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Theft in Price-Volatile Markets: On the Relationship between Copper Price and Copper Theft

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Abstract

Recently, against a backdrop of general reductions in acquisitive crime, increases have been observed in the frequency of metal theft offences. This is generally attributed to increases in metal prices in response to global demand exceeding supply. The main objective of this article was to examine the relationship between the price of copper and levels of copper theft, focusing specifically on copper cable theft from the British railway network. Results indicated a significant positive correlation between lagged increases in copper price and copper cable theft. No support was found for rival hypotheses concerning U.K. unemployment levels and the general popularity of theft as crime type. An ancillary aim was to explore offender modus

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operandi over time, which is discussed in terms of its implications for preventing copper cable theft. The authors finish with a discussion of theft of other commodities in price-volatile markets.

Keywords
copper theft, metal theft, price-volatile markets

Introduction

Against a backdrop of general reductions in acquisitive crime (see Tseloni et al. 2010), metal theft has emerged as one of the fastest growing crime types in the United Kingdom (Bennett 2008; Haynes 2008), with steep increases also being observed in the United States (Kooi 2010; Whiteacre at al. 2008). The recurrent explanation is that metals have become attractive targets for theft due to the soaring price of scrap metal. This is generally attributed to global demand for metals exceeding supply. Consequently, it is proposed that price increases have stimulated the creation of illegal markets that provide opportunities to sell stolen metals at financially rewarding prices. Copper in particular has experienced marked price growth and dramatic increases of copper theft have been reported in the United States (Kooi 2010) and internationally (Bennett 2008). Copper is one of the most industrially used metals and opportunities for copper theft are therefore likely higher than that of other metals (International Copper Study Group [ICSG] 2007). At the time of writing, no published research has examined the relationship between metal price and metal theft. This absence likely reflects a lack of (accessible) data on the theft of particular items such as copper-bearing products. Herein, data were made available for the specific problem of copper cable theft from the British railway network. Therefore, in this article, we concentrate on copper cable theft as the first empirical test of the metal price-theft hypothesis—that increases in the price of copper are associated with increases in the levels of copper cable theft.[1]

Railway networks are characterized as copper-intensive systems. The ECI estimates that for high-speed train lines around 10 tons of copper are required per kilometer of track (European Copper Institute [ECI] 2008). Copper cabling is typically used for the electrification of trains and for the transmission of signaling information and can be found in various forms: laid along the trackside—both in operation and occasionally awaiting installation, buried underground, as overhead cabling above railroads, at junction boxes, or reserved in large spools in storage sheds. Copper cable

theft has recently been described as a "strategic priority" by the British Transport Police (BTP). The BTP are responsible for policing the railway system of England, Wales and Scotland as well as the London underground network. This network comprises over 16,000 km of track (connecting all major cities and most towns), around 3,000 railway stations and depots, and services an estimated 6 million rail passengers a day. High-volume rail offences include graffiti, theft of passenger property, theft of (motor) cycles at railway stations, and violent crime. In the case of copper cable theft, its implications range from the substantial monetary costs incurred through theft-induced cable replacement to the increased risk of train derailment or collisions through track disruption and/or faulty signaling (Bennett 2008).

The goals of this article are to (1) provide a theoretical foundation for metal theft by describing the volatile price-market for metals, outline reasons for recent price surges, and propose a link between legal and illegal metal markets; (2) contrast the price–theft relationship for typically stolen consumer items with commodities such as copper, which we term *theft in price-volatile markets*; (3) present findings on the price–theft relationship for copper cabling and compare the results with those from two alternative hypotheses; (4) discuss the implications of the findings for preventing copper cable theft, with specific reference to offender modus operandi; and (5) suggest further areas of research.

Theoretical Foundation: Copper in Demand

Felson (2006) describes crime as existing within a dynamic ecosystem—continually influenced by and influencing wider legal and illegal activities. Felson's thesis provides a useful theoretical framework to examine the link between local crime events and wider contributory factors, and document how changes within the crime ecosystem—some seemingly unrelated to crime—can dramatically alter crime opportunities. In support, Killias (2006) discusses the emergence of various crime types that occurred due to "breaches," "sudden new opportunities for offending that opened as a result of changes in the technological or social environment" (p. 11). By the same measure, Walsh (1994) describes the disappearance of numerous crime types—such as eavesdropping and highway robbery—rendered obsolete due to economic, social, scientific, and/or legal changes. The influence on crime exerted by such change can of course be varied: initiating different types of crime, producing different targets for crime, or providing different tools and techniques for crime commission. Theoretically, understanding such changes can shed light on the factors underpinning crime causation.

Practically, understanding and explaining such change is also important because changes in crime often necessitate adaptations in crime prevention (Ekblom 1999).

Our hypothesis is that increases in copper cable theft are positively influenced by increases in copper price, and consequently an increase in the desirability of copper as a target for theft. This hypothesis is derived from economic approaches to crime (Becker 1968; Farrell et al. 2000), which maintain that offenders tend to operate in a rational manner (Cornish and Clarke 1986), such that increases in perceived criminal gain—monetary or psychic—tend to be associated with increases in the frequency of criminal events. In relation to Felson's ecosystem approach, the proposed (ultimate) driver of increases in metal theft is the steep rise in the price of metals. Briefly, the price of commodities such as copper are determined through the trading of prospective consumers and producers on commodity markets. The copper market in particular is one of the most heavily traded and price-volatile (Bracker and Smith 1999; Bresnahan and Suslow 1985). For nonferrous[2] metal markets such as copper, Brunetti and Gilbert (1995) cite two principal sources of price volatility: (1) short-term price shifts due to new market information and/or hedging strategies and (2) long-term price adjustments due to a shortage in metal availability.

Regarding Brunetti and Gilbert's second point, price volatility in nonferrous metal markets is thus intimately linked to the "laws" of supply and demand. Global consumption of refined (non-scrap) copper was estimated to be around 17 million tons in 2007, up 41 percent from that of 1996 and ranking third in metal consumption behind iron and aluminium (Jolly 2009). Its demand stems from its pivotal role in various critical systems: its ductility, malleability, recyclability, resistance to corrosion, and excellent conductive properties make copper the metal of choice for numerous applications ranging from communication technologies to construction (ICSG 2007). This demand is maintained because there are few financially viable substitutes to replace copper in its many applications. In recent years, however, such demand has experienced a sustained surge primarily attributable to the accelerated economic expansion and industrialization of China and India (Sud 2008). Ideally, increases in copper consumption initiate a commensurate supply response to maintain supply–demand equilibrium. However, despite attempts by major copper producers to overturn supply shortages through increasing production, due to heightened production costs and dwindling copper inventories (see Gordon, Bertram, and Graedel 2006) supply has gradually been unable to satisfy increased demand. Amplified by intense speculation

activity for future copper supplies, the observed result is the natural consequence that would be predicted in such economic conditions, namely, steep increases in the price of copper.

A consequence of supply constraints for primary sources of copper—that which is extracted from the earth's surface—is an increased emphasis on using recycled copper, known as "secondary copper production." Unlike many other materials, the chemical and physical properties of copper tend not to be negatively impacted by the recycling process (ICSG 2007). Consequently, recycled copper constitutes an important (and in sustainability terms vital) component of world copper reserves. In the United States, for example, scrap copper provided around 30 percent of all copper consumed in 2007 (Jolly 2009). Such recycled sources typically enter the copper market through scrap metal merchants: copper-bearing scrap metal being purchased, smelted, refined for application, and then fed back into the copper system for use in its many applications[3] (ICSG 2007). The price of scrap copper is also found to closely match changes in the price of primary copper (Labys, Rees, and Elliott 1971). Davies (2007) claims that during sharp price increases, the value of scrap copper can reach as much as 90 percent of the price achieved for "virgin" copper.

We argue that the opportunities for offenders to dispose of stolen metals are central to the observed increases in metal thefts. Compared to common targets for theft such as cash or cell phones, copper (cabling) offers little in terms of inherent enjoyment or utility. Our proposal is that copper cabling is likely stolen with the intention of selling it on for financial gain through scrap metal markets. These markets may comprise both illegal and legal operations. Indeed, as is often the case, an illegal market may operate in the shadow of a legal market. For example, legal markets such as commonplace pawn shops may contribute to the problem by knowingly or unknowingly purchasing stolen copper or deliberately not inquiring into its origins or source. Our hypothesis is that price surges due to the described supply–demand imbalance, increases the opportunities to sell copper at financially rewarding prices and thus represents an outlet for offenders to sell *stolen* copper—an outlet that would not have been financially viable nor available when copper prices were lower. As scrap copper price increases, stolen copper thus becomes an increasingly attractive target for theft.

Theft and Price: Theft in Price-Volatile Markets

The preceding section introduced the theory underlying the price–theft relationship for commodities such as copper and the proposed impact

of price-volatile markets on offending. It is noteworthy that this price–theft relationship is different from theoretical models that explain the general patterns observed for theft of consumer items in relation to price. Felson and Clarke (1998) describe how theft levels for mass-produced consumer goods tend to display a somewhat proportional theft-price decline over time, influenced by four successive stages in a product's life course, namely: *innovation, growth, mass-market*, and *saturation*. Within the initial innovation stage, a product's price is usually prohibitively high and therefore levels of ownership (and opportunities for theft) are low. As prices drop, due to competition with newer rival items, levels of ownership increase. Theft is proposed to rise as the supply of available opportunities increases, indicative of legitimate market desirability. By extension, theft is proposed to fall at the juncture where market saturation implies that most people own a certain item and consequently demand to purchase that item illegally (at a financially appealing price) diminishes. Of course, the life-cycle hypothesis speaks to theft patterns at the *aggregate* level; theft levels for certain items in certain areas will be determined by more than retail price alone, such as the number of outlets at which stolen items can be sold. That said, Wellsmith and Burrell's (2005) analysis of theft of electrical goods in West Midlands, England, provides empirical support for the life-cycle hypothesis. They show that the frequency with which electrical goods were stolen closely followed the pattern described above, that is, theft patterns corresponded to the general (legitimate) purchasing trends. In further support, Reilly and Witt (2008) demonstrate that reductions in domestic burglary experienced in England and Wales over the last two decades can be attributed, in part, to falling retail prices for audiovisual goods.

The price (and attractiveness to offenders) of consumer items therefore tend to reflect *desirability* as a product of fashion, popularity, and/or competition with rival items. In contrast, the price of commodities such as copper is chiefly determined by speculation activity and global supply, demand, and availability. Rather than display a natural desirability-decay over an items' life-course like most consumer products, the market for copper is characterized as being volatile, with desirability (and hence theft levels) predominantly price-determined which we argue in turn facilitates greater disposability options. To distinguish this form of price-theft relationship with that for consumer items, we introduce the concept of *theft in price-volatile markets*; to refer to items whose increased attraction to offenders, as manifested in increased theft levels, is attributable to positive changes in market prices alone. It is useful to consider theft in price-volatile markets more generally and instances where price rises have generated

increases in theft. As an illustration of theft in other price-volatile markets, we provide an example of a recently documented case of rises in gasoline theft.

Gasoline is an important and much-used natural resource. Like copper, the market for oil is price volatile (Ferderer 1996). In recent years, the price of oil—and gasoline—has experienced unprecedented surges from US$25 per barrel in September 2003 to US$145 per barrel in July 2008 (Pagnamenta 2008). Causal explanations include increased automobile dependency and supply constraints due to conflict in the oil-rich Middle East (Roberts 2008). From a criminological perspective, Moffat and Fitzgerald (2006) demonstrate how escalating prices positively correlated with increases in gasoline thefts—defined as the unlawful taking of gasoline from gas stations.[4] Analyzing gasoline theft data in New South Wales, Australia, they found a 33 percent increase from 9,163 incidents in 2004/2005 to 12,201 in 2005/2006. Such increases could not be explained as being a by-product of a wider crime surge, as other crimes in the study area fell over the same time period. Despite gasoline not being a traditional crime target, Moffat and Fitzgerald argue that increases in gasoline theft are the product of significant market changes that have increased the price and thus illegal demand for gasoline. They go further to show that a linear regression equation using gasoline price as the independent variable explained 90 percent of the variation in gasoline theft per unit of time.[5]

Research Questions

We noted at the outset that to the authors' knowledge no empirical research is available which has analyzed the relationship between the price of metals and metal theft. After outlining the theory underlying this relationship, we now aim to use time-series data and appropriate statistical techniques to examine the price–theft relation for the specific problem of copper cable theft from the British Railway Network.

Thus:

Hypothesis 1: Variation in the volume of copper cable theft will be positively correlated with the price of copper.

Two rival (alternative) hypotheses regarding changes in the level of copper cable theft are also tested. The first (Hypothesis 2) is that the variation in copper cable theft over time would simply reflect broad changes in the levels of theft offences; copper theft increased because theft offences in

general increased. If changes in the variation in copper cable theft simply reflect changes in theft patterns more generally, we should therefore expect a positive relationship. If this is not found to be the case, this would suggest that any results are specific to copper cable theft rather than being attributable to more general changes in this type of crime over time.

The second alternative hypothesis (Hypothesis 3) relates to unemployment. Historically, the relationship between unemployment and crime has attracted considerable research attention (see Tang and Lean 2007). Witt, Clarke, and Fielding (1999) describe how unemployment can hold both a positive and a negative relationship with levels of crime. Briefly, high unemployment levels often reduce the availability for individuals to participate in legal activities to gain income. This is proposed to increase the perceived benefits of engaging in criminal activity; a positive relationship between levels of crime and levels of unemployment is therefore predicted. In contrast, unemployment levels can also be viewed as an indicator of general economic conditions. In this vein, high unemployment may be associated with increased guardianship due to more people being at home and/or a reduction in the opportunities for (acquisitive) crime because of a reduction in the circulation of goods; increased unemployment might therefore be associated with a drop in crime. Given this potential to influence crime either way, the unemployment–crime hypothesis tested here is two-tailed; that monthly variation in copper cable theft would be related to variation in levels of unemployment. If there is little or no relation between these variables, this would suggest that something other than simple changes in unemployment rates is responsible for changes in the volume of copper cable theft.

Data

Copper Cable Theft Data

Time-series data, aggregated to the monthly level, were provided by the BTP for the period January 2004 to October 2007. Data comprised all recorded incidents of copper cable theft from the railway system of England, Wales and Scotland. Data included time and date information, theft location (e.g., line side cable/ cable storage depots), and a free text field containing a description of the crime event. An initial analysis found that some non–copper-related crimes (122 incidents) such as vandalism and criminal damage were present in the data set and these were therefore removed prior to analysis. The final sample comprised 2,870 copper cable thefts. One important limitation of the data, which is discussed later but is noted at this point, is

that while the number of discrete cases of cable theft is known, the quantity of copper stolen per event is unknown. Hence, in the analysis that follows each incident is treated with the same level of importance, even though the seriousness of the event, that is, the quantity of copper stolen, may vary quite substantially.

Copper Price Data

Copper price data reflect the daily prices traded on the London Metal Exchange (LME), widely accepted as the global reference price for nonferrous metals (Watkins and McAleer 2004).[6] For analytic purposes, price data are aggregated to the monthly level. Prices are in US dollars per metric ton in keeping with the standard denomination used by the LME.

Other Data

Two additional sources of monthly time-series data were used as covariates in the analyses that follow. The first is *other theft* recorded crime data, aggregated across all 43 law enforcement agencies of England and Wales for the period January 2004 to October 2007.[7] This constituted 4,657,252 offences. *Other theft* offences comprise theft of personal property outside the home, such as thefts of unattended property in the workplace and theft of property while at licensed premises, cafés, restaurants, or open spaces. Many *other theft* offences describe the theft of mass-produced consumer items like those captured in Felson and Clarke's (1998) lifecycle model discussed earlier. Its inclusion here therefore offers insight as to whether the levels of theft of such items differ from theft of copper cabling.

The second data set concerns levels of unemployment in the United Kingdom for individuals of working age for the period January 2004 to October 2007.[8] These are compiled by the Office of National Statistics as part of the annual Labour Force Survey that asks a random sample of around 60,000 private U.K. households about their recent economic activity and employment status.

Results

Copper Price–Theft Relationship

Table 1 shows the number of recorded incidents of copper cable theft from the British railway network and the mean LME copper price for 2004 to 2007. Noteworthy is the 649 percent increase from 2005 to

Table 1. Number of Copper Cable Thefts ($n = 2{,}870$) and the Mean LME Price of Copper, 2004 to 2007

Year	Copper Cable Thefts	Change from Previous Year (%)	Mean Copper Price (US$ per ton)	Change from Previous Year (%)
2004	78	–	2,864	–
2005	144	+66 (+84.6%)	3,678	+ 813 (+28.4%)
2006	1,078	+934 (+648.6%)	6,719	+ 3,042 (+82.7%)
2007[a]	1,570	+492 (+45.6%)	7,190	+ 471 (+7.0%)

Note: a. 2007 only contains 10 months data.

2006 in recorded cable thefts. This increase occurs in the same time period in which copper prices rose considerably, almost double the price per ton for the previous year. Despite the results for 2007 comprising just 10 months of data, the number of recorded thefts exceeds the total for the previous three years.

Annual trends can fail to capture the described volatility of copper prices and the potential within-year theft variations. A more detailed picture is provided in Figure 1, which shows the monthly price of copper plotted against the monthly count of copper cable theft. Figure 1 suggests a strong correspondence in the trajectories of the two variables. Noteworthy is the short-term sensitivity of theft levels in relation to shifts in price. For example, there is a noticeable decline in both price and theft levels in late 2006 followed by increases in both variables commencing mid-2007. That selective dips in copper price are closely mirrored by falls in the volume of copper cable theft, suggests that the similar trajectories observed are not merely the product of a methodological artifact representative of some wider upward trend.

To examine the price–theft relationship using inferential statistics, a simple analysis would be to compute the regression coefficient β_1 for the equation:

$$\text{Theft}_t = \beta_0 + \beta_{1.}\text{Price}_t + \varepsilon_t,$$

Where,

Theft_t is the number of thefts in month t
Price_t is the price of copper in month t
ε_t is the residual error

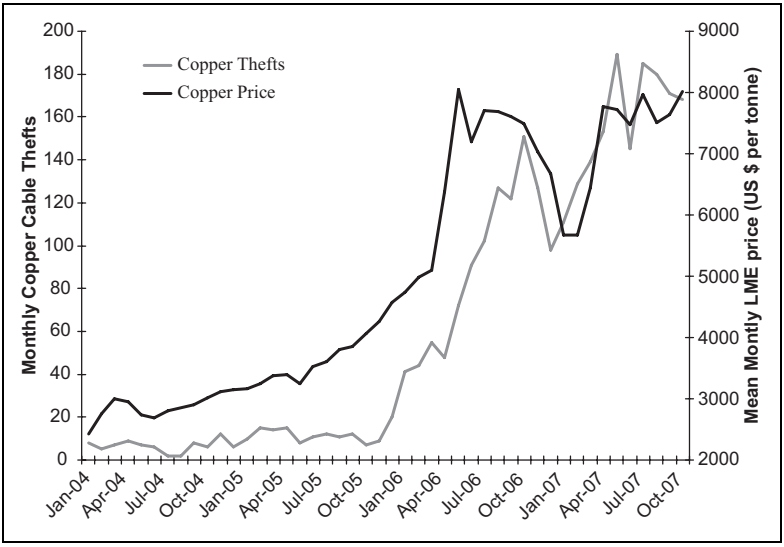


Figure 1. Monthly copper cable thefts ($n = 2{,}870$) and the Mean LME Price of Copper (US$ per metric ton), January 2004 to October 2007.

However, it seems reasonable to assume that the influence (on offending) of changes in the price of copper would have a lagged effect, that is, changes in copper price do not initiate an immediate impact on numbers of thefts: offenders (both thieves and receivers) need to register and adapt to changing rewards from the offense. For this reason, the equation was modified using the conservative estimate of a one month lag:

$$\text{Theft}_t = \beta_0 + \beta_{1.}\text{Price}_{t-1} + \varepsilon_t.$$

As already discussed, things other than the price of copper may influence the frequency with which it is stolen. For this reason, other independent variables were included in the regression analysis, these are the monthly volume of *other theft* offences—the null hypothesis being that the two types of theft are generated by the same factors and so there should be a positive relationship in changes in the two variables—and the monthly level of unemployment in the United Kingdom. The results of an Ordinary Least Squares (OLS) regression, shown in Table 2, computed using the logged values for all variables confirmed that there was a statistically significant positive relationship between the theft and price of copper, and a negative relation with levels of other theft.

Table 2. OLS Regression Analysis of the Copper Price–Theft Relationship (Robust Standard Errors)

	β	*SE* (Robust)	*p* Value
Log price of Copper	3.03	0.43	.0001
Log other theft	−2.97	0.96	.005
Log levels of unemployment	0.31	2.61	nonsig

However, a problem with using OLS regression for the analysis of time-series data is the assumption that residual values (the difference between the observed and modeled values) will be randomly distributed. Where data are structured, as is the case with time ordered data, and variables that might influence the time series are omitted from the analysis (because they are unavailable), it is possible that there will be a pattern or serial dependency in the residual errors (referred to as autocorrelation). Where this is the case, the standard errors of the beta coefficients estimated using OLS regression will be biased. To determine if there was serial dependency in the residual errors, a Durbin-Watson statistic (see Barreto and Howland 2006)—a measure of association for the time-lagged residual errors—was computed. If there were no evidence of serial dependency in the residual errors, the correlation between the lagged residual values would be low and the value of the Durbin-Watson statistic should be approximately 2. When the values of the latter are less than 2, autocorrelation is indicated. Here, the correlation between the lagged residual scores of .34 and the value of the Durbin-Watson statistic of 1.32 suggested the presence of serial dependency. Unlike most statistical tests, the statistical significance of the Durbin-Watson statistic cannot be determined with reference to statistical tables, as no such tables exist. Instead, a Monte Carlo re-sampling test (Barreto and Howland 2006) was used. This confirmed that the value observed was statistically significant ($p < .005$).

Given the serial dependency in the data, it was necessary to account for this in the analysis to ensure that the estimates of the standard errors were unbiased. Two approaches are possible (for further discussion, see Spelman 2008). First, one can difference the data by subtracting sequential values of the relevant variables from each other prior to (OLS) analysis. This removes the trend in the data meaning that the analysis is focused on short-term changes. The alternative is to use a *generalized* least squares regression that adjusts for evident serial correlation. We performed both types of analysis, which produced the same conclusions, but for parsimony only report the latter.

Table 3. Auto-Regression Analysis of the Copper Price–Theft Relationship (Robust Standard Errors)

	β	*SE* (Robust)	*p* Value
Log price of Copper	2.76	0.55	.0001
Log other theft	−1.84	1.53	nonsig
Log levels of unemployment	1.99	3.65	nonsig
AR1 term	0.40	0.23	.08

Table 3 shows the results for a generalized least squares regression (AR1) model. The results indicate that the relationship between copper price and copper cable theft was reliable. The relationship between levels of unemployment and levels of other theft with copper cable theft were not. Visual inspection of the residuals indicated a constant mean and variance centered around zero, suggesting that the model had corrected for the autocorrelation present in the data.[9] Thus, having estimated the effects of unmeasured variables, an unbiased estimate of the standard error for the copper price–theft relation was computed and this confirmed that the association was robust and highly significant.

In summary, the results are consistent with Hypothesis 1: a significant positive correlation was found between higher prices of copper and increases in copper cable theft while controlling for serial dependency in the data. In regard to the rival hypotheses, there was little or no relationship between the volume of copper cable theft and other thefts and with monthly variation in levels of U.K. unemployment.

Discussion

Support was found for the metal price–theft hypothesis: higher prices of copper were positively correlated with increases in copper cable theft. No support was found for the rival hypotheses concerning changes in U.K. unemployment levels or theft of personal property from outside the home (*other thefts*). Though causation cannot be inferred from regression analysis, the findings are consistent with the proposal that copper has become an attractive target for theft due to the higher prices of copper and that such price shifts may have increased the (disposability) opportunities for offenders to achieve financially rewarding sale prices. In relation to theft patterns more generally, this finding supports research that shows increased opportunities to sell stolen items are often associated with increased theft levels

(Langworthy and LeBeau 1992; Nelson, Collins, and Gant 2002; Stevenson and Forsythe 1998).

The results of the time-series analysis also indicated, however, that other variables currently omitted (perhaps currently unknown) from the analytic model may explain a significant amount of the variance in observed theft levels. To advance the research agenda, it is worth considering what those variables might be. Possibilities include police activity, such as the number of arrests per month. A second possibility is some measure relating to the supply and demand for stolen copper at the *local* level. In regard to the latter, we stated at the outset that shifts in the price of scrap copper tend to match changes in the price of "virgin" copper. It is probable however that those markets or individuals who receive stolen copper will have a limited capacity in terms of the quantity they can process per unit of time. If so, short-term local saturation of illegal markets due to receivers' limited handling capacity would thus restrict their purchasing of further stolen copper, and therefore impact the local levels of copper theft.

Data Limitations

Before considering the implications of the above findings, two data limitations warrant discussion. The first is underreporting. A familiar problem with using recorded crime data is that bias may exist in terms of which crimes reach the police's attention. For example, according to the British Crime Survey, reporting of "other theft" offences to the police occurred in 25 percent of cases in 2008/2009 (Walker et al. 2009). It is possible the patterns for copper cable thefts that go unreported are quite different from those reported here. However, given the high financial costs of this type of crime and its negative impact on the functioning of the railway system, we expect that the majority of cable thefts are recorded by the BTP. Second, as mentioned earlier, the data available for analysis provide no indication of the quantity of copper cable stolen per incident. This is unfortunate as it is feasible (even likely) that there will have been substantial variation in the amount of copper cable stolen across events. In the absence of a volume metric, this could not be considered in the current analysis and consequently each cable theft event had to be treated as homogenous in terms of crime yield. If such data were available, replication of the above analyses would be welcomed using the quantity of copper stolen as the dependent variable. However, while this might provide a more sensitive indicator of the intensity of offender activity, we argue that the number of thefts remains a useful unit of analysis that is simple to interpret.

Policy Implications and Modus Operandi

The main aim of this article was to establish the empirical relationship between the price of copper and theft levels of copper cabling. Central to that relationship is the ability of offenders to sell stolen copper. From a policy perspective, the most effective prevention strategy may therefore center on efforts to disrupt illegal channels for stolen metals, namely, market reduction approaches (MRA; Sutton 2005). MRA aim to make the buying and selling of stolen goods more risky. Strategies include gathering and using intelligence to detect and investigate suspect businesses dealing with stolen goods; enforcing local legislation to ensure proper records are maintained about the provenance or sellers of secondhand goods; test selling to check compliance with legislation; and using interagency support to crack down on irregularities committed by suspect businesses (Sutton et al. 2001). Though concerns have been raised regarding the lack of knowledge on illegal markets in general (Freiberg 1997) and the difficulty in practically disrupting such operations (Clarke 2000), initiatives that have successfully interrupted this process are found to be an effective means of crime reduction (Sutton 2005). In relation to metal theft more generally, one possible market-related strategy would be to make stolen metals easier to identify. Knox (2007) states that detecting stolen metals is difficult because few bear sufficient distinguishing features to discriminate legitimate from stolen metals. Because of this target anonymity, marking metals (including copper cabling) in a manner tantamount to property marking schemes (see Laycock 1985) may serve to reduce theft by making it easier to identify stolen metals and consequently harder to dispose of.

MRA seek to prevent crime through focusing on the stages that typically follow an acquisitive crime, thereby initiating a knock-on effect to deter offenders. Equally important from a practical perspective is getting upstream of offenders and closing off crime opportunities. This is often aided by analysis of *how* a given crime type is committed—namely, the *modus operandi* (MO)—in order to understand the opportunity structure that influences crime levels (and signatures) in particular settings (Clarke 1997).

With the present data set, we had the opportunity to conduct a simple analysis on the MO of copper cable thieves. Consequently, where possible ($n = 2{,}678$) analysis of the free text field of the copper cable theft data were carried out with each event coded in terms of how the cable theft was committed. Four MOs emerged, in descending order these were: (1) theft of line side cable[10] ($n = 1{,}899$); (2) theft of cabling (likely in the forms of

copper drums) from depots or storage sheds ($n = 635$); (3) theft of line side cabling where it was reported that the cable had been laid over the railway tracks to be severed by a passing train and therefore more easily removable ($n = 111$); and (4) distraction thefts from depots or storage sheds, again likely stealing copper drums ($n = 33$).

Visual inspection of time-series data (see Appendix 1) clearly suggests that the proportion of incidents committed using each MO has changed considerably over time. Specifically, there was a marked reduction in the proportion of incidents recorded at storage depots, while for theft at line side locations the reverse was true. Though we are aware of the potential fallacies borne of drawing inferences about individual offender tendencies from aggregate-level data, a plausible explanation for the former is that increased awareness of the problem of copper cable theft—likely because of increases in the volume of cable theft incidents—encouraged greater security at storage locations making them relatively less attractive targets. Increased guardianship may have initiated offender adaptation and the targeting of line side locations which, due to the sheer size of the railway system (compared to isolated storage depots), are more difficult to protect. In terms of preventing line side cable theft, Bennett (2008) suggests that better coordination of when cabling is delivered and left track side and when it is fitted and/or secured offers a relatively simple intervention. Of course, in practice this may be easier said than done.

Implications of the Findings and Suggestions for Further Research

The research described here is just one case study within the larger topic of what we have termed theft in price-volatile markets. Like copper, various metal markets are price volatile. Moreover, copper goes missing from locations other than the British railway system. Further research that examines whether the price–theft relationship found here applies to other metals, and copper in other contexts merits attention. Two additional analyses would make this comparison of further empirical and theoretical importance. First, copper is among the most industrially used metal type and therefore one might expect the greater availability of copper to result in a greater volume of copper theft offences. Whether this is apparent in recorded crime statistics would shed light on the role of environmental abundance on the occurrence of different types of metal theft, and, inter alia, the disposability options for different metals.

The second relates to target-related criminological theory and concerns the variation in theft across different types of metals. For mass-produced

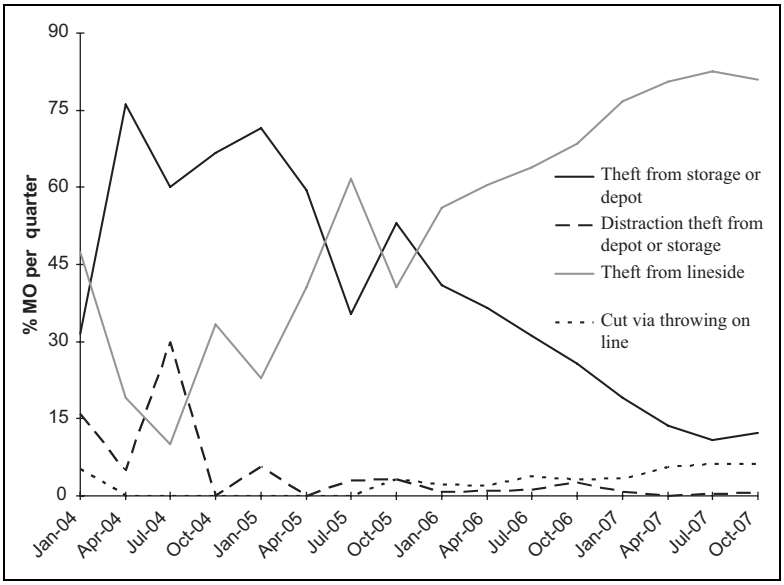
consumer items, Clarke's (1999) CRAVED model usefully details the attributes that influence a products' attraction to offenders. Clarke argues that an item's risk of theft is heightened when each of the CRAVED features are high—its *concealability, removability, availability, value, enjoyability*, and *disposability*. Commodities such as gasoline and copper possess few CRAVED characteristics, with theft levels principally (perhaps solely) determined by changes in *Value* and *Disposability*. It is worth considering what other attributes make for highly attractive commodities as targets for theft. For the crime of metal theft, for example, *identifiability* may influence the theft levels for different types of metal. Copper, differing from other forms of readily available metals is more easily *identifiable* due to its reddish coloration. This contrasts with other commonly used metals such as aluminium, lead, iron, and nickel, which are "silvery" metals. From a rational choice perspective, offenders should exhibit preferences for crime targets for which the risk of false positives are minimized (Ekblom and Sidebottom 2008). For example, despite general increases in most metal prices, the price of aluminium or platinum far exceeds that of (say) iron. However, the risks associated with wrongly differentiating one silvery metal from another are far greater than that of distinguishing copper from its silvery metal counterparts. Research exploring differences in the volume of incidents *between* metals may therefore aid in discovering what factors underpin offender decision-making. Such research may also cast light on the possibility of (situational) crime prevention interventions aimed at reducing theft through concealing the characteristics of certain metals and thus heightening offender uncertainty.

Finally, in this article, we introduced the concept of *theft in price-volatile markets*—to refer to items (particularly commodities) whose theft levels are influenced by price shifts as the product of supply and demand dynamics. We feel this concept applies to other natural resources such as minerals and raw agricultural commodities, which though traditionally are not common targets for crime, are nonetheless susceptible to theft increases if price changes are sufficient to stimulate resale markets. What constitutes *sufficient* in terms of engendering or expanding such markets is an empirical question. Of note, however, is that such targets for theft exist within a closed system: natural nonrenewable resources such as copper have a finite supply; mass-produced consumer products, due to the ability of manufacturers to usually find different ways of producing them, do not. In terms of theft then, for those natural resources on which humanity is so reliant, high demand will likely continue until suitable replacements are found, which, if possible, will take considerable time, expense, and effort. From a sustainability

(and criminological) perspective, this implies that current externalities that dictate this process might become increasingly important drivers of crime problems, particularly if the supply and demand balance for certain closed-system resources continues to teeter precariously. Compared to theft of mass-produced items, little criminological attention has been devoted to the theft of commodities in price-volatile markets, to strengthen the evidence base with which to inform policy, practice, and research, we think it deserves more.

Appendix 1

Quarterly percentages of copper cable theft MO (n = 2, 678), January 2004 to October 2007.



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Notes

1. Of course, copper cabling is not the only copper-based product reported stolen. Other forms of copper theft include theft of copper wiring from electrical substations and the theft of copper-based ecclesiastical objects from places of worship.
2. Nonferrous metals are those which contain little, if any, iron.
3. For the purposes of this article, this is a very simplified model of the scrap flow process. In reality, recycling copper requires detailed analyses assessing, among other things, the composition of the copper and whether it contains any oxidized pieces, with various refinement processes also taking place where necessary. For an overview, see Jolly (2009).
4. LaVigne (1994) and Tilley (2005) report similar incidents occurring in the United States and United Kingdom, respectively.
5. We thank an anonymous reviewer who suggested that this relationship is not inevitable and may differ by context. They noted that in certain areas in the United States, increases in the price of gasoline were not accompanied by increases in gasoline theft because merchants increased their vigilance in order to avoid larger monetary losses.
6. A review of research modeling the behavior of nonferrous metal prices published in leading economic and finance journals between 1980 and 2002 found the LME to be the most frequent source for price data (see Watkins and McAleer 2004).
7. England and Wales is divided into 43 independent law enforcement agencies. The geographic area each agency is responsible for corresponds fairly closely to county boundaries.
8. Working age in the United Kingdom is defined differently by sex, for men working age is 16-64 and for women 16-59.

9. The nonsignificant Durbin-Watson statistic of 1.87 ($p = .27$) confirmed this.
10. Examples of cabling found at the line side are earthing, straps, bonds, tapes, signaling, power, and overhead cables.

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