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# Prices, Policing and Policy: The Dynamics of Crime Booms and Busts

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**Abstract**
In many historical episodes, the extent of criminal activity has displayed booms and busts. One very clear example is the case of metal crime, where in the face of big increases in value driven by world commodity prices, the incidence of metal thefts in the UK (and elsewhere) rose very sharply in the 2000s. Early in the current decade, they fell sharply again. This paper studies the roles of prices, policing and policy in explaining these crime dynamics. The empirical analysis shows sizeable and significant metal crime-price elasticities, in line with the idea that changing economic returns do shape crime. However, the rapid upward and downward trends are not only due to price changes. Their temporal evolution is also explained by changes in policing and policy. On the former, a difference-in-differences approach is used to document an important role of policing as a consequence of an anti-metal crime operation introduced in 2012. On the latter, the introduction of the Scrap Metal Dealers Act 2013 is exploited to study the impact of policy on the economic activity of scrap metal dealers in England and Wales. Results from our difference-in-differences specification suggest that the tougher regulatory system introduced by the policy hindered the economic activity of pre-existing dealers, reflecting the reduced market size for potential metal criminals to sell what they have stolen.

Key words: metal crime, metal prices, commodity prices
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## 1. Introduction

In many historical episodes, the extent of criminal activity has displayed booms and busts. One recent, very clear, example of this has been the case of metal crime. Big increases in commodity prices, in particular in the prices of metals, occurred worldwide in the 2000s. This substantively increased metal values, and in line with the first order predictions of economic models where the economic returns to crime matter for people's decisions on whether or not to engage in crime (Becker, 1968, Ehrlich, 1973, 1996), there were spectacular increases in metal crimes in many places.[1] Empirical study has revealed sizeable metal crime-price elasticities in London in this wave of metal crime (Draca et al., 2015).

However, as with other (crime) booms, a bust has followed this, at least in the context of the UK. Metal theft has fallen very rapidly since near the start of the current decade. Generating an understanding of the reasons for such a marked boom and bust is an important research question in the economics of crime field. The UK setting offers a particularly good testing ground, first because of the scale of the crime changes, and second because these big magnitudes generated policing and policy responses that we are able to analyse as quasi-experiments that can potentially affect crime.

The metal crime dynamics embodied in the boom and bust are studied to more generally consider how crime rises due to economic incentives and falls due to policing, legislation and technology interventions. Examples of technology interventions that deterred crime in recent years include the 'electronic engine immobilisers' for cars, the 'Find your IPhone' application for smartphones and the 'chip and pin' technology for credit cards. The metal crime boom and

[1] Examples from recent years include the theft of more than 700 meters of iron from the Longfellow Bridge in Boston in 2008, the theft of power transmission wires that caused a four-hour power outage in Canada in 2011, and the theft of a 10-ton bridge in Czech Republic in 2012 (see, respectively: http://archive.boston.com/news/local/massachusetts/articles/2008/09/12/case_of_the_purloined_ironwork/; http://www.thepeterboroughexaminer.com/2011/09/01/power-outage-north-of-city-caused-by-wire-theft; and http://www.telegraph.co.uk/news/newstopics/howaboutthat/9235705/Czech-metal-thieves-dismantle-10-ton-bridge.html).

bust in England and Wales that is studied is one extreme example of how economic incentives, policing and policy can shape crime dynamics.

Over and above the boom and bust, metal theft is a particularly useful crime to study in economic research for several reasons.[2] First, from a purely economic perspective, one defining characteristic of metal crimes is their motivation for the prospective criminal. Whereas other property items are generally stolen for their extrinsic value, items involved in metal theft are stolen for their intrinsic value as raw material or commodities. Indeed, these thefts often have negative externalities much greater than the value of the metal stolen, such as the destruction of valuable statues, power interruptions, and the disruption of railway traffic. Additional indirect costs generated by metal theft, e.g., in the forms of extra-insurance, are also estimated to be in the order of several millions of British pounds every year.[3] Second, there is a liquid market, and public market prices for both new and scrap metal. Third, much of the price fluctuations seen in the 2000s was driven by the rapid economic development of China that has increased its demand for the metals, with copper being a striking case in point. Therefore, in all likelihood, the extraordinary increase in prices for some of those (scrap) metals provided an economic incentive to steal more metal from the railway network, other utilities and beyond.

The big rises and big falls in metal crimes seen in the UK form the focus of this paper. The objective, however, is to study a more general empirical connection between crime and prices, crime and police intervention, as well as crime and policy, and to evaluate their respective roles in explaining the boom and bust that is embodied in crime dynamics.

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[2] Metal crime refers to thefts of items for the value of their constituent metals, rather than the acquisition of the item. Apart from precious metals like gold and silver, the metals most commonly stolen are non-ferrous metals such as copper, lead, aluminium, brass, and bronze. However, even cast iron and steel have experienced higher rates of theft which coincided with increased scrap metal prices.

[3] As an example, the insurance cost for the Church of England hit approximately £10 million pounds in 2011 as a result of metal theft (http://www.telegraph.co.uk/news/uknews/crime/9126648/Metal-theft-costs-Church-of-England-10-million.html).

The empirical analysis starts by examining whether the changing prices of metals affect the level of crime over time. To do so, monthly-level British Transport Police (BTP) microdata on the count of metal crime incidents in England and Wales between January 2007 and December 2015 were utilised. A similar exercise was carried out using data in London from the Metropolitan Police Service (MPS), on monthly counts of metal theft in the region covered by the MPS. These data were combined with data on local scrap metal prices in the UK collected from www.letsrecycle.com and with data on international metal prices from the online platform "Index Mundi". Sizeable crime-price elasticities emerge from this analysis, reporting a strong sensitivity of metal crimes to scrap metal prices, including instrumental variable (IV) estimates where the exogenous variation in the world commodity prices is utilised.

The second and third parts of the empirical analysis are motivated by the fact that, by 2011, the scale of metal theft in the UK had reached unprecedented levels.[4] As a response, the BTP introduced an anti-metal crime policy - "Operation Tornado" – that was trialled across the police forces of Northumbria, Durham and Cleveland in early 2012. The UK government also responded by introducing the Scrap Metal Dealers Act of 2013, which was implemented in October 2013. Whether these policing and policy interventions affected the path of metal crime is therefore studied.

The second main part of the empirical analysis focuses on the impact of policing on metal theft. This analysis exploits exogenous variation in the intensity of policing across a panel of police force areas induced by a novel initiative of the BTP, called Operation Tornado (OT). Since OT was piloted in January 2012 in the North East, and then extended to all other regions in England and Wales by September 2012, a difference-in-differences specification is defined whereby late adopters of OT are used as controls for the early adopters. The high frequency of the data allows us to exploit a time window between January and September 2012 to identify

[4] Figure A1 in the Appendix shows that media coverage of metal theft on UK National Newspapers increased dramatically in 2011 and 2012 from previous years, and it returned to the pre-2011 levels from 2013 until today.

the impact of OT on metal theft incidence in England and Wales. For this analysis, microdata from the BTP were aggregated up at the police force area level with monthly frequency.[5]

The paper then moves on to study the third question, namely what was the impact of the Scrap Metal Dealers Act (SMDA) 2013 on the economic activity of Scrap Metal Dealers (SMDs) in England and Wales. The SMDA 2013 came into force in October 2013 and it superseded the SMDA of 1964. Amongst other things, the SMDA 2013 introduced new provisions for the issuance and revocation of a scrap metal licence, for the verification of scrap metal suppliers' identities and it introduced the offence of buying scrap metal for cash. By regulating the economic activity of SMDs, this policy intervention *de facto* increased the risk of being apprehended and punished for selling stolen metal to SMDs. This part of the paper utilises a panel of firm-level data from the Fame database and it exploits variation across firms in the intensity of exposure to the provisions of the SMDA 2013. A difference-in-differences specification is defined comparing the economic activity of SMDs with the economic activity of pawnshops and other firms involved in the collection of non-hazardous waste, in the recovery of sorted materials, in the wholesale of metals and metal ores, and in the wholesale of waste. The results show that, following the SMDA 2013, SMDs in England and Wales experienced a significant reduction in their turnover, turnover per employee and EBITDA margin. This suggests that the stricter regulation regime under the SMDA 2013 decreased the potential for metal thieves to sell stolen metal to these businesses. This is a relevant finding not only for the market of metals, as lessons can be learnt also on the likely crime-reduction effects of stricter regulation in other industries, such as for cars, smartphones and credit cards.

The rest of the paper is structured as follows. In Section 2 we describe the aggregate time series data, offer some descriptive analysis and present some metal crime-price elasticities.

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[5] Morgan et al. (2015) constitute an early attempt to evaluate the effectiveness of Operation Tornado in reducing metal theft. However, from their analysis, it is impossible to separate out the impact of Operation Tornado on metal theft from the impact of the Scrap Metal Dealers Act (2013) and additional related interventions on metal theft.

Section 3 shows the statistical results on policing and metal crimes using a police force area panel, and Section 4 presents the results of the firm-level analysis of how specific legislation affected SMDs. Section 5 offers some concluding remarks.

## 2. Metal Crime and Prices

The empirical analysis begins with an investigation of the impact of metal prices on the incidence of metal theft. In the analysis of the determinants of metal theft, this seems as a natural starting point since prices represent the direct benefit from engagement in property crime. In this case (unlike for other prices, like some of the consumer goods studied in Draca et al., 2015) the resale price is likely to be the actual price when selling on to a scrap metal merchant. In the case of metal theft, these prices (e.g. for copper, lead or aluminium) are largely determined on international commodity markets and, thus, the exogenous nature of international metal prices allows us to identify the causal impact of changes in scrap metal prices on crime.

Only a few studies have investigated the impact of prices on crime. Using British data, Reilly and Witt (2008) show that the fall in the real price of audio-visual goods led to a reduction in domestic burglary. D'Este (2014) presents evidence from the US on the positive link between the size of the local market for the trade of stolen property and the responsiveness of burglars to changes in prices. In particular, he shows that the predetermined stock of pawnshops within a county increases the consequences of variations in gold prices for burglaries. Draca et al. (2015) use data from the Metropolitan Police Service (MPS) of London to present evidence of significant positive crime-price elasticities for a panel of 44 consumer goods and for commodity related goods (jewellery, fuel and metal crimes). Draca (2016) also points to the role of prices in explaining the fall in crime in the UK since the early 1990s. Braakmann et al. (2017) show that increases in the price of gold lead to disproportionate increases in property crime in neighbourhoods in the UK with a large share of South Asian population; due to the perception that South Asians keep a substantial amount of gold in their properties, the return to property crime increases in these neighbourhoods when the price of gold rises (Braakmann et al., 2017). In criminology, there are a number of case studies that focused on goods such as copper cable (Sidebottom et al., 2011; and Sidebottom, Ashby, and Johnson, 2014), electrical equipment (Wellsmith and Burrell, 2005) and livestock (Sidebottom, 2013).

This section of the paper sets up an empirical framework to study the role of prices in the metal theft boom and bust. First, metal crime-price elasticities are estimated using different data sources. Then the robustness of the estimated metal crime-price elasticities to the inclusion of additional variables, notably male unemployment to reflect labour market incentives and lagged metal theft to model crime dynamics, is appraised.

*Data and Research Design*

For this analysis, information on metal theft is derived from two data sources. The first is the administrative dataset of criminal offences of the British Transport Police (BTP). This dataset contains detailed information on all crimes recorded by the BTP from January 2007 until December 2015. Among all the categories of crime recorded, it includes information on metal theft and scrap metal dealer offences. It reports detailed information on the precise nature, time (i.e., hour and date) and location (i.e., latitude and longitude) of each crime incident. The BTP data covers the regions of England, Wales and Scotland. In total, it contains detailed information on 940,227 crime incidents that occurred in these regions from January 2007 to December 2015 and that were recorded by the BTP.

The empirical analysis also uses data on metal theft from the administrative records of the Crime Record Information System (CRIS) of the MPS. The CRIS contains information on the type and count of metal stolen in thefts, burglaries and robberies. It constitutes the standard crime recording system of the MPS, with stolen properties grouped by type at the two-digit level. The CRIS provides metal theft records separately for seven categories of metal, namely gold, silver, copper, lead, brass, aluminium and a residual group of other metals. For this analysis, data are used from January 2007 to December 2015. For a given month, the metal theft records indicate the count of a stolen metal across all incidents in that month. Thus, for example, if a set of metals were stolen in a given incident, each of the different metals would be recorded separately as a stolen item by the CRIS of the MPS. The measure of metal theft that is used for this analysis is therefore the count of stolen metals in a given month. Data on metal theft are used in the first and second parts of the empirical analysis.

This part of the empirical analysis not only estimates metal crime-price elasticities, but it also tests their robustness to the inclusion of male unemployment and lagged metal theft in the metal crime equation. To this end, it combines time series records of metal theft with time series records of metal prices and labour market dynamics. The BTP microdata were aggregated up at the monthly level in order to obtain the count of stolen metals in England and Wales in each month from January 2007 to December 2015. A similar exercise was done using the MPS data, whereby crime records for different metals were summed up to obtain the monthly count of metal theft in the region covered by the MPS.

Direct data on scrap metal prices were collected from www.letsrecycle.com, a trade industry media outlet for the waste management and recycling sector. On www.letsrecycle.com, monthly scrap metal prices are available for the period 2007 to current for many types of ferrous and nonferrous metals. These data were collected for this study as they are the prices metal thieves are likely to view as the true resale value from metal theft. Data on world prices from international commodity markets were also collected for this study. This is due to the potential endogeneity of local scrap metal prices in the determination of metal theft, e.g., due to the potential presence of unobservable non-random factors that may influence metal prices in England and Wales as well as may have an independent effect on metal theft, which would result in a well-known problem of omitted variable bias. Thus, international metal prices were collected from the online platform “Index Mundi”, where data on international metal prices are measured in pounds sterling and are available at the monthly frequency. Finally, data on labour market conditions were extracted from the UK Quarterly Labour Force Survey (QLFS) data from 2007 to 2015. The QLFS covers the whole of the UK and it was used for this analysis as it collects nationally representative information on demographics and labour market conditions of the working-age population in England and Wales.

*Descriptive Analysis*

Figure 1 shows the count of metal theft incidents in England and Wales from January 2007 to December 2015 that were recorded by the BTP. Starting from January 2007, a positive trend clearly appears in the incidence of metal theft up until 2011. Except in the year 2008, in England and Wales the incidence of metal theft grew rapidly in the observation period and it hit a record high in 2011. In the same years, largely driven by the demand for raw materials from China and other fast-growing economies, the 2000s commodities boom pushed upwards the prices of many physical commodities up until 2014. Commodities affected by these trends include oil, chemicals, fuels and metals.

Figure 2 shows the log values of metal theft in England and Wales and the log values of scrap metal prices in England and Wales. Two features are noticeable in Figure 2. First, Figure 2 shows that metal prices also grew starting from 2007, and they too hit a record high in 2011. Up until 2012, Figure 2 shows metal prices and metal theft to follow very similar trends over time, arguably reflecting the responsiveness of metal crime to metal prices. One interpretation of Figure 2 is that, from 2007 to 2011, metal thieves may have started to steal more driven by the growing incentive to steal and sell metal. By 2011, the scale of metal theft in the country reached unprecedented levels, and a sense spread across politicians, police forces and the media that metal theft had become a major problem. It costed the lives of thieves trespassing on the railways, it carried large financial costs for the Network Rail (NR), it disrupted transport services, it caused large costs for cultural heritage, and it also generated large financial costs for insurers. For these reasons, anti-metal crime policing and policy interventions started to be viewed as necessary to tackle "Britain's most annoying crime wave" (BBC, 28 September 2011[6]).

The second noticeable feature of Figure 2 is the negative trend in metal theft from 2012 to 2015. Although metal prices did not continue on the positive trend experienced from 2007 to 2011, they remained quite stable after 2011. In contrast, starting from 2012, metal theft fell sharply. Figure 3 shows the residual (log) metal theft after (log) metal prices have been taken into account. In Figure 3 a clear difference appears in the residual incidence of metal theft between the periods before and after January 2012. This is after prices have been taken into account in the determination of metal theft, thus it suggests that the fall in metal theft from 2012 to 2015 cannot be explained entirely by the interruption of the pre-2012 positive trend in metal prices. Rather, the policing and policy responses implemented in 2012 and 2013 respectively, which are assessed in Sections 3 and 4 of the paper, may have played a role.

Figure 4 provides an additional piece of evidence that is consistent with this claim. In Figure 4, the predicted evolution of metal crime based on pre-2012 metal prices is added to Figure 2. To this end, data on metal crime and metal prices was used from January 2007 to October 2011, i.e., prior to the Chancellor George Osborne's announcement of the UK government's intention to use £5 million of Treasury funding to set up a nationwide metal theft taskforce.[7] Figure 4 clearly suggests that, based on the pre-2012 metal prices, metal crime should have remained relatively stable until the end of 2013, with only a marginal decline between 2014 and 2015. The actual evolution of metal crime in England and Wales looks clearly different from this prediction, as it shows a much steeper fall starting from 2012. This was possibly the result of the anti-metal crime policing and policy interventions implemented

[6] See http://www.bbc.co.uk/news/magazine-15062064
[7] See http://researchbriefings.files.parliament.uk/documents/SN06150/SN06150.pdf

in England and Wales starting from 2012. Sections 3 and 4 below subject these descriptive findings to a more rigorous statistical testing that defines a proper set of treatment and control groups and that takes into account the potential confounding effect of common nationwide time trends.

*Research Design*

To investigate metal crime-price elasticities, and their robustness when other controls are added to the analysis, a time series analysis is conducted. In formal terms, the following log-log equation is estimated:

$$Log(MT_t) = \alpha_1 + \beta_1 Log(SP_t) + \gamma_1 X_t + f(t) + v_{1t} \quad (1)$$

where $MT_t$ is the count of metal theft incidents in month $t$ and $SP_t$ are local scrap metal prices in England and Wales in month $t$. $X_t$ is a vector of controls that includes male unemployment in month $t$ and $MT_{t-1}$, i.e., the value of metal theft in month $t-1$, while f(t) represents a time control, i.e., either a linear time trend or a set of year fixed effects. Controlling for male unemployment aims to estimate the effect of labour market conditions on metal theft. The one-month-lag value of metal theft was also included in the equation to test the robustness of the estimated metal crime-price elasticities to the inclusion of past levels of metal theft in the equation. This is relevant due to the potential serial correlation in metal theft and its potential correlation with metal prices.

Equation (1) forms a baseline specification and is estimated using OLS and Newey-West standard errors. The key parameter of interest is $\beta_1$, the metal crime-price elasticity. There are at least two reasons why one might worry about the estimate of $\beta_1$ being biased. First, it may not reflect a causal impact of metal prices on metal theft if simultaneity bias arises from some unobserved factors specific to England and Wales that may have an effect on both the dependent variable and the key explanatory variable of interest. To circumvent this, international metal prices are used to instrument local scrap metal prices. In formal terms, the instrumental variable (IV) approach can be described in terms of the two reduced forms:

$$Log(SP_t) = \alpha_2 + \beta_2 Log(IP_t) + \gamma_2 X_t + f(t) + v_{2t} \quad (2)$$

$$Log(MT_t) = \alpha_3 + \beta_3 Log(IP_t) + \gamma_3 X_t + f(t) + v_{3t} \quad (3)$$

where $IP_t$ is the international price of metals in month $t$.

In the first stage (2), estimates of $\beta_2$ show the impact of international metal prices on local scrap metal prices in England and Wales. Equation (3) is the reduced form regression of log metal theft on the instrument. The IV local average treatment effect (LATE) estimate is then the ratio of the reduced form to the first stage coefficient, $\beta_3/\beta_2$.

The second modelling issue arises because of the highly seasonal nature of crime. Thus, seasonally differenced versions of equations (1) to (3) are also presented where all variables are transformed by the 12-month operator, $\Delta_{12}$, to remove month-specific unobservable effects from the data. For example, equation (1) now becomes:

$$\Delta_{12} Log(MT_t) = \alpha_4 + \beta_4 \Delta_{12} Log(SP_t) + \gamma_4 \Delta_{12} X_t + f(t) + \Delta_{12} v_{4t} \quad (4)$$

Using monthly data from January 2008 to December 2015, the analysis is conducted on a total of 96 months[8], and results are presented for the whole of England and Wales using the BTP data, and for London only using both the BTP data and the MPS data described above.

*Results*

Tables 1 and 2 show the results from the time series analysis of metal crime-price elasticities. Results are presented from the BTP data for the whole of England and Wales, from the BTP data for London only, and from the MPS data. Looking at Table 1, Panel A (i.e., columns (1) to (4)) shows metal crime-price elasticities without seasonal differencing and Panel B (i.e., columns (5) to (8)) shows metal crime-price elasticities with seasonal differencing.

[8] Data from 2007 were only used to retrieve the 12-month differenced value of metal crime in 2008.

Either a linear time trend control or year fixed effects were included in all estimates, and Newey-West standard errors were used for inference and are reported in parentheses.

The key finding from this exercise is that metal crime-price elasticities always appear to be statistically significant and sizeable, with magnitudes greater than unity. Seasonal differencing, shown in Panel B, decreases a bit the size of the estimated elasticities, but the elasticities remain above unity and statistically significant at all conventional levels. The comparisons of our OLS elasticities in columns (1) and (5) with our IV elasticities in columns (4) and (8) show the OLS estimates to be downward biased. This may be due to potential measurement error in local scrap metal prices in England and Wales, or due to the presence of relevant omitted factors that may be correlated with local scrap metal prices. The results in Table 1 also show metal crime-price elasticities to be greater in London than in the rest of England and Wales. The seasonally-adjusted metal crime-price elasticities in London appear very similar whether they are calculated using the BTP data or the MPS data. Greater metal crime-price elasticities appear in London both when comparing the estimates from the BTP data for England and Wales with estimates from the BTP data for London only, and when comparing the estimates for England and Wales with those derived from the MPS data.

Table 2 shows the robustness of our estimated IV metal crime-price elasticities to a richer Becker specification. The analysis is done again separately on the three datasets presented in Table 1 (i.e., BTP data for England and Wales, BTP data for London and MPS data), and controls are added for male unemployment and lagged metal theft to the IV metal crime equation. These results are shown in the upper panel of Table 2. Although the estimated coefficients for metal prices appear smaller in all specifications compared to Table 1, they are still large and statistically significant at one percent. Male unemployment appears to be a positive predictor of metal theft, suggesting that deteriorating labour market conditions and increased joblessness may induce an increase in metal theft. A word of caution is in order though, since the crime-unemployment elasticities do not appear statistically significant when seasonal differencing is applied to the analysis. The estimates for lagged metal theft suggest there is strong serial correlation in the incidence of metal theft, as the estimated coefficients appear positive and significant in all the specifications. For a direct comparison between the metal crime-price elasticities reported in Table 1 and those in Table 2, when lagged values of metal theft are included in the set of covariates long run crime-price elasticities are calculated as $\beta/(1-\lambda)$, where $\beta$ is the estimated coefficient for Log(Scrap Price) and $\lambda$ is the estimated coefficient on the lagged dependent variable. These long run elasticities are also reported below the estimated coefficients in each column of Table 2, and are of very similar magnitude to those from the static models reported in Table 1.

The lower panel of Table 2 shows what happens to these results when the linear time trend is replaced with year fixed effects in the estimated equation. While male unemployment no longer appears to predict significantly metal theft, the lagged value of metal theft still appears as a positive and significant predictor of metal theft. The estimated crime-price elasticities also appear robust to the inclusion of year fixed effects in the equation. In some cases, the estimated crime-price elasticities appear even larger than in the upper panel. However, the general conclusion that emerges throughout our estimates in this section is that metal crime is highly responsive to fluctuations in metal prices. This is the case regardless of whether labour market conditions or even past metal theft are taken into account, and it suggests that metal thieves are highly responsive to changes in the direct incentive to engage in this type of property theft.

## 3. Metal Crime and Policing

The second part of the empirical analysis aims to estimate the impact of policing on metal theft. To this end, it exploits the exogenous variation in the intensity of policing across police force areas (PFAs) in England and Wales that was induced by "Operation Tornado". Operation

Tornado is a novel, problem-oriented policing initiative that was conducted by the BTP in England and Wales at the beginning of 2012, i.e., when metal crime was hitting a record high in the country. Starting from Levitt (1997), a number of studies have exploited sources of plausibly exogenous variation in police workforce to document a crime-reducing effect of police staffing (Levitt, 2002; Evans and Owens, 2007; and Lin, 2009)[9]. Multiple studies have also exploited natural experiments to assess the crime-reducing effect of police deployment and tactics (Cohen and Ludwig, 2003; Di Tella and Schargrodsky, 2004; Klick and Tabarrok, 2005; Draca et al., 2011; and MacDonald, Klick and Grunwald, 2016). These studies show consistent evidence from different cities of the crime-reducing effect of police deployment.[10] However, very few studies exist on problem-oriented policing initiatives, and concerns regarding identification suggest caution in the interpretation of the existing evidence (Skogan and Frydl, 2004; and Chalfin and McCrary, 2017).

Operation Tornado (OT) was piloted in January 2012 in the North East regions of England (i.e., in the police force areas of Durham, Cleveland and Northumbria) and then progressively extended to other regions. Thus, a difference-in-differences specification can be defined whereby late adopters of OT are used as controls for the early adopters of OT. For this analysis, microdata from the BTP were aggregated up at the PFA-level with monthly frequency. These data were combined with data on metal prices in the UK from www.letsrecycle.com and with data on international metal prices from the online platform "Index Mundi".

*Operation Tornado*

The Scrap Metal Dealers Act 1964 was acknowledged as an out of date and ineffective piece of legislation that was failing to stem the increases in metal theft. The previous section has discussed the significant increase in metal theft from 2007 to 2011 that is shown in Figures

[9] Chalfin and McCrary (2017) provide a comprehensive review of this literature.

[10] A different conclusion appears in Mastrobuoni (2013), who finds that criminals are not responsive to large regular shift changes among the different police forces in Milan.

1 and 2. As a result, in April 2011 the Association of Chief Police Officers (ACPO), the BTP and the Home Office (HO) entered into negotiations with the British Metals Recycling Association (BMRA) and Directors from the three largest recyclers within the UK to try and negotiate a cashless trial. Following Chancellor Osborne's announcement in November 2011, the first intervention was Operation Tornado, which was designed to support the police in tackling metal theft and to make it easier to trace sellers and dealers of stolen metals. It required participating scrap metal dealers in England and Wales to request identification documentation (UK driving licence, passport or utility bill) for every cash sale and retain copies for twelve months for inspection by the police. Dealers were requested to ensure CCTV systems covered entrances and weighbridges of recycling centres and the images to be of sufficient quality to enable identification of vehicle registration numbers and secure facial recognition. Posters describing the identification measures in force were prominently displayed to sellers. The intervention, which was backed with police enforcement, was piloted in the police forces in the North East in January 2012 before being rolled out on a phased basis across England and Wales by September 2012. From the perspective of scrap metal dealers, Operation Tornado can be thought of as a sudden negative cost shock.

A Red, Amber, Green (RAG) standardisation of dealer categorisation was adopted within police force areas as part of the Operation Tornado implementation process. This enabled enforcement activity to be directed, focused and efficient in terms of tackling criminality within a standardised framework. According to BTP, over 80 percent of scrap metal dealers signed up to OT and all police forces introduced the national RAG status as part of the roll out of the project. These voluntary measures were acknowledged as an effective means of reducing metal theft and formed the backbone that supported the introduction of cashless trading in December 2012.

Although the measures were widely accepted, the absence of a legislative requirement to enforce the measures allowed participants to drop in and out with no penalties. In addition, one of the larger partners withdrew from the program, and this may have resulted in many others following, and thus in a reduction in the overall effectiveness of the measures. These risks brought a degree of uncertainty in terms of sustainability, which was one of the factors that supported the inclusion of identification in a new Scrap Metal Bill in December 2012. Even though, as shown in Figure 4, metal crime after 2012 dropped by much more than it would have been predicted at the end of 2011, the absence of a legislative requirement to enforce the measures of OT implies that its effectiveness is not obvious *a priori*.

*Research Design*

The next step is to move on from the time series analysis undertaken in the previous section to study the causal effect of policing on metal theft. The first part of the empirical analysis has documented the large metal crime-price elasticities and their robustness to a richer Becker specification. This part of our analysis investigates the impact of policing on metal theft by exploiting the implementation of Operation Tornado (OT) in England and Wales in 2012. It investigates whether the discrepancy between the expected and realised evolution of metal crime in England and Wales was indeed the result of OT, or it was the result of other underlying confounding nationwide factors. For this purpose, a difference-in-differences research design is adopted that exploits the gradual introduction over time of OT between different police force areas.

Table 3 provides a timeline of OT adoption between the beginning of 2012, when no police force area had adopted OT yet, and September 2012, when the national rollout of OT was complete. As Table 3 shows, OT was piloted in the North East police force areas of Cleveland, Durham and Northumbria. These regions were chosen for the pilot of the programme in order to minimise the risk that OT may result in the displacement, rather than the reduction, of metal theft in the region. In April 2012 the programme was extended to the Yorkshire, the Humber and East Midlands police force areas. OT was introduced in the North Western regions of England in May 2012 and in the Eastern and Southern regions of the country in June 2012. Police forces in London, Wales and the West Midlands did not adopt OT until the end of the summer 2012, when they decided to introduce it in their respective jurisdictions.

The approach taken here is to compare metal crime in police force areas that adopted OT before the summer with metal crime in police force areas that adopted OT only at the end of the summer. The time window between January and September 2012 is used to evaluate the causal impact of OT on metal crime. Scotland is excluded from the analysis since OT was not implemented there, and comparable provisions were not adopted until September 2016.[11] Restricting the analysis to PFAs where OT was adopted within a relatively short period of time ensures that treated and comparison regions share unobservable common reasons to adopt OT (like ethos or urgency to tackle metal theft). As Table 3 shows, 33 police forces introduced OT before the summer, while 10 police forces introduced it after the summer. The set of police force areas that adopted OT before the summer is labelled 'early adopters', and the set of police force areas that adopted OT after the summer is labelled 'late adopters'. Since the control regions in our analysis receive the treatment in September 2012, BTP data on metal theft by police force area is used from January 2007 to August 2012. Metal crime in the set of 'early adopters' is then compared with metal crime in the set of 'late adopters' in the time window from January to August 2012. The unit of observation in our analysis is the police force area, $p$, over time and metal crime is measured with monthly frequency. In formal terms, the basic difference-in-differences set up is:

$$MT_{pt} = \theta_p + \beta_5 SP_t + \pi_5 POST_t + \varphi_5 POST_t * OT_p \ + \ \theta_t \ + \ v_{5t} \qquad (5)$$

[11] See https://www.recyclemetals.org/newsandarticles/cash-ban-arrives-in-scotland.html.

Equation (5) is specified in the levels of $MT_{pt}$ and $SP_t$ because there is a relatively high frequency of zeros in $MT$ at the police force area level with monthly frequency. $MT_{pt}$ is the monthly count of metal theft incidents in police force area $p$ in month $t$ per 10,000 population, $SP_t$ is local scrap metal prices in month $t$, and $OT_p$ is a binary variable that takes up value 1 if police force area $p$ is an 'early adopter' of OT and value 0 otherwise. $Post_t$ is a binary variable that takes up value 1 starting from January 2012, i.e., from the beginning of OT, and value 0 in the previous month-years. $\theta_p$ denotes a set of police force area fixed effects (which also absorbs the time invariant $OT_p$ levels variable, which is not shown in (5)) and $\theta_t$ is a set of time fixed effects.

Insofar as, prior to the policing intervention, metal theft displayed similar trends in treatment and control regions, the interaction between these variables, i.e. $Post_t * OT_p$, identifies the causal effect of OT on metal theft and, thus, $\varphi_5$ is the key coefficient of interest. Similarly to what was done in the previous section, all throughout this part of the analysis, local scrap metal prices in England and Wales in month $t$ are instrumented using international metal prices in month $t$, i.e., $IP_t$ in equations (2) and (3). Given the possibility that there may be unobservable police force area-specific trends in crime that may affect our results, a more stringent specification additionally includes police force area-specific linear time trends, $\theta_p$*t. In all our analysis, Newey-West standard errors are estimated for inference. Finally, equation (5) is estimated with and without seasonal differencing to control for seasonality in metal crime.

*Descriptive Difference-in-Differences*

Table 4 shows the results from an unconditional difference-in-differences exercise comparing metal crime in early adopters of OT with metal crime in late adopters of OT. Considering first early adopters of OT in panel A of Table 4, column (1) reveals that, on average, 0.032 incidents of metal crime per 10,000 population occurred per month in the years prior to January 2012, and that this dropped to 0.020 in the time window from January to August

2012. There is much less change in the late adopters' regions where, if anything, metal crime decreased only slightly in 2012 compared to previous years. By taking the difference between these 'pre' and 'post' metal crime rates, and then differencing across these yields the difference-in-differences (DiD) estimate shown in column (3). This is sizeable at -0.011 for the early adopters, showing that they did experience a reduction in metal crime during the implementation period of OT. Since the average count of metal theft per 10,000 population per month prior to 2012 was 0.031, this statistically significant drop represents a 35 percent decrease in metal theft following the introduction of OT. Panel B shows the results of the seasonally adjusted (i.e., 12-month differenced) unconditional difference-in-differences comparison. As column (6) shows, adjusting for seasonality does not affect our conclusion, as a 0.012 statistically significant reduction in metal crime appears again for police force areas that adopted OT before the summer 2012.

The validity of these conclusions is supported by Figure 5, which shows our treated and control regions to be on very similar metal crime trends in the years prior to the implementation of OT. In particular, Figure 5 shows metal crime trends after seasonal adjustment was applied to the metal crime figures. The Figure shows that until the end of 2011 both the levels and the trends of metal crime appear very similar between early adopters and late adopters of OT. Starting from January 2012, however, a discrepancy appears between the two groups, with treatment regions experiencing a drop in metal crime compared to control regions. The discrepancy in metal crime between the two groups appears particularly evident in the March to June period, when all the early adopters gradually adopted OT.

*Results*

This section turns to the main statistical estimates that look at the causal effect of OT on metal crime. Table 5 shows the main set of estimates of the causal effect of OT on metal crime. Overall, the results confirm the conclusions from the unconditional DiD estimates of the previous section, as they show a reduction in metal theft in the order of 35 percent. To be precise, columns (a) to (c) show our results without seasonal differencing, whereas columns (d) and (e) show our estimates with seasonal adjustment. In a similar manner to the analysis of metal crime and prices, local scrap metal prices in England and Wales in month $t$ were instrumented with international metal prices in month $t$.

Column (a) of Table 5 shows results without controlling for month-year fixed effects, as this allows us to identify both the causal impact of OT and the causal impact of metal prices on metal crime. Column (a) displays the positive and significant impact of metal prices on metal theft. This result is consistent with our results from the previous section, as it shows the importance of price incentives for metal thieves to engage in metal crime also once the causal impact of policing on metal crime is taken into account. Column (b) shows that inclusion of month-year fixed effects has no effect on our estimate of the effect of OT on metal crime. Controlling for PFA-specific time trends, as shown in column (c), results in a slightly smaller estimate of the impact of OT, but the effect of OT on metal theft is still estimated to be negative and significant at the five percent level. Column (d) shows that seasonal differencing increases the size and significance of the estimated effect of OT on metal theft.

This conclusion that there was a reduction in metal theft as a result of the introduction of OT is further corroborated by the results in column (e) of Table 5, which displays seasonally-adjusted event study difference-in-differences estimates of the impact of OT on metal crime. Figure 6 provides a graphical representation of these results. The event study generates separate estimates of OT impact months since January 2012, but also allows examination of possible pre-2012 differences in trends between treatment and control police force areas. To be precise, each coefficient represents the interaction between treatment status (i.e., $OT_p$ in equation (5)) and a dummy for two months of observation in our study period. Thus, 'OT x Pre 1' tests whether there were any differential crime trends between treatment and control regions in

November and December 2011 (i.e., two months prior to the start date of OT). ‘OT x Pre 2’ tests whether there were any differential crime trends between treatment and control regions in September and October 2011. ‘OT x Pre 3’ tests the presence of differential pre-trends between treatment and controls in July and August 2011, and ‘OT x Pre 4’ tests this in May and June 2011. By the same token, OT x Post 1 shows the impact of OT in January and February 2012, OT x Post 2 shows the impact of OT in March and April 2012, OT x Post 3 shows the impact of OT in May and June 2012, and OT x Post 4 shows the impact of OT in July and August 2012, just before the control police force areas also introduced OT.

There are two notable features. First, are parallel pre-2012 trends between treatment and control PFAs. This is also confirmed by the joint insignificance of the estimated differential pre-trends that is displayed in Figure 6. This suggests that treated regions were not experiencing differential trends in metal crime prior to the introduction of OT, and thus any negative discrepancy between treatment and controls after the start of OT can be safely interpreted as the impact of the adoption of OT on metal crime. Second, there is a steep drop in the count of metal theft incidents per 10,000 population starting from March/April 2012 in the treated police force areas. Although Figure 6 shows all the estimated treatment effects after January 2012 to be jointly significant at one percent, the impact of OT on metal theft appears to be concentrated in the months from March to June 2012, when all treated police forces had started OT in their respective regions. This makes intuitive sense, and it reflects the importance of policing in deterring crime also in the presence of strong economic incentives to engage in such illicit activities.

## 4. Metal Crime and Policy

The third part of the empirical analysis assesses the impact of the Scrap Metal Dealers Act 2013 (SMDA) on the economic activity of Scrap Metal Dealers (SMDs) in England and Wales. The

SMDA 2013 came into force in October 2013 and it superseded the Scrap Metal Dealers Act 1964. Amongst other things, the SMDA 2013 introduced new provisions for the issuance and revocation of a scrap metal licence, for the verification of scrap metal suppliers' identities and it introduced the offence of buying scrap metal for cash.[12] This part of the paper investigates to which extent these provisions affected the economic activity of scrap metal dealers in England and Wales that were the target of this reform. The idea here is that the new legislation may have decreased the fungibility of stolen metal and, thus, it may have reduced the market size for metal thieves to sell what they have stolen.[13]

Related studies on the effect of changes in the legislation on property theft include Morgan et al. (2016) and Van Ours and Vollaard (2016). Morgan et al. (2016) shows the negative link between vehicle theft and the pace at which electronic immobilisers were mandated on new vehicles in Europe, Australia, the US and Canada. Van Ours and Vollaard (2016) documents the crime-reducing impact of the compulsory application in new passenger cars in the European Union of the electronic engine immobiliser.[14] The channel through which the diffusion of electronic immobilisers reduced crime was by making vehicle theft more difficult. The introduction of the SMDA 2013 also brought about a crime bust. However, it constitutes a different kind of natural experiment because the SMDA 2013 did not make metal theft more difficult; rather, it made stolen metal harder to sell and, thus, it made metal theft unlikely to be as profitable as it was before.

*The Scrap Metal Dealers Act 2013*

The Scrap Metal Dealers Act 2013 (SMDA) was enacted on the 28 February 2013 and its implementation was carried out by October 2013. The SMDA followed Operation Tornado

[12] A complete description of the provisions of the SMDA 2013 is publicly available here: http://www.legislation.gov.uk/ukpga/2013/10/enacted.
[13] A number of recent studies in economics has used data on licit markets to provide insights into illegal activities (e.g., Fisman and Wei, 2004; Olken, 2007; Sukhtankar, 2012; and Parey and Rasul, 2016).
[14] Ayres and Levitt (1998) and Gonzalez-Navarro (2013) previously studied the vehicle theft deterrence effect of the Lojack, a small device hidden inside a vehicle that allows it to be tracked after a theft occurs.

and it superseded the Scrap Metal Dealers Act 1964, as it aimed to provide a more effective regulatory framework to the scrap metal and recycling industry in England and Wales. By generating a tougher licensing regime that was run by local authorities, the SMDA 2013 aimed to support legitimate SMDs while hindering the activities of unscrupulous dealers. As a result of the SMDA 2013, local authorities were given the power to grant or refuse a licence upon application, depending on whether they were persuaded or not that the applicant was a suitable person to run an SMD. The SMDA 2013 also enabled local authorities to revoke a licence at any time, as well as to shut down SMDs that operate without a licence.

Local authorities can grant two types of licences to SMDs, namely a site licence or a mobile collector licence. The site licence requires identification of all the sites within the local authority where the SMD intends to operate and the identification of a manager for each of them, as it allows the SMD to operate only at the sites listed on the licence. The mobile collector licence allows the SMD to collect both domestic and commercial scrap metal in the area of the issuing local authority. This licence does not permit to operate at a fixed site, nor to collect scrap metal from any other local authority area. For this, an additional licence from another local authority ought to be obtained by the mobile collector. SMD licences normally last for a period of three years starting from the date of issuance of the licence. In line with Operation Tornado, the SMDA 2013 also posed a legal obligation on SMDs to keep records of all transactions and to request a proof of identity from their counterpart in every transaction.

### *Research Design*

A natural question to ask is whether the provisions of the SMDA 2013 affected the economic activity of pre-existing SMDs in England and Wales? This section of the paper exploits the differential intensity in exposure to the SMDA 2013 across different firms to define a difference-in-differences specification to investigate this question. Since the SMDA 2013 introduced strict regulations to the activity of SMDs, while it did not alter the laws governing the activity of other similar businesses, the latter can be used as a control group for the former. In order to compare the economic activity of SMDs with the economic activity of firms that share similar observable and unobservable features, the control group includes only pawnshops and firms involved in the collection, recovery and wholesale of other waste (i.e., not scrap metal).

For this analysis, firm-level data from the Fame website were used from the fiscal year 2010 to 2015 with yearly frequency. The analysis includes firms which are still active at the time of writing, and for which complete information was available from the Fame website for the fiscal years 2010 to 2015. The unit of observation in this analysis is the firm, *f*, over time and economic activity is measured with yearly frequency. In formal terms, the basic difference-in-differences set up can be expressed as follows:

$$Y_{ft} = \theta_f + \beta_6 SMD_f + k_6 POST_t + \tau_6 POST_t * SMD_f + \theta_t + v_{6t}, \qquad (6)$$

where $Y_{ft}$ is the yearly measure of economic activity of firms in England and Wales. Three measures of economic activity are used in this analysis. The first is the firm *f*'s turnover in year *t*; this information is collected on the Fame database every year at the end of the fiscal year and it includes national and international turnover. The second outcome of interest is the firm *f*'s turnover normalised by number of employees in year *t*, which is firm *f*'s turnover in year *t* divided by firm *f*'s number of employees in year *t*. The third outcome of interest in this analysis is the firm *f*'s EBITDA margin at time *t* (i.e., Earnings Before Interest, Taxes, Depreciation and Amortization), which is defined as firm *f*'s operating profit in year *t* divided by firm *f*'s turnover in year *t*. $SMD_f$ is a binary variable that takes up value 1 if the firm is a scrap metal dealer and value 0 for control firms, $Post_t$ is a binary variable that takes up value 1 starting from the fiscal year 2014, i.e., after the SMDA 2013 came into force in October 2013, and value 0 in previous years. $\theta_f$ denotes a set of firm fixed effects (which also absorbs the time invariant $SMD_f$ levels variable) and $\theta_t$ is a set of time fixed effects.

Insofar as, prior to the SMDA 2013, our outcomes of interest were on similar trends in treatment and control firms, the estimate of $\tau_6$ in equation (6) identifies the causal impact of the SMDA 2013 on the economic activity of scrap metal dealers in England and Wales. Similarly to what was done in the previous section, this proposition was tested formally for every outcome variable with the inclusion in equation (6) of a set of interactions between pre-treatment time dummies and the treatment status, i.e., $SMD_f$. As before, Newey-West standard errors were computed and used for inference in all specifications.

*Descriptive Difference-in-Differences*

Table 6 shows the results from an unconditional difference-in-differences exercise comparing our measures of economic activity of interest in SMDs with our measures of interest in control firms. Considering first turnover of firms in panel A of Table 6, column (1) reveals that, on average, the turnover of SMDs decreased after the introduction of the SMDA 2013. Column (2) shows that much less variation occurred in control firms, where, if anything, the turnover increased slightly after 2013. The difference-in-differences comparison between treatment and control firms shows a negative and significant coefficient, suggesting that the turnover of SMDs was significantly hindered by the provisions of the SMDA 2013.

Analysis of firms' turnover per employee, in panel B of Table 6, shows a very similar pattern in column (1) for SMDs over time. Control firms experienced a negative growth in this outcome variable, but the change is much smaller than in treated firms. The resulting difference-in-differences coefficient is again negative and significant, further suggesting that the SMDA 2013 had a negative effect on the economic activity of SMDs. The consistency in the results in panels A and B arguably suggests that little modifications in the number of employees took place in SMDs following the SMDA 2013 relative to the fall in turnover.

Panel C of Table 6 shows unconditional difference-in-differences results for EBITDA margin. While both treatment and control firms experienced a decline in EBITDA margin over time, the decline was seen to be significantly more pronounced in the treatment group. The resulting difference-in-differences estimate is negative and statistically significant at five percent, further suggesting that the SMDA 2013 may have hampered the economic activity of SMDs in England and Wales. The visual inspection of Figure 7, which shows the evolution of average EBITDA margin for scrap metal dealers and control firms from 2010 to 2015, confirms this. While similar patterns are observed in the average EBITDA margin of treatment and control firms until 2013, after the SMDA 2013 scrap metal dealers recorded a lower average EBITDA margin and a larger discrepancy appeared compared to control firms. The next section subjects these descriptive findings to more stringent specifications that take into account year- and firm-specific unobserved fixed effects, as well as evaluate the potential presence of differential pre-treatment trends between treatment and control firms.

*Results*

Table 7 shows the results of this analysis. Columns (a) to (c) show results for turnover, columns (d) to (f) show results for turnover per employee and columns (g) to (i) show results for EBITDA margin. All specifications include firm fixed effects, and Newey-West standard errors clustered at the firm level are reported in parentheses. Columns (a) and (b) show that, on average, the SMDA 2013 had a negative and statistically significant impact on the turnover of SMDs in England and Wales. Inclusion of year fixed effects does little to our estimates, as the estimated negative effect is stable at 17.3 percent in columns (a) and (b)[15]. Column (c) shows the result of this exercise when only firms for which complete data on all outcome variables of interest are included in the analysis. In column (c), the estimated coefficient appears slightly larger, but it appears very similar to the estimates in columns (a) and (b). The inspection of columns (d) to (f), where turnover per employee is the outcome of interest, leads to similar conclusions. The SMDA 2013 decreased turnover per employee of SMDs by 14.7 percent, with

[15] Since the natural logarithm of turnover is modelled on the right hand side of equation (6), the size of the percent effect was calculated as follows: $100 * (e^{\tau_6} - 1)$, where $\tau_6$ is the difference-in-differences coefficient in (6).

a slightly larger effect displayed in column (f), where the analysis is restricted to firms for which complete data on all outcome variables of interest is available.

Columns (g) to (i) show that, due to the introduction of the SMDA 2013, SMDs also experienced a slowdown in their EBITDA margin. Since EBITDA margins can take up negative values, the unit value (and not the logarithmic value) of EBITDA margin was modelled on the right-hand side of the equation[16]. Columns (g) and (h) show that, on average, EBITDA margins of SMDs fell by 2.3 percentage points as a result of the SMDA 2013. Column (i) shows that, also in this case, a slightly larger effect appears when the analysis is restricted to firms for which complete data on all outcome variables of interest is available.

Table 8 shows the results from a set of event-study estimates for our outcome variables of interest. Columns (a) and (b) show results for turnover, columns (c) and (d) show results for turnover by number of employees and columns (e) and (f) show results for EBITDA margin. In all cases, Table 8 shows there to be no differential pre-treatment trends, with the estimated effects of the SMDA 2013 on our outcomes of interest appearing negative and significant, and larger in magnitude in 2015. These results confirm that the SMDA 2013 had a negative effect on the economic activity of SMDs, and it also plausibly reflects the moderate time lag with which the economic activity of SMDs started to be negatively affected by the provisions of the SMDA 2013.

Overall, the results in Tables 6, 7 and 8 provide evidence that the stricter regulation regime introduced by the SMDA 2013 had a negative effect on the economic activity of SMDs. This is likely to reflect the reduced scope for selling stolen metal to SMDs for metal thieves under the new regulatory regime. In turn, this also suggests that the provisions of the SMDA 2013 may have reduced metal theft. This is not tested explicitly in this section, but it appears as one plausible channel explaining the results presented here. Since the SMDA 2013 was

[16] For this exercise, only firms that recorded EBITDA margins from -.3 to +.3 were included in the analysis.

introduced after our sample period ends for the evaluation of Operation Tornado (i.e., after September 2012), the results in this section document the importance of policy and regulatory interventions, over and above policing, for the deterrence of crime in the presence of strong economic incentives to engage in illicit activities. This is an important conclusion that extends beyond the market of metals, as it is of immediate relevance for the regulation and security of other markets, such as the market for cars, smartphones and credit cards.

## 5. Conclusion

This paper studies the roles of prices, policing and policy in shaping the metal crime boom and bust that occurred in the UK in the nine years between 2007 and 2015. Each of the three dimensions has a significant impact. First, the analysis documents important metal crime-price elasticities that are big in magnitude. This very much confirms that economic motives lie behind the metal crime boom. Secondly and thirdly though, it seems like the reaction to the boom by the authorities (police and government) brought about the bust. A difference-in-differences analysis shows that a novel anti-metal crime operation led by the British Transport Police led to significant consequences – and so did the government's introduction of the Scrap Metal Dealers Act 2013, which is exploited to study the impact of policy on the economic activity of scrap metal dealers in England and Wales.

Our estimates document that metal crime is highly responsive to metal price dynamics. However, the policing response of the BTP in England and Wales reduced metal crime by an estimated 35 percent. The ensuing introduction of the SMDA 2013 caused a fall in the turnover of scrap metal dealers operating in England and Wales of around 17 percent between 2014 and 2015. Turnover per employee of SMDs also fell by an estimated 15 percent, suggesting that the drop in turnover is not explained by disproportionate rates of dismissal of employees in SMDs. The EBITDA margin of SMDs also reduced by a sizeable amount. This is likely the result of the reduced scope for potential metal criminals to sell what they have stolen to SMDs, and by association reflects the diluted economic returns of metal crime under the new, stricter, regulatory regime.

In conclusion, the evidence reported in the paper shows that prices, policing and policy all played a significant role in shaping the boom and bust of metal crime. Its initial rapid rise into a crime boom was driven by big rises in commodity prices, and then police intervention and government policy quelled the rise, bringing about a crime bust. This is probably one of the more extreme cases of crime boom and bust that one can study, but the basic notion that crime dynamics embodied in the boom and bust apply is very likely to be a broader one that is relevant for other crimes, and one that future research should certainly investigate in other contexts.

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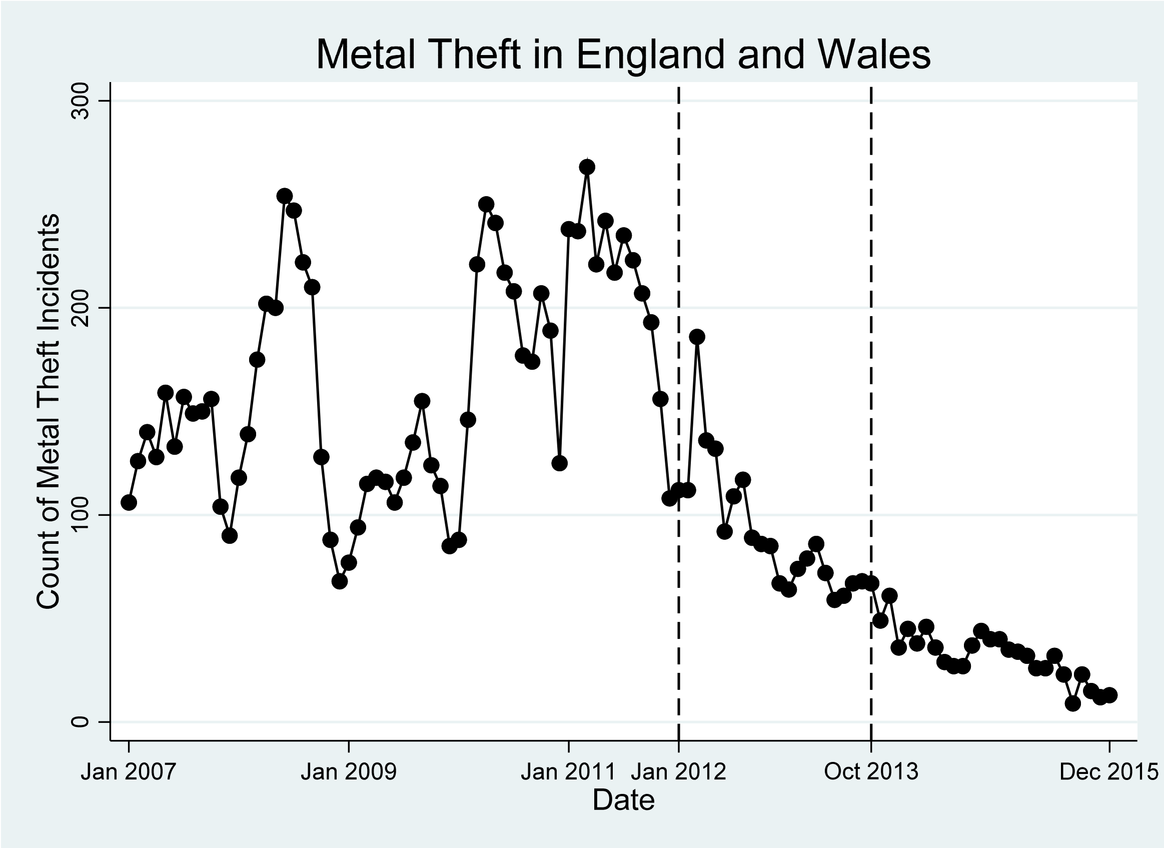
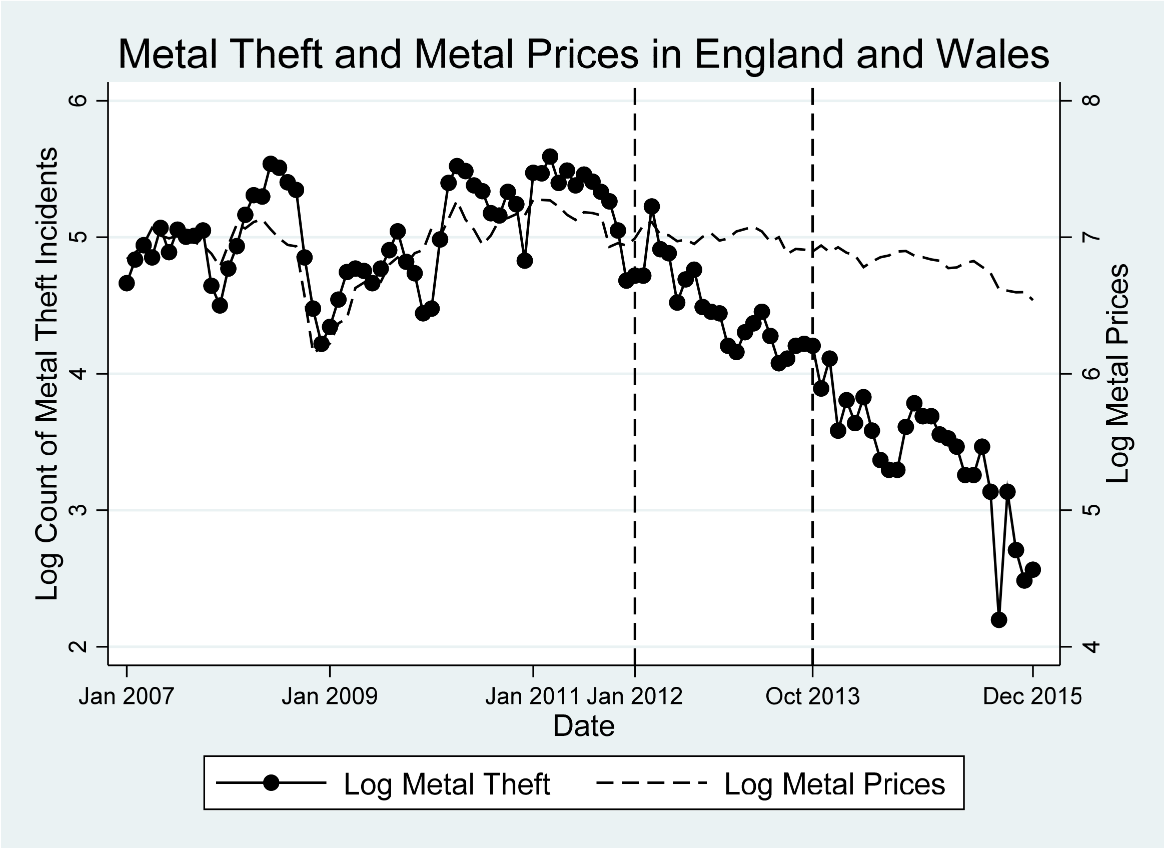
**Figure 1. BTP Levels of Metal Theft in England and Wales**



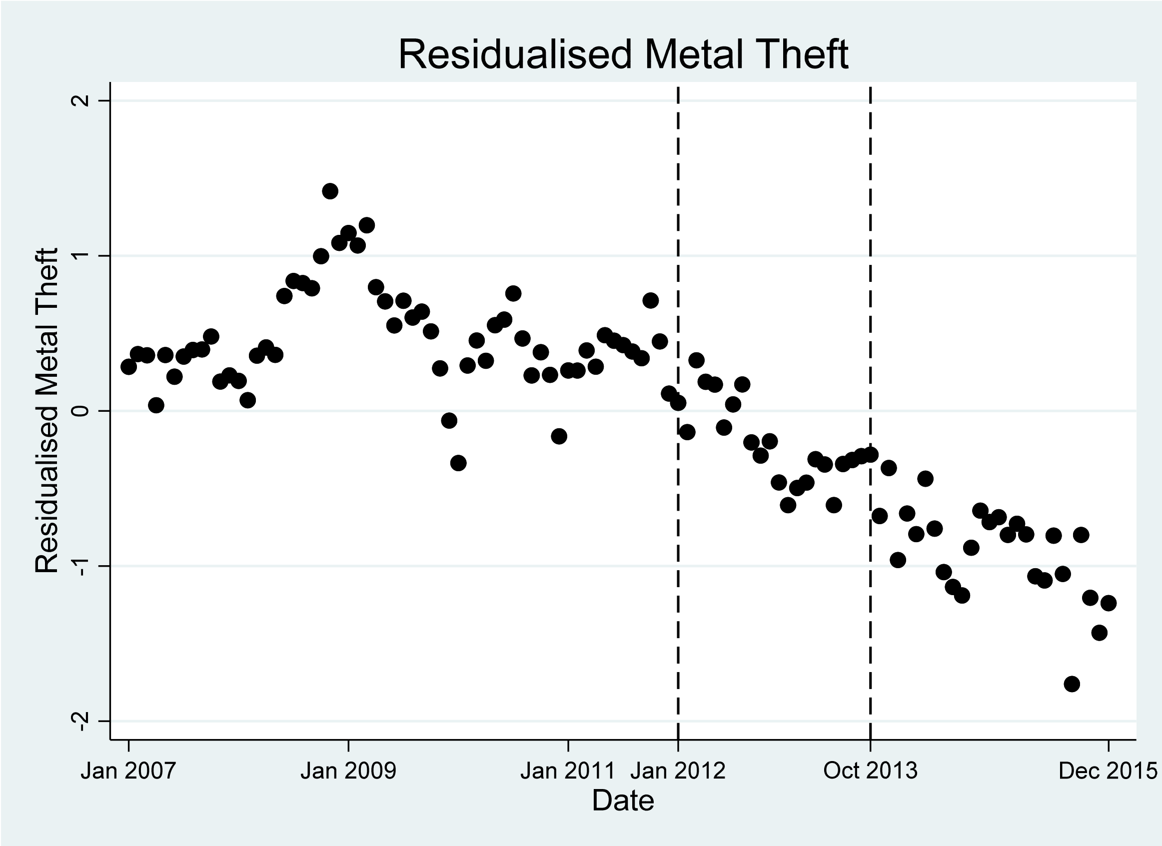

*Notes*: Monthly counts of metal theft were calculated using metal crime records from the British Transport Police in England and Wales. Data from the BTP was available from January 2007 to December 2015. The 'Jan 2012' dotted line represents the time of the introduction of Operation Tornado, while the 'Oct 2013' dotted line represents the time of the introduction of the Scrap Metal Dealers Act 2013.

**Figure 2. BTP Logs of Metal Theft and Metal Prices in England and Wales**



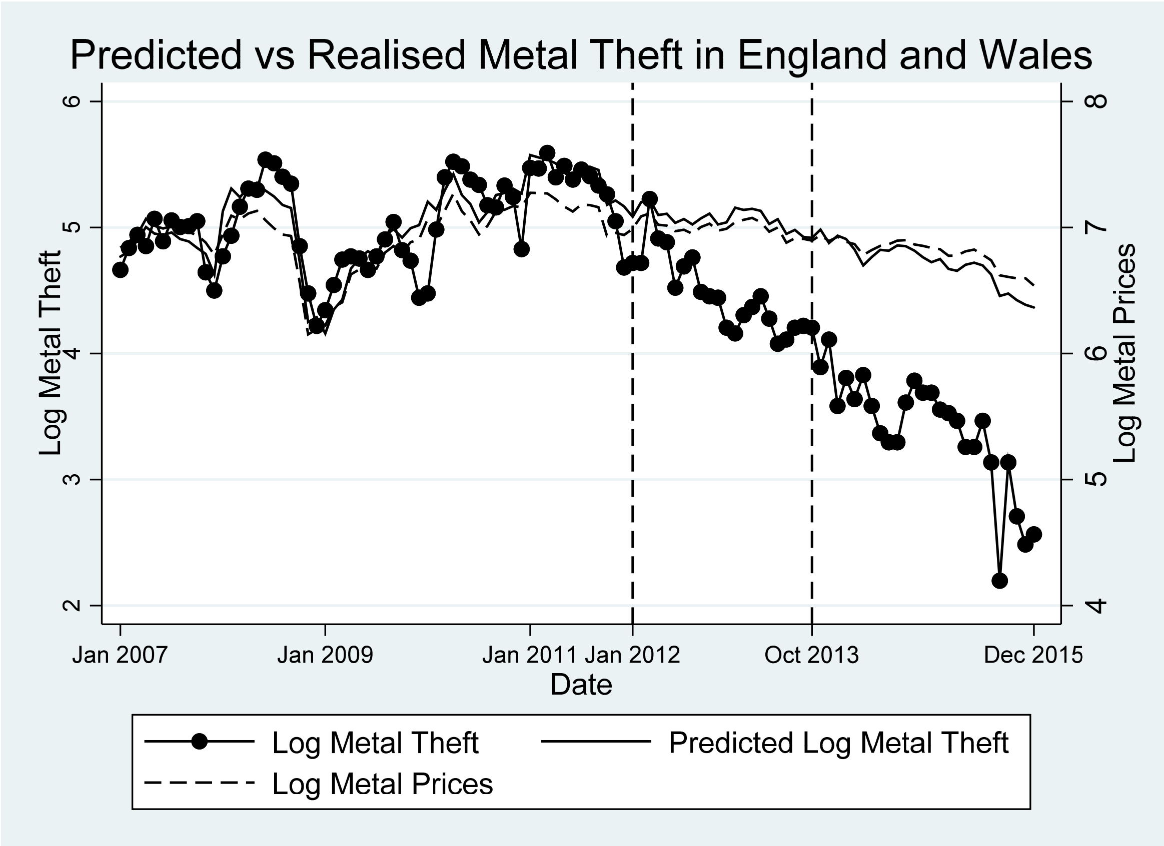

*Notes*: Monthly counts of metal theft were calculated using metal crime records from the British Transport Police in England and Wales. Data from the BTP was available from January 2007 to December 2015. Data on local scrap metal prices in England and Wales was collected from www.letsrecycle.com. The 'Jan 2012' dotted line represents the time of the introduction of Operation Tornado, while the 'Oct 2013' dotted line represents the time of the introduction of the Scrap Metal Dealers Act 2013.

**Figure 3. BTP Logs of Metal Theft Residuals after Metal Prices in England and Wales**



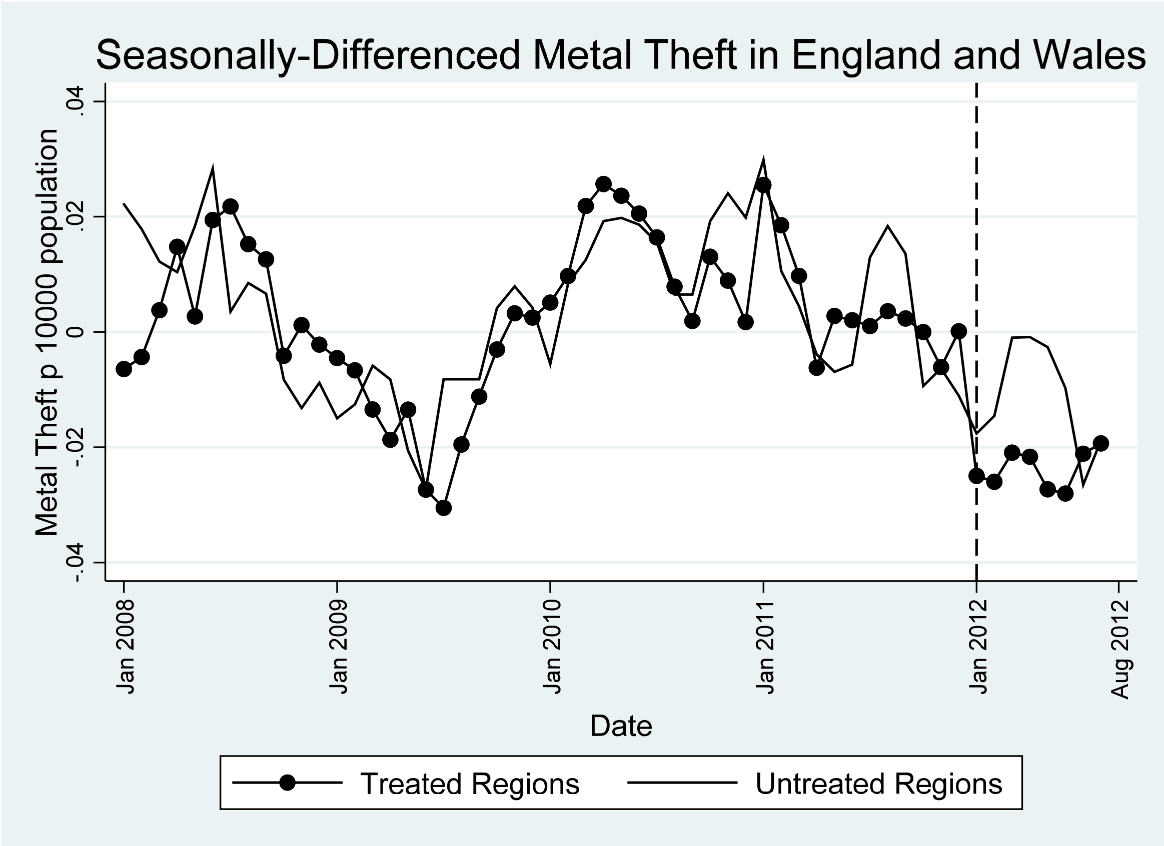

*Notes*: Figure 3 shows the predicted residual monthly counts of metal theft in England and Wales in the regression of monthly counts of metal theft on local scrap metal prices in England and Wales from January 2007 to December 2015. Monthly counts of metal theft were calculated using metal crime records from the British Transport Police in England and Wales. Data from the BTP was available from January 2007 to December 2015. Data on local scrap metal prices in England and Wales was collected from www.letsrecycle.com. The 'Jan 2012' dotted line represents the time of the introduction of Operation Tornado, while the 'Oct 2013' dotted line represents the time of the introduction of the Scrap Metal Dealers Act 2013.

**Figure 4. BTP Log of Metal Theft, Forecasted Log of Metal Theft and Log Metal Prices in England and Wales**



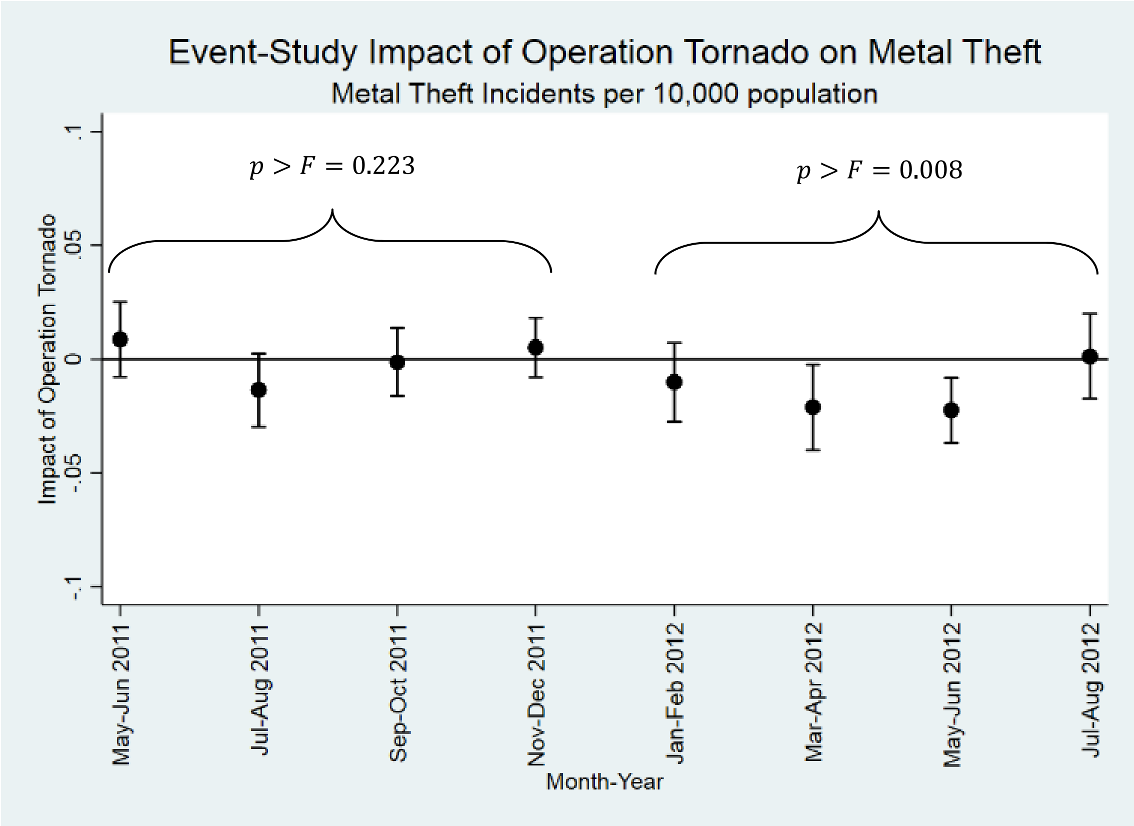

*Notes*: Monthly counts of metal theft were calculated using metal crime records from the British Transport Police in England and Wales. Data from the BTP was available from January 2007 to December 2015. Data on local scrap metal prices in England and Wales was collected from www.letsrecycle.com. The 'Jan 2012' dotted line represents the time of the introduction of Operation Tornado, while the 'Oct 2013' dotted line represents the time of the introduction of the Scrap Metal Dealers Act 2013. Predicted Metal Crime was calculated using data from January 2007 to October 2011, i.e., before any anti-metal crime policing and policy intervention was announced.

**Figure 5. Metal Theft, Difference-In-Differences, 2008 – August 2012.**
**(With Seasonal Differencing)**



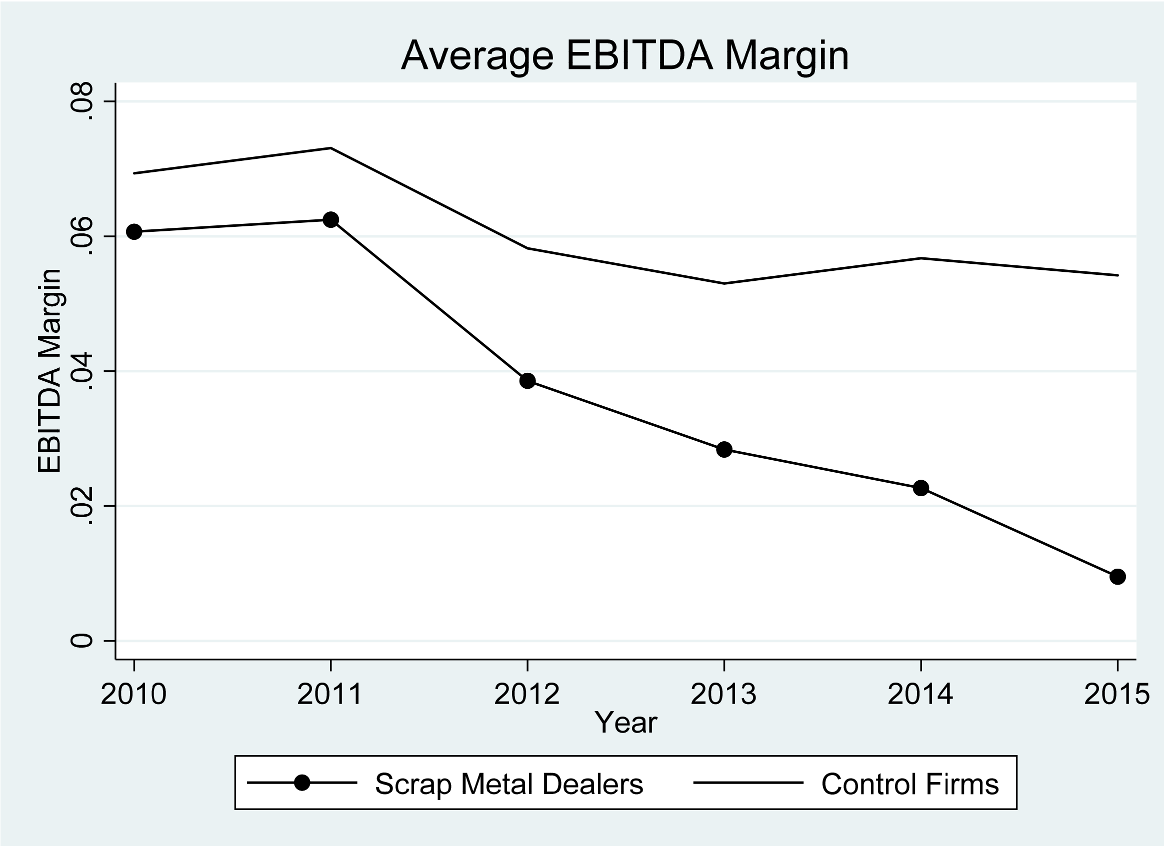

*Notes*: Number of observations: 2408. Post-period defined as starting from January 2012, i.e., the earliest date of adoption of Operation Tornado. Treatment regions (T = 1) defined as police forces of Cleveland, Durham, Northumbria, Humberside, North Yorkshire, South Yorkshire, West Yorkshire, Norfolk, Derbyshire, Leicestershire, Lincolnshire, Northamptonshire, Nottinghamshire, Cheshire, Cumbria, Greater Manchester, Lancashire, Merseyside, Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Suffolk, Hampshire, Kent, Surrey, Sussex, Thames Valley, Avon and Somerset, Devon and Cornwall, Dorset, Gloucestershire, Wiltshire. Untreated Regions (T = 0) defined as Dyfed-Powys, Gwent, North Wales, South Wales, Staffordshire, Warwickshire, West Mercia, West Midlands, Metropolitan Police Service and City of London. Metal theft defined as 12-month differenced total monthly counts of metal thefts per 10,000 population at the police force area level.

**Figure 6. Event-Study OLS Estimates of Impact of Operation Tornado on Metal Theft, 2008 – Aug 2012.**




*Notes*: Post-period defined as starting from January 2012, i.e., the earliest date of adoption of Operation Tornado. Treatment group (T = 1) defined as police forces of Cleveland, Durham, Northumbria, Humberside, North Yorkshire, South Yorkshire, West Yorkshire, Norfolk, Derbyshire, Leicestershire, Lincolnshire, Northamptonshire, Nottinghamshire, Cheshire, Cumbria, Greater Manchester, Lancashire, Merseyside, Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Suffolk, Hampshire, Kent, Surrey, Sussex, Thames Valley, Avon and Somerset, Devon and Cornwall, Dorset, Gloucestershire, Wiltshire. Comparison group (T = 0) defined as Dyfed-Powys, Gwent, North Wales, South Wales, Staffordshire, Warwickshire, West Mercia, West Midlands, Metropolitan Police Service and City of London. Metal theft defined as total monthly counts of metal thefts per 10,000 population at the police force area level. Regressions weighted by population at the police force area level. Reported dots are point estimates and capped bars are 95 percent confidence intervals.

**Figure 7. Average EBITDA Margin for Scrap Metal Dealers and Control Firms in England and Wales, 2010 – 2015.**




*Notes*: Figure 7 reports average EBITDA Margin for treatment and control firms by year. Treatment group (T = 1) defined as scrap metal dealers. Comparison group (T = 0) defined as pawnshops and all other businesses involved in the collection of non-hazardous waste, recovery of sorted materials, wholesale of metals and metal ores and wholesale of waste. Only firms that were still active at the time of writing, i.e., early 2018, and for which complete data was available from 2010 to 2015 were included in the analysis. EBITDA Margin was calculated as Operating Profit / Turnover. Operating Profit equals Gross Profit - Administration Expenses + Other Operating Income/Costs pre OP + Exceptional Items pre OP. Turnover includes both national and international turnover.

**Table 1. Estimates of Metal Crime-Price Elasticities, 2008 to 2015.**

| | Panel A | | | | Panel B | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | OLS | OLS Reduced Form | First Stage | IV Structural Form | OLS | OLS Reduced Form | First Stage | IV Structural Form |
| | $Log$ $(Crime)$ | $Log$ $(Crime)$ | $Log$ $(Scrap\ Price)$ | $Log$ $(Crime)$ | $Log$ $(Crime)$ | $Log$ $(Crime)$ | $Log$ $(Scrap\ Price)$ | $Log$ $(Crime)$ |
| **A. BTP Data, England and Wales** | | | | | | | | |
| $Log(Scrap\ Price)$ | 1.673*** | | | 1.875*** | 0.900*** | | | 1.044*** |
| | (0.168) | | | (0.190) | (0.146) | | | (0.164) |
| $Log(World\ Price)$ | | 2.090*** | 1.115*** | | | 1.146*** | 1.098*** | |
| | | (0.150) | (0.090) | | | (0.131) | (0.096) | |
| **B. BTP Data, London** | | | | | | | | |
| $Log(Scrap\ Price)$ | 2.181*** | | | 2.524*** | 1.473*** | | | 1.645*** |
| | (0.252) | | | (0.295) | (0.196) | | | (0.248) |
| $Log(World\ Price)$ | | 2.813*** | 1.115*** | | | 1.805*** | 1.098*** | |
| | | (0.290) | (0.090) | | | (0.260) | (0.096) | |
| **C. MPS Data, London** | | | | | | | | |
| $Log(Scrap\ Price)$ | 1.849*** | | | 2.018*** | 1.435*** | | | 1.449*** |
| | (0.173) | | | (0.185) | (0.166) | | | (0.183) |
| $Log(World\ Price)$ | | 2.250*** | 1.115*** | | | 1.591*** | 1.098*** | |
| | | (0.165) | (0.090) | | | (0.207) | (0.096) | |
| F-Statistic | | | 127.94 | | | | 74.99 | |
| Linear Time Trend | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| $\Delta_{12}$ Differenced | No | No | No | No | Yes | Yes | Yes | Yes |
| Number of Months | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |

*Notes*: Metal theft defined as (Log) total monthly counts of total thefts. Newey-West standard errors are reported in parentheses. *** indicates significance at the 1 percent level. ** indicates significance at the 5 percent level. * indicates significance at the 10 percent level.

**Table 2. Estimates of Metal Crime, Price and Labour Market Elasticities, 2008 to 2015.**

| | BTP Data, England and Wales | | BTP Data, London | | MPS Data, London | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | IV Structural Form | IV Structural Form | IV Structural Form | IV Structural Form | IV Structural Form | IV Structural Form |
| | $Log\ (Crime)$ | $Log\ (Crime)$ | $Log\ (Crime)$ | $Log\ (Crime)$ | $Log\ (Crime)$ | $Log\ (Crime)$ |
| $Log(Scrap\ Price)$ | 0.907*** | 0.527*** | 1.299*** | 0.977*** | 0.741*** | 0.449*** |
| | (0.170) | (0.119) | (0.371) | (0.315) | (0.123) | (0.112) |
| $Log\ (Male\ Unemployment)$ | 0.495*** | -0.044 | 0.502 | 0.308 | 0.272*** | 0.008 |
| | (0.166) | (0.185) | (0.305) | (0.370) | (0.087) | (0.101) |
| $Log\ (Lagged\ Metal\ Theft)$ | 0.477*** | 0.579*** | 0.419*** | 0.447*** | 0.623*** | 0.749*** |
| | (0.103) | (0.075) | (0.111) | (0.110) | (0.053) | (0.057) |
| Long Run $Log(Scrap\ Price)$ | 1.734*** | 1.250*** | 2.235*** | 1.767*** | 1.966*** | 1.786*** |
| | (0.226) | (0.238) | (0.412) | (0.418) | (0.304) | (0.299) |
| Linear Time Trend | Yes | Yes | Yes | Yes | Yes | Yes |
| $\Delta_{12}$ Differenced | No | Yes | No | Yes | No | Yes |
| Number of Months | 96 | 96 | 96 | 96 | 96 | 96 |
| $Log\ (Scrap\ Price)$ | 0.905*** | 0.553*** | 1.788*** | 1.511*** | 0.860*** | 0.351** |
| | (0.206) | (0.143) | (0.504) | (0.389) | (0.144) | (0.139) |
| $Log\ (Male\ Unemployment)$ | 0.566 | -0.047 | 0.363 | 0.585 | 0.165 | -0.131 |
| | (0.382) | (0.305) | (0.469) | (0.482) | (0.138) | (0.136) |
| $Log\ (Lagged\ Metal\ Theft)$ | 0.388*** | 0.410*** | 0.235* | 0.265** | 0.414*** | 0.768*** |
| | (0.125) | (0.101) | (0.133) | (0.113) | (0.070) | (0.101) |
| Long Run $Log(Scrap\ Price)$ | 1.479*** | 0.937*** | 2.336*** | 2.054*** | 1.469*** | 1.516*** |
| | (0.279) | (0.245) | (0.544) | (0.492) | (0.235) | (0.383) |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| $\Delta_{12}$ Differenced | No | Yes | No | Yes | No | Yes |
| Number of Months | 96 | 96 | 96 | 96 | 96 | 96 |

*Notes*: Metal theft defined as (Log) total monthly counts of total thefts. Newey-West standard errors are reported in parentheses. *** indicates significance at the 1 percent level. ** indicates significance at the 5 percent level. * indicates significance at the 10 percent level.

**Table 3. Timeline of Roll Out of Operation Tornado.**

| Start Date | Region<br>(Local Police Forces) |
|---|---|
| **03 January 2012** | **North East**<br>(Cleveland, Durham, Northumbria) |
| **02 April 2012** | **Yorkshire and the Humber**<br>(Humberside, North Yorkshire, South Yorkshire, West Yorkshire), Norfolk. |
| **03 April 2012** | **East Midlands**<br>(Derbyshire, Leicestershire, Lincolnshire, Northamptonshire, Nottinghamshire). |
| **09 May 2012** | **North West**<br>(Cheshire, Cumbria, Greater Manchester, Lancashire, Merseyside). |
| **11 June 2012** | **Eastern**<br>(Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Suffolk). |
| **25 June 2012** | **South East and South West**<br>(Hampshire, Kent, Surrey, Sussex, Thames Valley, Avon and Somerset, Devon and Cornwall, Dorset, Gloucestershire, Wiltshire). |
| **01 September 2012** | **Wales**<br>(Dyfed-Powys, Gwent, North Wales, South Wales) |
| **10 September 2012** | **West Midlands**<br>(Staffordshire, Warwickshire, West Mercia, West Midlands) |
| **17 September 2012** | **London**<br>(Metropolitan Police Service, City of London) |

**Table 4. Metal Theft, Difference-In-Differences, 2008 – August 2012.**

Dependent Variable: Metal Theft Incidents per 10,000 population

Early Adopters vs Late Adopters

| | | **Panel A Not Seasonally Differenced** | | | **Panel B Seasonally Differenced** | | |
|---|---|---|---|---|---|---|---|
| | | Not Seasonally Differenced | | | Seasonally Differenced | | |
| | All | Total | | Difference | Total | | Difference |
| | | Pre | Post | (post-pre) | Pre | Post | (post-pre) |
| | | (1) | (2) | (3) | (4) | (5) | (6) |
| Treated Police Forces | 33 | 0.032 | 0.020 | -0.012 | 0.003 | -0.024 | -0.027 |
| Late Adopters | 10 | 0.028 | 0.027 | -0.001 | 0.004 | -0.011 | -0.015 |
| Difference-in-differences | | | | -0.011***<br>(0.004) | | | -0.012**<br>(0.004) |

*Notes*: Number of observations: 2408. Post-period defined as starting from January 2012, i.e., the earliest date of adoption of Operation Tornado. Treatment group (T = 1) defined as police forces of Cleveland, Durham, Northumbria, Humberside, North Yorkshire, South Yorkshire, West Yorkshire, Norfolk, Derbyshire, Leicestershire, Lincolnshire, Northamptonshire, Nottinghamshire, Cheshire, Cumbria, Greater Manchester, Lancashire, Merseyside, Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Suffolk, Hampshire, Kent, Surrey, Sussex, Thames Valley, Avon and Somerset, Devon and Cornwall, Dorset, Gloucestershire, Wiltshire. Comparison group (T = 0) defined as Dyfed-Powys, Gwent, North Wales, South Wales, Staffordshire, Warwickshire, West Mercia, West Midlands, Metropolitan Police Service and City of London. Metal theft defined as total monthly counts of metal thefts per 10,000 population at the police force area level. Newey-West standard errors are reported in parentheses. *** Difference-in-Differences statistically significant at the 1 percent level. ** Difference-in-Differences statistically significant at the 5 percent level. * Difference-in-Differences statistically significant at the 10 percent level.

**Table 5. OLS Estimates of Impact of Operation Tornado on Metal Theft, 2008 – August 2012.**

| | Dependent Variable: Metal Theft Incidents per 10,000 population | | | | |
|---|---|---|---|---|---|
| | (a) | (b) | (c) | (d) | (e) |
| OT x Post | -0.011*** (0.003) | -0.011*** (0.003) | -0.009** (0.003) | -0.013*** (0.005) | |
| Metal Price (X 100) | 0.003*** (0.000) | | | | |
| OT x Pre 4 | | | | | 0.009 (0.008) |
| OT x Pre 3 | | | | | -0.014* (0.008) |
| OT x Pre 2 | | | | | -0.001 (0.008) |
| OT x Pre 1 | | | | | 0.005 (0.007) |
| OT x Post 1 | | | | | -0.010 (0.009) |
| OT x Post 2 | | | | | -0.021** (0.010) |
| OT x Post 3 | | | | | -0.022*** (0.007) |
| OT x Post 4 | | | | | 0.001 (0.009) |
| Mean Dep. Var. Pre | 0.031 | 0.031 | 0.031 | 0.031 | 0.031 |
| PFA FE | Yes | Yes | Yes | Yes | Yes |
| Month-Year FE | No | Yes | Yes | Yes | Yes |
| PFA-Specific Trends | No | No | Yes | Yes | Yes |
| Seasonal Differencing | No | No | No | Yes | Yes |
| No. of Observations | 2408 | 2408 | 2408 | 2408 | 2408 |
| No. of PFAs | 43 | 43 | 43 | 43 | 43 |

*Notes*: Post-period defined as starting from January 2012, i.e., the earliest date of adoption of Operation Tornado. Treatment group (T = 1) defined as police forces of Cleveland, Durham, Northumbria, Humberside, North Yorkshire, South Yorkshire, West Yorkshire, Norfolk, Derbyshire, Leicestershire, Lincolnshire, Northamptonshire, Nottinghamshire, Cheshire, Cumbria, Greater Manchester, Lancashire, Merseyside, Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Suffolk, Hampshire, Kent, Surrey, Sussex, Thames Valley, Avon and Somerset, Devon and Cornwall, Dorset, Gloucestershire, Wiltshire. Comparison group (T = 0) defined as Dyfed-Powys, Gwent, North Wales, South Wales, Staffordshire, Warwickshire, West Mercia, West Midlands, Metropolitan Police Service and City of London. Metal theft defined as total monthly counts of metal thefts per 10,000 population at the police force area level. Regressions weighted by population at the police force area level. Newey-West standard errors are reported in parentheses. *** Difference-in-Differences statistically significant at the 1 percent level. ** Difference-in-Differences statistically significant at the 5 percent level. * Difference-in-Differences statistically significant at the 10 percent level.

## Table 6. Difference-in-Differences Before and After the SMDA 2013.

| | Scrap Metal Dealers<br><br>(treatment group) | Other firms involved in collection, recovery and wholesale of other waste<br>(control group) | Treatment – Control Firms | Unconditional DiD Estimate |
|---|---|---|---|---|
| | (1) | (2) | (3) =<br>(1) – (2) | (4) |
| **A. Turnover (Log)** | | | | |
| Pre-Period | 9.943 | 9.823 | 0.120 | DiD = |
| Post-Period | 9.812 | 9.882 | -0.070 | -0.190*** |
| Post - Pre | -0.131 | 0.059 | | (0.057) |
| Number of Firms | 31 | 307 | | |
| **B. Turnover per Employee (Log)** | | | | |
| Pre-Period | 6.370 | 6.199 | 0.171 | DiD = |
| Post-Period | 6.159 | 6.148 | 0.011 | -0.160*** |
| Post - Pre | -0.211 | -0.051 | | (0.053) |
| Number of Firms | 26 | 255 | | |
| **C. EBITDA Margin** | | | | |
| Pre-Period | 0.048 | 0.063 | -0.015 | DiD = |
| Post-Period | 0.016 | 0.055 | -0.039 | -0.024** |
| Post - Pre | -0.032 | -0.008 | | (0.010) |
| Number of Firms | 30 | 258 | | |

Notes: Table 6 shows the results of an unconditional difference-in-differences exercise comparing our outcomes of interest before and after the Scrap Metal Dealers Act 2013 in scrap metal dealers and control group firms. Post-period defined as starting from the fiscal year 2014. Treatment group (T = 1) defined as scrap metal dealers. Comparison group (T = 0) defined as pawnshops and all other businesses involved in the collection of non-hazardous waste, recovery of sorted materials, wholesale of metals and metal ores and wholesale of waste. Only firms that were still active at the time of writing, i.e., early 2018, and for which complete data was available from 2010 to 2015 were included in the analysis. Panel A shows the result of this exercise for Turnover (Log). Panel B shows the result of this exercise for Turnover per Employee (Log). Panel C shows the result of this exercise for EBITDA Margin. EBITDA Margin was calculated as Operating Profit / Turnover. Turnover includes both national and international turnover. Operating Profit equals Gross Profit - Administration Expenses + Other Operating Income/Costs pre OP + Exceptional Items pre OP. Newey West standard errors clustered at the firm level are reported in parentheses. * indicates significance at 10 percent, ** indicates significance at 5 percent, *** indicates significance at 1 percent.

**Table 7. OLS Estimates of Impact of SMDA 2013 on the Economic Activity of Scrap Metal Dealers in England and Wales, 2010 – 2015.**

| | Dependent Variable: Turnover (Log) | | | Dependent Variable: Turnover / Number of Employees (Log) | | | Dependent Variable: EBITDA Margin (Operating Profit / Turnover) | | |
|---|---|---|---|---|---|---|---|---|---|
| | (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) |
| SMD x Post | -0.190*** | -0.190*** | -0.217*** | -0.159*** | -0.159*** | -0.180*** | -0.023** | -0.023** | -0.027** |
| | (0.057) | (0.057) | (0.050) | (0.053) | (0.053) | (0.050) | (0.010) | (0.010) | (0.011) |
| Mean Dep. Var. Pre | 9.834 | 9.834 | 10.146 | 6.215 | 6.215 | 6.195 | 0.062 | 0.062 | 0.060 |
| Year FE | No | Yes | Yes | No | Yes | Yes | No | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| No. of Observations | 2028 | 2028 | 1506 | 1686 | 1686 | 1506 | 1728 | 1728 | 1506 |
| No. of Firms | 338 | 338 | 251 | 281 | 281 | 251 | 288 | 288 | 251 |

*Notes*: Post-period defined as starting from the fiscal year 2014. Treatment group (T = 1) defined as scrap metal dealers. Comparison group (T = 0) defined as pawnshops and all other businesses involved in the collection of non-hazardous waste, recovery of sorted materials, wholesale of metals and metal ores and wholesale of waste. Only firms that were still active at the time of writing, i.e., early 2018, and for which complete data was available from 2010 to 2015 were included in the analysis. Turnover includes both national and international turnover. Operating Profit equals Gross Profit - Administration Expenses + Other Operating Income/Costs pre OP + Exceptional Items pre OP. Newey-West standard errors clustered at the firm level are reported in parentheses. *** Difference-in-Differences statistically significant at the 1 percent level. ** Difference-in-Differences statistically significant at the 5 percent level. * Difference-in-Differences statistically significant at the 10 percent level.

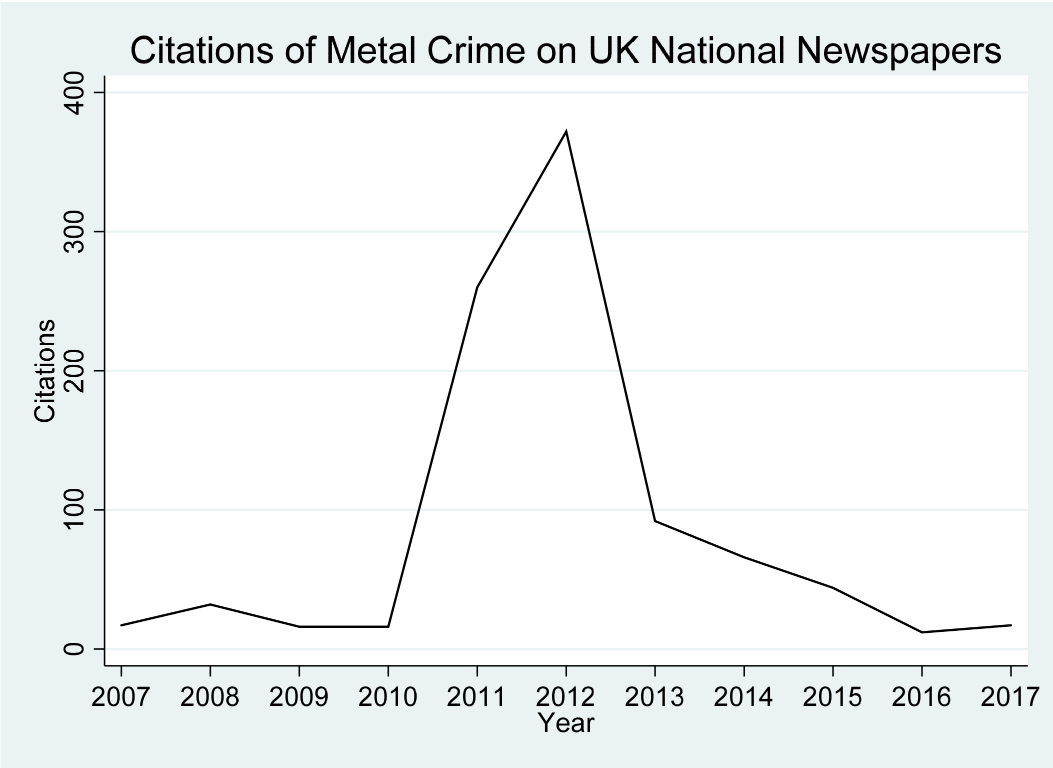
**Table 8. Event-Study Estimates of Impact of SMDA 2013 on the Economic Activity of Scrap Metal Dealers in England and Wales, 2010 – 2015.**

| Dependent Variable: | Turnover (Log) | | Turnover / Number of Employees (Log) | | EBITDA Margin (Operating Profit / Turnover) | |
|---|---|---|---|---|---|---|
| | (a) | (b) | (c) | (d) | (e) | (f) |
| SMD x Pre 2 | 0.081 | 0.081 | 0.033 | 0.033 | -0.010 | -0.010 |
| | (0.053) | (0.053) | (0.056) | (0.056) | (0.007) | (0.007) |
| SMD x Pre 1 | -0.045 | -0.045 | -0.065 | -0.065 | -0.015 | -0.015 |
| | (0.063) | (0.063) | (0.057) | (0.057) | (0.012) | (0.012) |
| SMD x Post | -0.181** | | -0.167** | | -0.030*** | |
| | (0.074) | | (0.068) | | (0.011) | |
| SMD x Post 1 | | -0.106* | | -0.111 | | -0.024** |
| | | (0.064) | | (0.068) | | (0.011) |
| SMD x Post 2 | | -0.255*** | | -0.222*** | | -0.035** |
| | | (0.095) | | (0.079) | | (0.015) |
| Mean Dep. Var. Pre | 9.779 | 9.779 | 6.204 | 6.204 | 0.070 | 0.070 |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| No. of Observations | 2028 | 2028 | 1686 | 1686 | 1728 | 1728 |
| No. of Firms | 338 | 338 | 281 | 281 | 288 | 288 |

*Notes*: Post-period defined as starting from the fiscal year 2014. Treatment group (T = 1) defined as scrap metal dealers. Comparison group (T = 0) defined as pawnshops and all other businesses involved in the collection of non-hazardous waste, recovery of sorted materials, wholesale of metals and metal ores and wholesale of waste. Only firms that were still active at the time of writing, i.e., early 2018, and for which complete data was available from 2010 to 2015 were included in the analysis. Turnover includes both national and international turnover. Operating Profit equals Gross Profit - Administration Expenses + Other Operating Income/Costs pre OP + Exceptional Items pre OP. Newey-West standard errors clustered at the firm level are reported in parentheses. *** Difference-in-Differences statistically significant at the 1 percent level. ** Difference-in-Differences statistically significant at the 5 percent level. * Difference-in-Differences statistically significant at the 10 percent level.

## APPENDIX

**Figure A1. Citations of Metal Theft and Metal Crime in UK National Newspapers From 2007 to 2017**




*Notes*: Citations of metal theft and metal crime for every year were calculated using LexisNexis (www.nexis.com) from January 2007 to December 2017.

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