delta\left\{\left(\mathrm{v}_2\mathrm{Q}^{\mathrm{N}} - \mathrm{c}(0)\right)\right\}. \tag{10}$$

Subtracting equation (9) from equation (10) we obtain:

$$\mathrm{c}(D_1^*) - \mathrm{c}(0) + \delta\left\{\left(1 - \frac{\alpha \mathrm{v}_1 \mathrm{Q}^0(D_1^*)}{2k}\right)[\mathrm{v}_2\mathrm{Q}^N - C(0) - \mathrm{v}_2\mathrm{Q}^0(D_1^*)]\right\},$$

which is greater than 0 given assumption 3.

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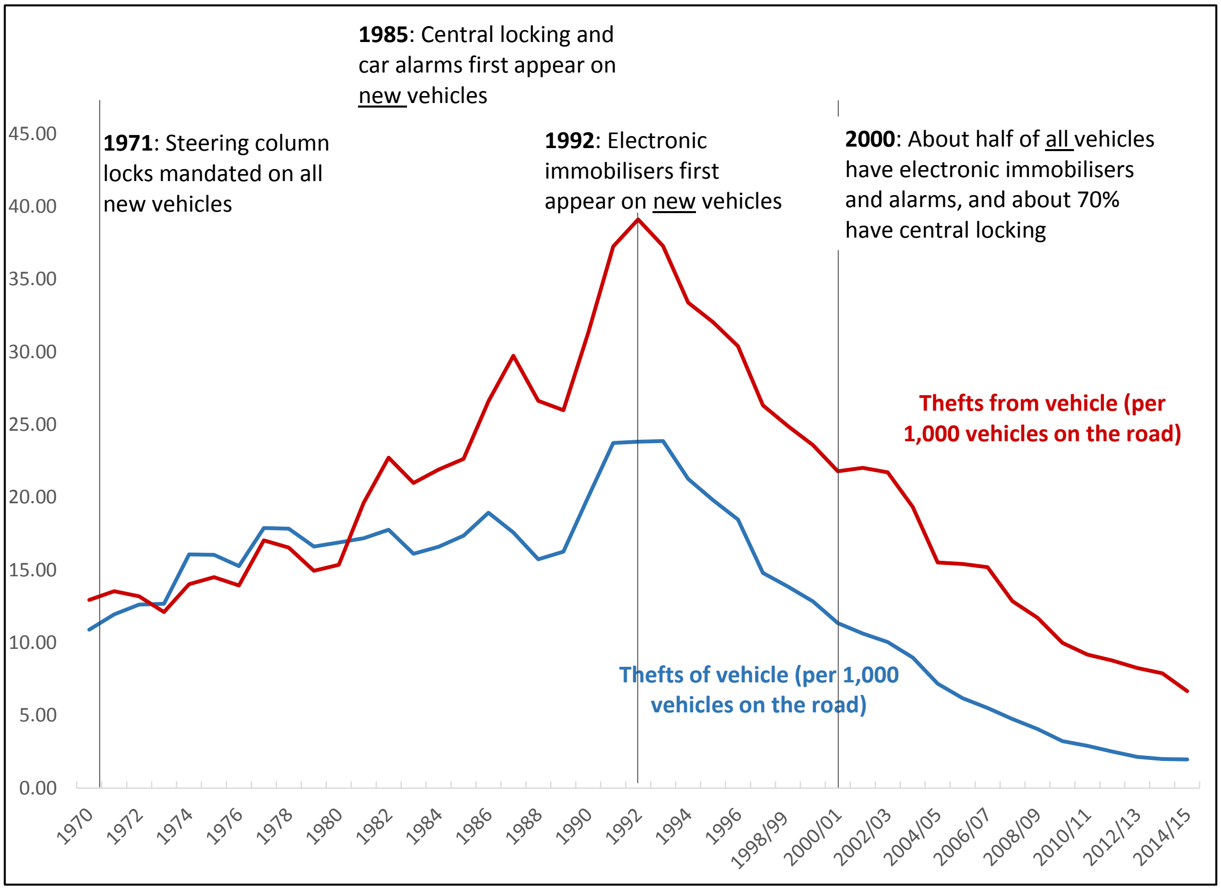
Figure 1. Thefts of and from Vehicles Recorded by the Police in England and Wales

(Per 1,000 vehicles on the road)



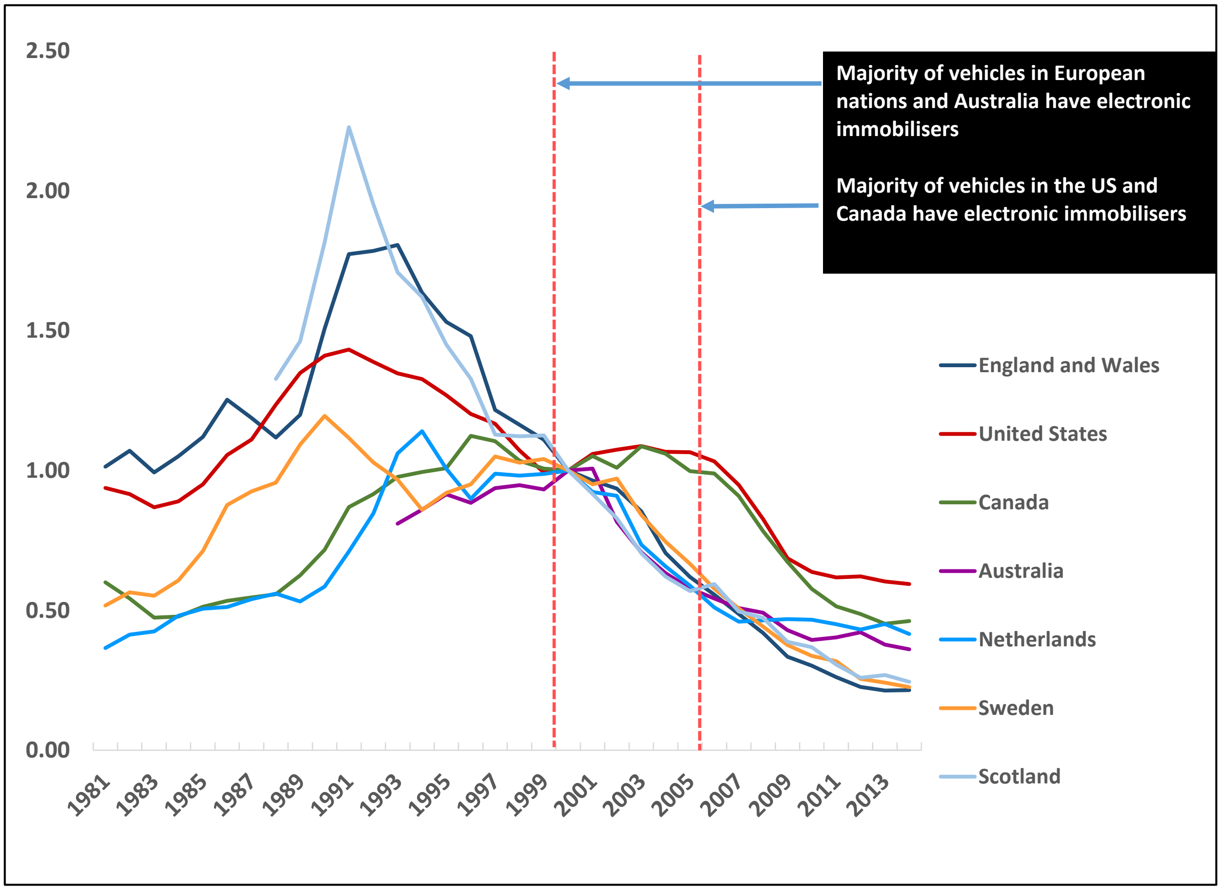
Source: Authors' calculations using data from national police departments based on Morgan et al. (2016).

Table 1. Cross-National Implementation of Electronic Immobilizers

	England and Wales	Scotland	Netherlands	Sweden	Australia	US	Canada
Dates of electronic immobiliser spread							
Estimated first appearance of electronic immobiliser in mass market vehicles	1991-92	1991-92	1991-92	1991-92	1989-1990	1988-1992	1988-1992
Year in which electronic immobiliser mandated on new	1998	1998	1998	1998	2001	None	2007
Estimated year in which 50% of all vehicles have electronic immobiliser (threshold)	2000	2000	2000	2000	2000	2006	2006
Changes in number of police-recorded vehicle thefts							
Five years pre-threshold	-33%	-31%	-5%	9%	9%	-2%	-6%
Five years post-threshold	-41%	-35%	-44%	-39%	-46%	-34%	-46%

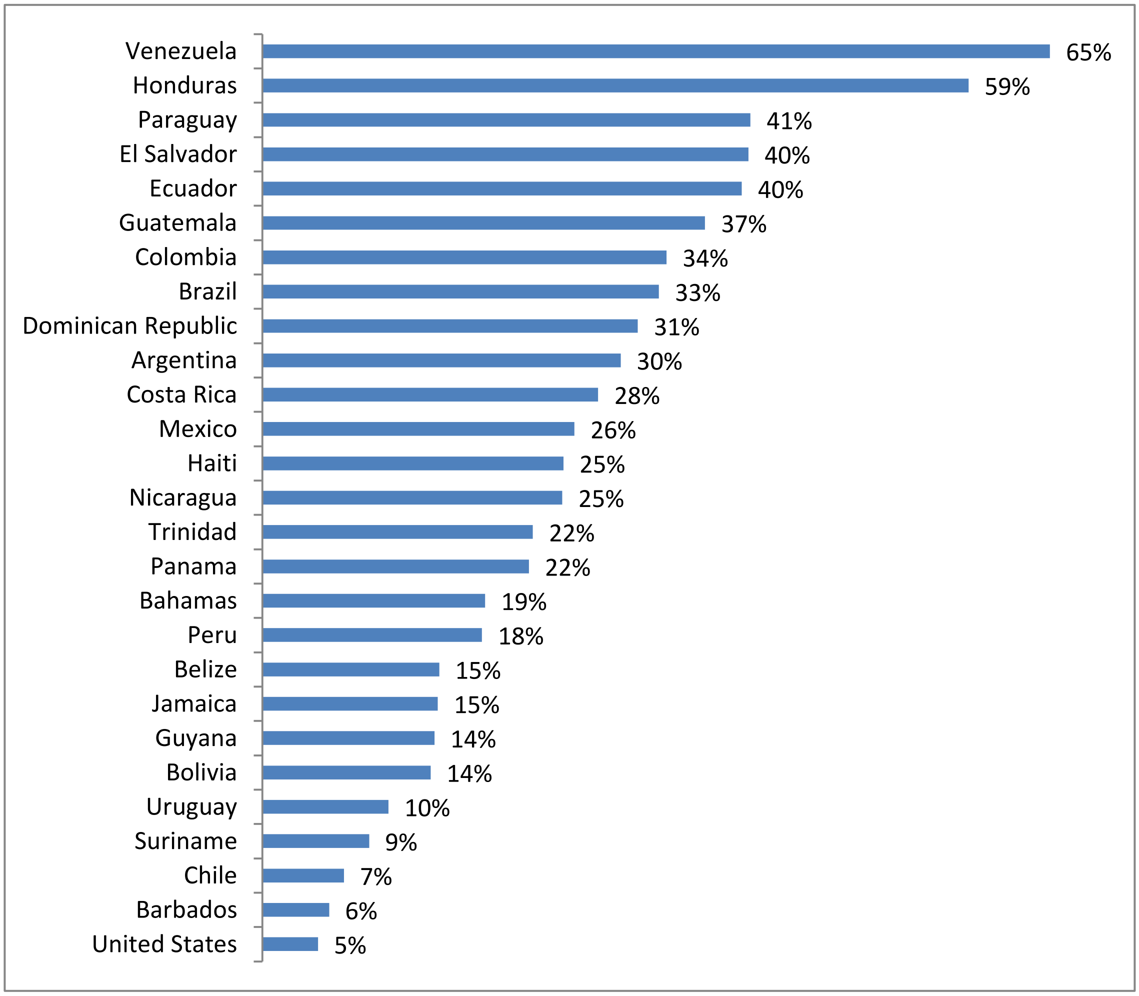
Source: Morgan et al. (2016).

Figure 2. Recorded Vehicle Thefts in Five Nations, Indexed to 2000 (2000 = 1)



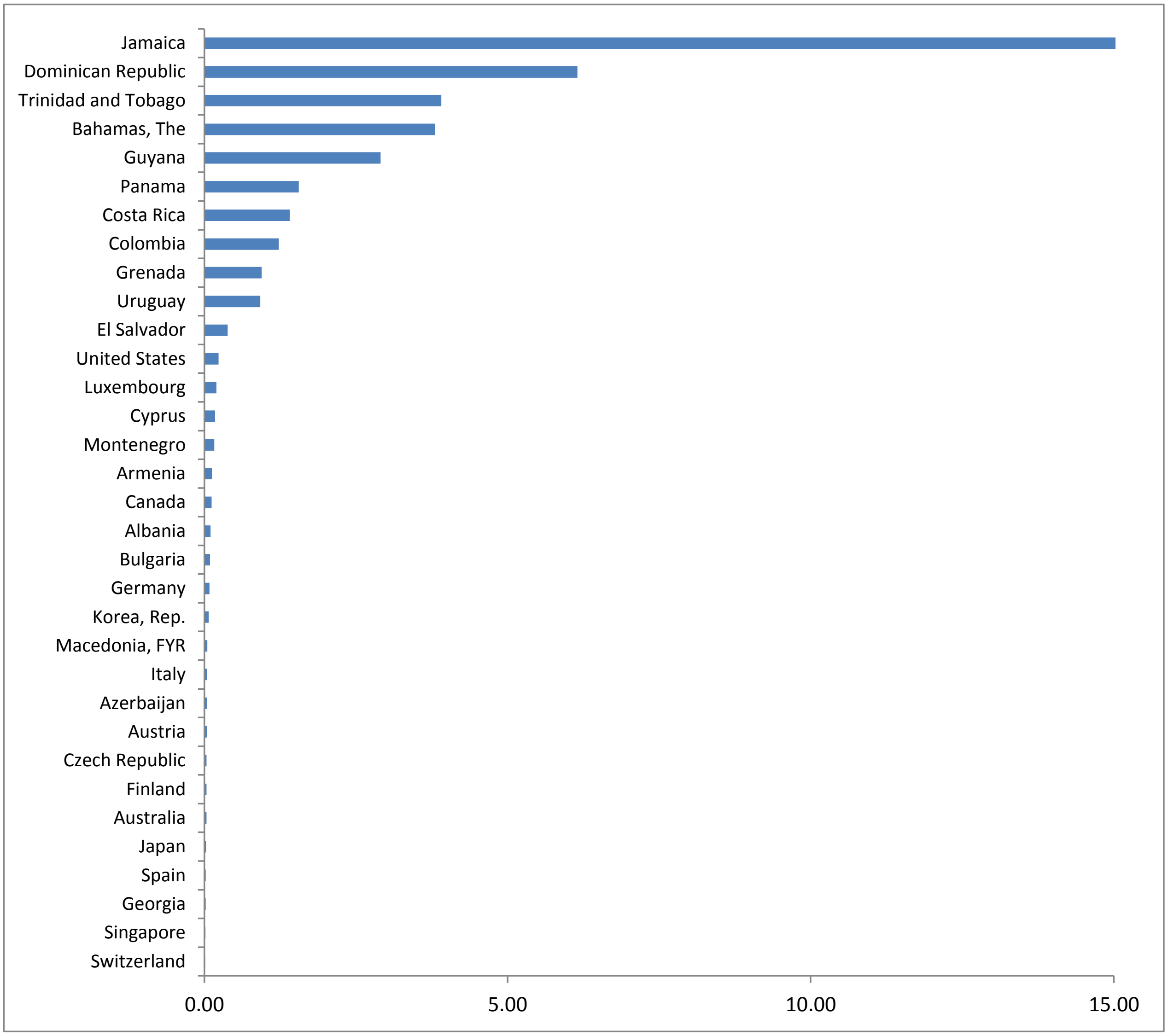
Source: Authors calculations using data from national police departments based on Morgan et al. (2016).

Figure 3. Percentage of Crime Victims Who Were Victims of an Armed Robbery



Source: 2014 Latin American Public Opinion Project.

Figure 4. Homicide Victims Killed during Commission of a Robbery (per 100,000 population)



Source: United Nations Office on Drugs and Crime, 2013.