Crime Highways: the Effect of Motorway Expansion on Burglary Rates

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Abstract

A high-quality road network promotes trade between regions, but burglars can exploit this connectivity because it reduces the time needed to travel to distant destinations which decreases the time in transit with stolen goods. To study the effect of motorway connections on burglary rates, spatial variation in connectivity to the motorway network and the timing of new connections are exploited using an annual panel of 562 police sub districts in Ireland during 2004-15. On average, connection to the motorway network causes a 10% rise (5 burglaries) in the burglary rate in sub districts. The rise in crime occurs temporarily in the year of connection, as no persistent effect is found on the level of crime. An estimated 12,150 burglaries were caused by motorway expansion. This paper shows for the first time that major road construction affects the spatial distribution of crime. The results highlight the need to account for the negative crime externalities of an unpoliced motorway network.

JEL classification: K42, R41
Keywords: roads, property crime, organised crime

1. Introduction

Transport infrastructure is an integral component of the production and consumption process because it helps goods move between locations. The transfer of goods is also required in criminal activity, such as the relocation of stolen goods to the market where they are traded for cash. There is a large literature that documents how transport infrastructure construction reduces trade costs and shapes economic outcomes, such as trade flows, population density and household commuting (Atack et al.,

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This paper studies the causal effect of connections to the motorway network on burglary rates in the (Republic of) Ireland. Motorways are the highest standard of road in Ireland and analysis from the Irish police service details how specialized burglary gangs are exploiting the motorways connectivity to burglar distant targets while evading police detection\(^2\). The empirical analysis in this paper uses a spatially detailed dataset that links motorway connections to burglary rates at a fine spatial dimension, consisting of 562 police sub districts and access to motorway junctions during 2004-15. The combination of the spatial variation in motorway connectivity, the timing of new connections and the inclusion of geographically detailed fixed effects creates exogenous variation in motorway connections. Sub districts are considered connected to the motorway network if there is a motorway junction within a \(\leq 30\)km’s radius of the centroid (centre). All motorways in Ireland, except one, connect to the capital city of Dublin. Therefore, connection to the motorway network intrinsically measures connection to Dublin City. This is important because Dublin is presumably where the majority of the trade in stolen goods takes place. To supplement the empirical analysis, a simple theoretical framework incorporating insights from the traditional Becker (1968) crime model outlines how motorways affect the criminal location choice, by affecting the probability of being caught.

This paper finds that new connections to the motorway network causes 5 burglaries in the average sub district, which equates to a 10% rise in the sub district burglary rate. The effect is small but this is expected because sub districts are geographically small units and presumably burglars seeking to evade police attention will disperse the location of their crimes. The rise in burglaries caused by motorway expansion is temporary, occuring in the year of connection only, as no statistically significant effect is found in the succeeding years. It is estimated that 12,150 burglaries were committed because of motorway expansion. The immediate response of burglars to motorway expansions is a curious result. A possible explanation is that the probability of being caught by the police is lowest in areas recently connected to the motorway network, because motorway-related burglaries have not happened yet and so police vigilance has not been initiated. Even if the police are alerted, it will take time for policing action to be organised and implemented. Criminals may exploit their ability to react quicker to insufficient policing, in comparison to that of the police force. The causal relationship with motorway connections is unique to burglary, and no effect is found among

\(^2\) See “An Garda Síochána Launches National Anti-Crime Strategy” available at http://garda.ie/Controller.aspx?Page=15036.
other types of crime such as theft and vandalism. Conceptually, this can be explained by the need to quickly transport bulky stolen goods away from the property, either to storage or to the selling market.

The novelty of this paper is to show that major road construction influences the spatial distribution of crime. This paper argues that the spatial distribution of burglaries is influenced by motorway expansion because motorways reduce a burglars escape time. This paper contributes a new economic outcome to the literature on the economic effects of infrastructure construction, as this is the first paper to causally identify the effect of road construction on crime. There is a large literature that focuses on understanding the way that transportation infrastructure reduces trade costs and how this affects economic activity. The empirical literature provides causal estimates on the effect of roads, railroads and subways on a range of economic outcomes. Donaldson and Hornbeck (2013) use a sample of U.S counties between 1870-90 and find that counties that receive rail access in a year experience an increase in aggregate agricultural land rent. Baum-Snow et al. (2012) find that railroads and ring road developments caused industrial production to move to the suburbs of large cities. The trade literature has generally focused on the transportation of goods, but other studies find transport costs are important in the movement of people. For example, Duranton and Turner (2011) find that driving increases by about 1% for each 1% increase in the stock of roadways. This paper also contributes to the literature on criminal location choice by showing that burglars take into account the layout major roads when deciding where to commit offences. There previous economic literature on the location of criminal activity, and criminology literature on the location of burglaries (Cracolici and Uberti, 2008; Glaeser and Sacerdote, 1999; Fabricant, 1979; Bernasco and Luykx, 2003; Fabricant, 1979; Polvi, Looman, Humphries, & Pease, 1991).

To note, this paper focuses on the importance of the motorway network to burglars, but the results do not show the relative unimportance of the layout of lower level roads, such as local roads. Even when using the motorway, a burglar must interact with lower level roads to travel to destinations (Brantingham and Brantingham, 1981). The key insight is that motorways provide a high-level of connectivity that other road types do not, and this special function is exploited by burglars to allow them to geographically expand their operations to maximise their return. For policymakers, the findings identify that there can be negative crime externalities generated by major road developments. Policymakers should incorporate the externality into any cost-benefit analysis of future road infrastructure developments. The main cost is the need for immediate targeted law enforcement on all new major roads to reduce the externality, such as police checkpoints at
Concerns about potential endogeneity are relaxed using detailed robustness checks. Firstly, a major potential source of endogeneity is the endogenous placement of motorways, as motorways are generally placed in areas of strong economic growth. However, connections to randomly postponed motorway junctions yield no statistically significant effect on burglary rates. Secondly, the uniqueness of the causal relationship between motorway connections and burglary rates over other crime types, suggests that there is no omitted variable bias present. Thirdly, the main result is robust to the inclusion of a control variable measuring local economic activity.

The analysis is extended to show that motorway targeted law enforcement in 2016 was successful in reducing burglaries nationwide. This provides additional weight to the argument that motorways are affecting the location of burglaries. Furthermore, the new policing measures were launched after a period of no motorway growth, suggesting that burglars continue to exploit motorways in the years after connection. It is very likely that burglar’s return to previously targeted areas after a period of time, but the revisitation does not appear to be patterned with the year of motorway connection, making it difficult to quantify in this paper. It is for this reason that this paper does not provide an estimation of all motorway-related burglaries and focuses instead on the immediate aftermath of motorway expansion. Due to this, the estimated overall value of stolen items gained from motorway-related burglaries cannot be compared to the cost of the motorway. In 2007, the average value of goods stolen from break-ins in Ireland was estimated to be €5,390 ($7,450)\(^3\). Multiplying this figure with the estimated 12,150 motorway burglaries caused by the initial motorway expansion, €72 million was stolen by burglary gangs. This is a small percentage of the total cost of the motorway (€8billion or $9.8billion), but it is still a significant amount of wealth to be forcibly redistributed from many households and to be held in the hands of a small number of individuals\(^4\).

An important aspect to the rise in burglaries near new motorways is whether motorway expansion increases the amount of burglary activity in the economy or whether it relocates existing burglaries\(^5\). No formal test is conducted, but it is hypothesized that motorways are the artery to attractive crime locations, rather than increasing the stock of burglaries nationwide. The major indication of

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\(^3\) In 2007, Eircom Phonewatch estimated that the average value of goods stolen from each home during a burglary is €5,930 see “House thefts total €86m in a year” available at https://www.irishtimes.com/news/house-thefts-total-86m-in-a-year-1.813645.

\(^4\) See “Total cost of motorway links to Dublin €8bn – NRA” available at https://www.irishtimes.com/news/total-cost-of-motorway-links-to-dublin-8bn-nra-1.667286.

\(^5\) Chandra and Thompson (2000) find that highways affect the spatial allocation of economic activity by drawing existing activity towards counties that receive the highway. While Banerjee et al. (2012) find that transportation infrastructure affects the level of output, but has no effect on its growth.
reorganisation is that the number of burglaries in Ireland remains relatively steady between years (see figure 2), despite vast motorway growth. Secondly, the rise in burglaries occurs temporarily, suggesting that the criminals are committing the same crimes each year, but in different locations. Thirdly, it is intuitive that motorways do not induce criminal activity, because by virtue of the criminal tracking motorway expansions, they are signaling premeditation, intent to commit a crime and some level of organisation. Indeed, the Irish police service have outlined that specialized burglary gangs are committing the burglaries, rather than petty criminals. Fourthly, the motorway burglaries coincide with a period of rising burglaries across the European Union, so the inducement into burglary activity is likely driven by international factors. Recent research posits a strong link between recent property crime rates and the change in world prices of metals and other commodities that can be stolen from properties (Draca et al., 2015).

The remainder of the paper is structured as follows. Section 2 discusses the background of organised burglaries and Section 3 outlines the theoretical framework. In Section 4, the data sources and the variables used in the empirical analysis are described. The empirical strategy is described in detail in Section 5. In Section 6, the empirical results are explained and robustness checks are provided in Section 7. Section 8 extends the analysis to the effect of the introduction of anti burglary measures in Ireland, and Section 9 concludes.

2. Background

Approximately one burglary is committed every one and half minutes in the European Union (EU), and some member states register one thousand burglaries per day (Europol, 2017). Organised property crimes carried out by highly specialised and mobile organised crime groups are one of Europol’s priority crime areas under the EU policy cycles of 2014-17 and 2018-21 (EU Commission, 2017). The property crime offences include organised burglaries, thefts, robberies and motor vehicle crimes. Burglary is one of the only crimes in the EU that grew in intensity during 2007 to 2010, rising by approximately 7% in the period (De Stercke et al., 2014). Organised crime tends to conjure up imagery of the traditional Mafia-type models such as the Sicilian Mafia (Hess, 1973; Arlacchi, 1986; Gambetta, 1993). However, a recent EU-funded Organised Crime Portfolio research project shows that removing the prominent Italian criminal networks from the picture, organised

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6 The Irish Government issued a report investigating the rise in burglaries to the rise in the price of gold and the rapid increase in Cash for Gold shops operating across the country, no conclusive evidence was found. See “Report on the Cash for Gold trade” available at www.inis.gov.ie/en/JELR/20120619Report%20on%20the%20Cash%20for%20Gold%20trade.pdf

7 Information regarding the 2014-17 policy cycle is available at “EU Policy Cycle- EMPACT” available at https://www.europol.europa.eu/crime-areas-and-trends/eu-policy-cycle-empact.
Crime groups in Europe are largely similar and reflect a new strand of organised criminal activity (Savona and Riccardi, 2015). Criminal organisations are changing and adapting their strategies by shifting their interests to new areas of activity that are less risky and less violent (Savona and Riccardi, 2015).

Illegal activity in the Irish economy is estimated to 1.1 per cent of GDP and organised crime in Ireland generates at least €1.7billion a year, which is more than the Irish Governments annual spend on the police service in 2016 (Savona and Riccardi, 2015)\(^8\). This is smaller than the 7 per cent of Italian GDP, but it is still one of the highest percentages in the EU (Savona and Riccardi, 2015; UNODC, 2011)\(^9\). The Irish police service has stated that specialized burglary gangs are exploiting the motorways connectivity and speed limits to burgle distant rural targets\(^10\). Figure 1 illustrates that burglary rates are higher in police sub districts closer to the motorway network, relative to more isolated parts of the country. In 2016, the Irish police service launched nationwide measures to reduce motorway-related burglaries, which decreased the number of burglaries nationally by 30%\(^11\). Criminals using motorways as an escape route does not appear to be investigated by police services abroad in the same detail as it has been in Ireland, but it has been cited in crime and media reports for several other EU member states, including the United Kingdom and Belgium\(^12\). The lack of police attention towards motorway burglaries is not necessarily a reflection of a lack of this type of crime in other countries but likely due to the classification of individual burglary incidents as petty criminality (EU Commission, 2017).

The Irish police service estimates that 75% of all burglaries are carried out by 25% of offenders\(^13\). The most common items stolen are jewelry, cash and televisions, and the average amount stolen\(^14\). There are at least seven criminal gangs involved in the burglaries, with one gang committing up to

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8 See ‘Organised crime in Republic worth at least €1.7bn annually’ available at www.irishtimes.com/news/crime-and-law/organised-crime-in-republic-worth-at-least-1-7bn-annually-1.2848801.
9 The top 7 are Ireland, Spain, France, Italy, Netherlands, Finland, and the United Kingdom.
10 See “An Garda Síochána Launches National Anti-Crime Strategy” available at http://garda.ie/Controller.aspx?Page=15036.
11 Details about the National Anti-Crime Strategy are available at: http://garda.ie/Controller.aspx?Page=15036.
12 For Belgium see http://www.domesticburglary.eu/, and for the United Kingdom see https://www.theguardian.com/business/2017/jan/24/ilford-highest-burglary-uk-moneysupermarket-insurance-cambridge-manchester.
13 See “An Garda Siochána Launches National Anti-Crime Strategy” available at http://garda.ie/Controller.aspx?Page=15036.
14 See ‘Home Burglary Stats in Ireland’ available at https://www.homesecure.ie/home-burglary-stats-ireland/
25 burglaries per week, and therefore multiple burglaries per day\textsuperscript{15}. Unlike traditional Mafia-type
gangs, these gangs do not appear to compete territorially with another, but instead they cooperate by

\textbf{Figure 1.}

Burglary rates in police sub districts and the motorway network in 2015

selling information to rival gangs\textsuperscript{16}. The burglars exhibit a preference for targeting rural areas,
presumably because police presence is much lower than in urban areas\textsuperscript{17}. Flying drones, night
vision goggles and high-powered armored cars are among the tactics used by the professional

\textsuperscript{15}See “Ireland’s burglary gangs: The dirty half dozen who have created a climate of fear”, available at:
http://www.sundayworld.com/news/crimedesk/irelands-burglary-gangs-the-six-who-have-created-a-climate-of-fear,
retrieved and http://www.independent.ie/irish-news/courts/highly-sophisticated-eastern-european-thieves-making-a-
fortune-in-burglaries-targeting-rural-ireland-35605436.html

\textsuperscript{16}See “Gardai alert over postbox burglars” available at https://www.irishmirror.ie/news/irish-news/crime/gangs-
travelling-burglars-posting-stolen-1806747

\textsuperscript{17}Approximately 30\% of Ireland’s population lives in County Dublin and so policing resources are concentrated there.
Furthermore, a recent media report details how rural burglars receive lighter sentences. See “A new sense of fear is
stalking rural Ireland as people’s sense of isolation reaches dangerous levels” https://www.independent.ie/irish-
news/news/a-new-sense-of-fear-is-stalking-rural-ireland-as-peoples-sense-of-isolation-reaches-dangerous-levels-
35497924.html, and “Why do rural burglars receive lighter sentences than Dublin ones?” available at:
https://www.irishtimes.com/news/crime-and-law/why-do-rural-burglars-receive-lighter-sentences-than-dublin-ones-
1.3352167?mode=sample&auth-failed=1&pw-origin=https%3A%2F%2Fwww.irishtimes.com%2Fnews%2Fcrime-and-
law%2Fwhy-do-rural-burglars-receive-lighter-sentences-than-dublin-ones-1.3352167.
burglars to select targets and to escape\textsuperscript{18}. Although based in Irish cities, the criminal gangs have connections across the country and often hire local informants to carry out reconnaissance missions to scope out targets\textsuperscript{19}. The burglars are not all Irish residents and one of the gangs travelled to Ireland from Eastern Europe\textsuperscript{20}. The Irish police have detailed how it is difficult to catch these travelling burglars because they often offload their stolen loot as quickly as possible. In some cases, they travel immediately from the crime location to the selling market\textsuperscript{21}. In other cases, they store the stolen items; they put stolen items into padded envelopes and post them to a pre-arranged address, or they store the goods in wheelie bins over night\textsuperscript{22}.

3. Theoretical framework

The economic analysis of criminal behaviour is based on the premise that criminals are concerned with maximizing profit and avoiding detection. The economic incentives of crime are rooted in Becker’s (1968) seminal contribution and later extended by Ehrlich (1973). In the model an individual decides to commit a crime if the expected benefits from the crime are greater than the expected costs. The model has mainly been applied to property crimes, and a small literature has applied the model to violent crimes (Grogger, 2000). A simple framework is presented in this Section that adopts insights from the Becker model, to provide the basis to expect the allocation of burglaries to areas near a motorway. The decision to commit a burglary is outlined first, followed by the choice of crime location.

3.1 The decision to commit a burglary

A risk neutral agent (i) decides whether or not to commit a burglary by calculating the average expected profit (\(\pi\)) per burglary offence:

\[\pi = \text{Average expected profit per burglary offence}\]

\textsuperscript{18} This information was found in the following three newspaper articles: http://www.independent.ie/irish-news/news/burglary-thugs-have-night-vision-goggles-highpowered-cars-and-no-fear-of-gardai-30691784.html and http://www.independent.ie/irish-news/news/burglary-thugs-have-night-vision-goggles-highpowered-cars-and-no-fear-of-gardai-30691784.html and http://www.herald.ie/news/night-vision-assault-rifles-body-armour-gardai-are-outgunned-29245443.html

\textsuperscript{19} ibid.

\textsuperscript{20} See "Highly sophisticated' Eastern European thieves making a fortune in burglaries targeting rural Ireland", available at https://www.independent.ie/irish-news/courts/highly-sophisticated-eastern-european-thieves-making-a-fortune-in-burglaries-targeting-rural-ireland-35605436.html.

\textsuperscript{21} See “Gardai alert over postbox burglars” available at https://www.irishmirror.ie/news/irish-news/crime/gangs-travelling-burglars-posting-stolen-1806747

\textsuperscript{22} ibid.
\[ (1) \pi_i = P_i(Y_i - F_i) + Y_i(1 - P_i) \]

\( P \) is the probability of being caught and convicted, \( Y \) is the resale value of the stolen goods and \( F \) is the extent of the punishment. \( \pi \) is falling in \( P \) and \( F \), and rising in \( Y^{23} \). The first term on the right hand side of equation 1 is the expected gain from committing a crime that results in getting caught, while the second term represents the gain from crime that does not end in getting caught. The decision-maker chooses to commit the burglary if the expected profits from committing the offence are greater than earnings from legal work (\( w \)):

\[ (2) \text{Burgle}_i = \begin{cases} 1 & \text{if } \pi_i > w_i \\ 0 & \text{if } w_i > \pi_i \end{cases} \]

3.2 Location choice

If the individual chooses to commit a burglary, they next decide on a location for the crime. To arrive at this decision, the individual first calculates the expected gains of committing a burglary in \( j \) alternative locations\(^{24} \). The probability of being caught and convicted for committing a burglary in \( j \) is:

\[ (3) P_{t,j}(T_{i,j}, E_{i,j}, \varepsilon_{i,j}) \]

\( j = 1, 2, \ldots, k \)

\( T \) is the travel time from the target location to the base address of the individual or the selling-market, \( E \) is the effectiveness of the local police and \( \varepsilon \) is a residual term. The probability of being caught and convicted is rising in \( T \) and \( E \). Motorways connect distant locations through high-speed limits and a lack of traffic barriers, thereby decreasing the time that the individual is in transit with the stolen goods. The less effective the police, the more likely a burglar can evade detection. Policing action affecting the probability of being caught, alongside other factors, will vary by strength

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\(^{23}\)The decision to commit a burglary or theft in a certain area is argued to depend on the trade off between the probability of arrest and the possible stolen goods in the area (Deutsch, Hakim, and Weinblatt 1987; Deutsch and Epstein 1998).

\(^{24}\)This is in line with studies in criminology that argue that burglars follow a multiple-stage decision making process when trying to select a crime location (Bernasco et al., 2017)
The expected profits (\( \pi \)) accumulated from committing a crime in a given
eighbourhood are shown in equation 4. The values of \( Y \) and \( F \) calculated in equation 1 are inputted
into the calculation:

\[
\pi_{i,j} = P_{i,j} (Y_i - F_i) + Y_i (1 - P_{i,j})
\]

The individual chooses to commit the burglary in the location where they can collect the greatest
expected profit. Burgle is a binary variable that equals one when the offence will be committed in
location j, which is conditional on the expected profit in that location being greater than in an
alternative location:

\[
B_{burgle_{i,j}} = \begin{cases} 
1 & \text{if } \pi_{i,j} > \pi_{i,-j} \\
0 & \text{if } \pi_{i,-j} > \pi_{i,j} 
\end{cases}
\]

District diversification can occur if for example travel time from j and police effectiveness in j is
lower than in an alternative neighbourhood.

3.3 Extension

Extending the simple framework in Section 2.2.2 to a population of identical individuals, the number
of burglaries in j is equal to the number of individuals who choose j:

\[
B_{burglaries_j} = \text{Individuals}_j
\]

The theoretical framework is static and per burglary but it can also explain additional offences, as the
decision-maker follows the same process for each subsequent burglary. At every period of time, the
individual updates the value of the parameters and calculates another set of expected payoffs before
deciding where to commit the next burglary. As motorway expansion occurs, the probability of being
catched and convicted changes geographically (decreasing in recently connected areas). Police
effectiveness may also rise in areas connected in the previous period, if motorway-related burglaries

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25 For example, all local police forces might be required to campaign for burglary awareness among residents, but the
strength of this action will be greater the larger the police to population ratio.

26 Deutsch and Epstein (1987) show, using a theoretical model of two districts, that if the expected utility of crime and
the probability of success are higher in one district, then the criminal specializes in this district, and never switches to the
other district.
occurred. As the parameter values change, the chosen location changes. If there is no change in the parameter values then the burglar will commit more than one burglary in the same location.

4. Data

4.1 Geographical layout of policing

According to the 2016 Census, the (Republic of) Ireland has a population of 4.76 million people\textsuperscript{27}. Northern Ireland is a political jurisdiction that is part of the United Kingdom, and is therefore not included in this study. For policing purposes the Ireland is divided into 28 divisions. With the exception of Cork and Dublin, divisions largely coincide with county borders, and the average division population size is 163,866\textsuperscript{28}. These policing divisions are used as the unit of analysis in Section 7. Each policing division is made up of Garda sub districts (SD’s), and in total there are 563 SD’s throughout Ireland with an average population of 8,150. The main analysis in Section 5 uses SD’s as the unit of analysis and the delineation of SD’s is illustrated in figure 1. The SD containing the Aran Islands is excluded from the main analysis because the centroid is located on the Aran Island, which is not connected by a road network. The main analysis uses the remaining 562 SD’s\textsuperscript{29}. Each SD generally has 1 police station, the strength of which varies from 3 to 100 police officers. In some areas there are stations known as sub-stations, which typically feature one officer conducting administrative work adjacent to the parent station\textsuperscript{30}. Dublin City is made up of 9 SD’s, and Dublin County contains 39 SD’s.

4.2 Burglary

An Garda Síochána is the national police service in Ireland and is responsible for policing across the country. As part of their daily duties, police officers are required to record criminal activity on the PULSE system. The data is collated and added to the Garda Síochána Annual Report\textsuperscript{31}. The Central Statistics Office (CSO) is the Government body tasked with publishing the recorded crime statistics

\textsuperscript{27} Census Population returns are available at: http://www.cso.ie/en/census/.
\textsuperscript{28} Cork is split into Cork City, Cork North, and Cork West. Dublin is split into six Dublin Metropolitan Regions: North, South, East, West, North Central, and South Central. The remaining divisions are Cavan/Monaghan, Clare, Donegal, Galway, Kerry, Kildare, Kilkenny/Carlow, Laois/Offaly, Limerick, Louth, Mayo, Meath, Roscommon/Longford, Sligo/Leitrim, Tipperary, Waterford, Westmeath, Wexford, and Wicklow.
\textsuperscript{29} This main result is robust to the exclusion of outliers and SD’s containing inhabited islands.
\textsuperscript{30} See “Geographical Layout” available at http://www.garda.ie/Controller.aspx?Page=2.
\textsuperscript{31} For a detailed explanation of the annual report, see ‘Report of the Expert Group on Crime Statistics’, available at: http://www.justice.ie/en/JELR/ExpertGroupStats.pdf/Files/ExpertGroupStats.pdf.
that are provided on an annual basis for SD’s. In 2015, burglary was the third largest crime type in Ireland and the Irish Crime Classification System (ICCS) defines a burglary as the unauthorized entering of a building or part of a building, either with the intent to commit an offence or having committed an offence. To account for heterogeneity in SD size, the ratio of the absolute number of crimes committed in a SD to the population of the SD is used as the dependent variable (expressed per 10,000 persons). Population statistics for SD’s are only available in 2011, but Section 6.5 shows that the main results are robust to using population data constructed from population growth figures in the 8 regional authority areas in Ireland. The average number of burglaries in a SD is 46 and the average burglary rate is 48 per 10,000 persons (see appendix A).

Figure 2 shows the annual number of burglaries for different parts of Ireland during 2004-15. Appendix A presents the graph in annual changes. The number of burglaries in Ireland peaked in 2012 at 28,133, and was lowest in 2007 at 23,603. Burglaries are concentrated in the Dublin region, accounting for 37% of all burglaries during 2004-15. This is expected given that economic activity is concentrated in Dublin. More burglaries happen in regions served by a motorway, than in non-motorway regions and in Dublin. All regions experience a decrease in the number of burglaries in 2016 and this coincides with the introduction of national anti-burglary policing measures, which are analysed in Section 8.

There are some limitations associated with using Irish crime data that must be considered before analysing criminal activities in Ireland. Firstly, crime counts are often an under representation of the true count, because not all crimes are reported to the police. Furthermore, counting and recording rules typically mean that only the most serious offense is recorded in a criminal transaction. The CSO estimates that 62% of burglaries were reported to the police in 2015, and that burglary was the crime that was most likely to be reported at (73%) (CSO, 2016). Secondly, recorded crimes may be incorrectly categorised or re-categorised. Thirdly, the length of time between reporting a crime and the recording of the crime on the PULSE system could result in the misspecification or omission of crime data. Of course, the use of yearly data will offset this concern to some extent. Lastly, evidence suggests crime data in Ireland is often incorrectly labeled “detected” or “invalidated”. Nevertheless,

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32 Available at http://www.cso.ie/en/statistics/crimeandjustice/. No crime data is available before 2003.
33 ‘Domestic burglary’ is not included separately in the criminal code. See ‘Criminal Justice (Theft and Fraud Offences) Act, 2001’, available at http://www.irishstatutebook.ie/eli/2001/act/50/ /12/. The first and second largest crimes in 2015 were theft and public/social order offences, respectively.
34 The rate of burglaries expressed as a percentage of Ireland’s population is small and thus is not suitable for graphing.
35 These figures are taken from the CSO’s Crime and Victimisation National Household Survey that asks respondents about their experiences with crime.
these issues are systematic and patterns of variance are unlikely to exist across SD’s, or be correlated with motorway expansion.

4.3 Motorway

There is approximately 100,000 km of road network in Ireland. In 2015, there were 12 motorways in Ireland, the highest standard of road, representing 916km of the total road network. In order to construct a measure of motorway access, the location and year of opening of junctions is identified. There is no official database on junction locations so firstly, the name of motorway junctions in Ireland is compiled from a website that lists all motorway exits in Europe36. Secondly, the geographic coordinates for junctions are retrieved from Google Maps. Thirdly, the location of motorway junctions is verified with official documentation illustrating the location of motorway junctions provided by the Irish Roads Authority37. Fourthly, the year each junction opened is retrieved from a website that archives the development of the Irish road network38. All motorways in Ireland form part of a preexisting national primary route, and motorway upgrades happened in segments. In some cases, motorway junctions open before the year the official motorway status is designated to the junction. This means that some road Sections will be functioning as high-quality dual carriageways with motorway characteristics until the status is given. The year the junction opened is used to identify the timing of motorway connections, and not the year of designation39. Despite not being officially designated in some cases, criminals are able to exploit the connectivity and high-speed limits40. The speed limit on Irish motorways is 120 km/h (75 mph)41. To note, no Section of the motorway was downgraded during 2004-15.

Prior to 2004, there were 53 junctions and during 2004-15 84 junctions opened (table 1). The biggest growth years for the motorway network was during 2008-10, when 52% of new junctions opened. Infrastructure funding cuts after the 2008 recession, led to the delay of some motorway upgrades, and so no junctions opened during 2011-14. In 7.1, connections to postponed motorway junctions are used as a placebo test. A SD is considered connected to the motorway network, if there is a

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36 Available at: http://motorways-exitlists.com/
37 Available at: http://www.tii.ie/tii-library/Network_Management/
38 Available at: http://www.irishmotorwayinfo.com/
39 As a robustness check, regressions were also estimated with the opening date specified as one to three years later; there was no statistical significance.
40 As a robustness check, regressions were also estimated with the opening date specified as one to three years later; there was no statistical significance.
41 100 km/h (62 mph) for National Routes (Primary and Secondary) that are not motorway status. 80 km/h (50 mph) for local and regional roads (50 km/h (31 mph) in built up areas).
motorway junction within ≤ 30km’s of the SD’s centroid. See the scale bar in figure 1 for an illustration of 30km’s. Using buffer distances in GIS software, a dummy variable indicating

**Figure 2.**
The number of burglaries each year in Ireland, 2004-16

![Graph showing the number of burglaries each year in Ireland, 2004-16](image)

Notes: Refers to counties with (or without) a motorway in 2016

**Table 1.**
The number of motorway junctions opened and sub districts connected, each year during 2004-15

| Year       | Junctions opened | Sub districts connected |
|------------|------------------|-------------------------|
| Before 2004| 53               | 229                     |
| 2004-15    | 84               | 158                     |
| 2004       | 7                | 40                      |
| 2005       | 11               | 9                       |
| 2006       | 8                | 5                       |
| 2007       | 7                | 16                      |
| 2008       | 10               | 17                      |
| 2009       | 18               | 40                      |
| 2010       | 20               | 31                      |
| 2011-14    | 0                | 0                       |
| 2015       | 3                | 0                       |

Buffer distances up to 50km were attempted. 30km’s was chosen because the effect was largest and of stronger statistical significance.
connection to the motorway network is calculated for each year during 2004-15\textsuperscript{43}. For example, in 2005 a SD’s nearest junction is 45km’s away, and in 2006 motorway expansion places a junction 25km’s away. In 2005, the SD was disconnected from the motorway network, and it became connected in 2006. New connections to the motorway network are then defined as the year the first junction within ≤30km’s opens. Table 1 shows the number of annual motorway connections. A common problem in the transport literature is measurement error related to how road access is measured (Picot et al., 2015). This concern does not apply in this paper because using the geographic coordinates for motorway junctions takes into account the exact spatial distribution and local availability of motorways\textsuperscript{44}.

\textsuperscript{43} Studies find a very high correlation between straight line distances and drive time distances (Boscoe et al., 2012; Phibbs and Luft, 1995). However, exceptions exist near physical barriers (Boscoe et al., 2012). If burglary is always low in SD’s with physical barriers such as rivers, then this will be accounted for in the fixed effect.

\textsuperscript{44} Proximity to motorway junctions is used, rather than proximity to the nearest part of the motorway road, because the exact entry and exit point of criminals is necessary to identify the effect of motorway access.
5. Empirical strategy

The causal effect of motorway connections on burglary rates is analysed using standard panel data methods. The fixed effects estimation takes the following form:

\[
(7) \text{burglary}_{i,t} = \delta + \theta_i + \alpha_t + \beta \Delta \text{connect}_{i,t} + \epsilon_{i,t}
\]

‘burglary’ is the annual burglary rate (per 10,000 persons), \(i\) is the sub district (562) and \(t\) is time (2004-15). ‘connect’ is a dummy variable that takes on the value of 1 when the first junction within a \(\leq 30\text{km}\) radius of the SD’s centroid opens\(^{45}\). An alternative variable (denoted ‘motorway’) indicating the presence of a motorway junction within \(\leq 30\text{km}\) radius is also attempted. Motorway expansion is not the only determinant of burglary location so \(\theta_i\) is included which is a SD fixed effect that removes time invariant unobservable characteristics that vary across SD’s e.g. topography and deprivation. \(\alpha_t\) is a set of year dummies that control for national trends in crime e.g. higher rates of criminal behaviour during a recession (Bell, et al., 2014)\(^{46}\). Standard errors are clustered at the SD level.

As detailed in the theoretical framework in Section 3.2, a positive relationship between motorway connection and the burglary rate is expected. The rationale being that connection to the motorway network allows criminals to escape the SD and reach their destination more quickly. Exploiting the combination of: the spatial variation in motorway connectivity, the timing of new connections and the inclusion of geographically detailed fixed effects, creates exogenous variation in motorway connectivity. This is made possible by the geographically detailed nature of the data, which links sub districts to the motorway at a spatially granular dimension and overtime. Therefore, after adjusting for local and national factors that influence the level of crime, \(\beta\) is interpreted as the causal effect of motorway connections on burglary rates.

The main endogeneity issues revolve around the three common issues experienced in transport infrastructure studies: omitted variable bias, reverse causality and the endogenous placement of roads.

\(^{45}\) An alternative is the year of connection to the nearest junction i.e. the last junction to be placed nearby in the period of analysis. Using this measure, both fixed effects and differences-in-differences specifications are estimated, they yield statistically insignificant results. This is intuitive conceptually, because it is not about how close an area is to motorway junctions, rather the time at which access by the criminal begins. In this paper, accessibility is defined as a junction within 30km radius of the SD.

\(^{46}\) Hargaden (2016) finds a statistically significant positive relationship between property crimes and the unemployment rate in Ireland during 2003-16.
Unobserved effects causing crime may be present that can be time invariant or time varying. In the case of time-invariant effects, using spatially detailed location fixed effects alleviates the concern, but this will not solve the problem of time-variant effects. In Section 7.2, the relationship with motorway connections is shown to be unique to burglary rates, as other types of crimes yield statistically insignificant effects, when used as alternative dependent variables. This provides evidence that the results are reliable because if omitted variable bias were present, other crimes would be effected by the motorway.

The main omitted variable of concern is local changes in economic activity because it varies spatio-temporally. In Section 7.3, the main result is robust to the inclusion of a proxy of local economic activity as a control variable. The uniqueness of the causal relationship of motorways on burglary relaxes reverse causality concerns. For reverse causality to exist, the motorway connections would need to be driven by only burglary rates and no other crime type, which is unlikely. Motorways are generally allocated to specific locations according to unobserved characteristics not orthogonal to their economic potential (Picot et al., 2015). This endogenous placement of motorways might upwardly bias the estimates. This concern is eased because connections to randomly postponed motorway junctions have no statistically significant effect in Section 7.1. If problematic unobserved characteristics at motorway locations are biasing the result, this would be revealed by postponed junctions, because the unobserved variables exist even if the motorway does not yet.

6. Results

Table 2 presents the main results of the effect of motorway connections on burglary rates. The presence of a motorway nearby is measured using the dummy variable ‘motorway’ that equals 1 if there is a motorway junction within $\leq 30$km radius of a SD’s centroid, and 0 for disconnected subdistricts. New connections to the motorway are represented by the dummy variable ‘connect’, which equals 1 in the year a motorway junction is placed within $\leq 30$km radius of a SD’s centroid for the first time i.e. the year of motorway connection, and 0 otherwise. A positive coefficient is expected

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47 Many transport studies use an optimal road network instrumental variable to circumvent endogeneity issues. However, this IV is not easily applied to the panel data in this paper because the majority of the motorway is built in the period of analysis, and do the IV is not capable of exploiting the year-to-year variation.

48 For example, Holtz-Eakin and Schwartz (1994) show that the state-level impact of public capital can be entirely attributed to state-level time invariant unobserved effects.

49 A dummy variable equaling one every time a nearby junction is added was attempted, the coefficients are positive and of a similar magnitude to table 3, but not statistically significant. Distance to motorway junctions and changes in this distance where also attempted as an alternative measure of motorway connection. At the Division level (28), dummy
on both variables because criminals will commit burglaries in SD’s close to the motorway network for ease of escape.

Table 2.
The effect of motorway connections on sub district burglary rates (per 10,000 persons), 2004-15

| Independent Variables | All SD’s (1) Burglary rate | Excluding County Dublin (2) Burglary rate | (3) Burglary rate | (4) Burglary rate |
|-----------------------|---------------------------|----------------------------------|-----------------|-----------------|
| motorway              | -.45                      | -.71                             | (2.05)          | (2.04)          |
| connect               | 4.83***                   | 4.93***                          | (1.69)          | (1.69)          |
| Sub district FE       | YES                       | YES                              | YES             | YES             |
| Year dummies          | YES                       | YES                              | YES             | YES             |
| Standard error        | Clust.                    | Clust.                           | Clust.          | Clust.          |
| R-squared             | 0.94                      | 0.94                             | 0.94            | 0.94            |
| N                     | 6,744                     | 6,744                            | 6,252           | 6,252           |

Notes: ‘motorway’ is a dummy variable indicating the presence of a motorway nearby, and ‘connect’ is a dummy variable indicating the year of connection to the motorway network. ***p<0.01 **p<0.05 *p<0.1. Standard errors are clustered by sub district and are in parentheses. Numbers are rounded to two decimal places where possible.

New connections to the motorway network are statistically significant at 1% and the coefficient is positive as expected. Motorway connections cause 5 burglaries (10%) in the average sub district in the year of connection. On the other hand, the presence of a motorway is negative and is not statistically significant. The effect on burglaries in the year of connection only is verified in 7.4 when lead and lag values of connection are not statistically significant. Although the increase in burglaries is small, it is intuitive because SD’s (562) are geographically small units, and criminals seeking to evade police attention will presumably spread crime across a wide range of SD’s, rather than concentrate criminal activity. Using the estimated effect of 5 burglaries, 12,150 motorway-related burglaries occurred in SD’s in the year they received motorway connection. New connections to the motorway network are statistically significant at 1% and the coefficient is positive as expected. Motorway connections cause 5 burglaries (10%) in the average sub district in the year of connection. On the other hand, the presence of a motorway is negative and is not statistically significant. The effect on burglaries in the year of connection only is verified in 7.4 when lead and lag values of connection are not statistically significant. Although the increase in burglaries is small, it is intuitive because SD’s (562) are geographically small units, and criminals seeking to evade police attention will presumably spread crime across a wide range of SD’s, rather than concentrate criminal activity. Using the estimated effect of 5 burglaries, 12,150 motorway-related burglaries occurred in SD’s in the year they received motorway connection. One might suspect that activity in Dublin city and its surrounding suburbs is driving the result on ‘connect’ because County

variables indicating new motorway connections and the number of junctions were used but no statistical significance was found.

The effect is estimated used 2004-14 because no SD’s became connected to the motorway network after 2010. The average junction has 30 SD’s in a 30km radius of its centroid, and 84 junctions opened during 2004-10. Multiplying these figures with the estimated 5 burglaries per SD provides the total number of burglaries caused by motorway expansion.
Dublin is the main motorway node of Ireland, economic activity in the County accounts for 45% of national GDP and approximately 40% of burglaries occurred there during 2004-15. However, this is not the case as connections are robust to the exclusion of County Dublin (column 4)\textsuperscript{51}.

The immediate response of burglars to motorway connections shows that recent motorway improvements form part of the criminals risk assessment when choosing the location of the next burglary. Burglary statistics in SD’s are only available on an annual frequency, limiting more detailed analysis on the quickness of the response. One possible explanation for the fast response is burglars exploiting their ability to respond to lapses in policing, relative to the police forces ability to respond to rising crime. When a burglary is committed in an area, police attention might be drawn to the area, increasing the probability of apprehension with each additional offence committed there. In recently connected SD’s, motorway-related burglaries have not occurred yet and police suspicion has not been raised, nor has there been sufficient time for police forces to coordinate and mobilize a response. The theoretical framework presented in Section 3.2 shows that if the level of policing increases in an area, holding other variables constant, expected profits would fall. The desirability of that location as the next target area decreases, and this solidifies the explanation for the temporary rise in burglaries near new motorway stretches. According to the empirical results, the risk of apprehension outweighs the expected profit in a SD, after an average of 5 burglaries has been committed there.

7. Robustness checks

7.1 Postponed motorway junctions

Motorways are not assigned to locations at random, but on the basis of unobserved characteristics that affect economic activity, which in turn affect the level of criminal activity. Motorways will generally be placed in areas of above average economic prosperity, or areas with economic potential. The variable measuring connections to the motorway may be inflated as it fails to adequately disentangle this relationship. Sections of the Irish motorway planned to be built during 2004-15 were postponed and connections to these postponed junctions are included as a useful placebo test (table 3). There are twenty-two postponed junctions, belonging to two new motorways and extensions to

\textsuperscript{51}The results are also robust to the exclusion of the Greater Dublin Area (consisting of the counties of Meath, Kildare, Dublin and Wicklow), which is defined as a core socio-economic region in Ireland.
three existing motorways illustrated in Appendix C\textsuperscript{52}. As the year of opening of postponed junctions does not exist, the earliest year of reference that can be found for each motorway expansion is used. It is expected that connections to the motorway are exogenous, and that there will be no causal effect associated with the non existent junctions.

Table 3.
The effect of connections to existing and postponed motorway junctions on sub district burglary rates (per 10,000 persons), 2004-15

| Independent variables | Existing junctions | Existing & postponed junctions | Postponed junctions |
|-----------------------|--------------------|-------------------------------|---------------------|
|                       | (1) Burglary rate  | (2) Burglary rate             |                     |
| motorway              | -0.45 (2.05)       | -0.21 (1.87)                  | 2.03 (2.87)         |
| connect               | 4.83*** (1.69)     | 3.75** (1.65)                 | 1.91 (2.33)         |
| Sub-district FE       | YES                | YES                           | YES                 |
| Year dummies          | YES                | YES                           | YES                 |
| Standard errors       | Clust.             | Clust.                        | Clust.              |
| R-squared             | 0.94               | 0.94                          | 0.94                |
| N                     | 6,744              | 6,744                         | 6,744               |

Notes: ‘motorway’ is a dummy variable indicating the presence of a motorway nearby, and ‘connect’ is a dummy variable indicating the year of connection to the motorway network. ***p<0.01 **p<0.05 *p<0.1. Standard errors are clustered by sub district and are in parentheses. Numbers are rounded to two decimal places where possible.

For this to be a reliable placebo test, the junction postponements must be random. To ensure the validity of the test, only those junctions that had official architectural plans drawn up are used, as they are the most likely junctions to have been built had they not been cancelled. Indeed, one of the new motorways opened in 2017 and the second new motorway was granted construction approval in 2018\textsuperscript{53}. Secondly, the postponement of motorway upgrades was part of a wider cut in transport

\textsuperscript{52}The location of each junction is retrieved from individual planning websites detailing the postponed projects, and the geographic coordinates are located using Google maps.

\textsuperscript{53}Media reports document how the burglary level has risen in the immediate aftermath of the motorway opening. See “New motorway opens up rural parts of Galway to criminals” available at http://connachttribune.ie/new-motorway-opens-rural-parts-galway-criminals-911/. Also see a newspaper article confirming the construction approval of the other new motorway at 'Cork to Limerick motorway and Dublin Airport included in €115bn National Development Plan’
spending in 2011, when all pending transport upgrades, including expansion to bus and rail routes. For comparability, columns 1 and 2 show the main result found in table 2. Postponed junctions are added to the existing motorway network, and the results are shown in columns 3 and 4. Given that existing junctions are included, statistical significance is expected, however the inclusion of postponed junctions reduces significance to the 5% level. Given this, it is expected that connections to postponed junctions are not statistically significant in column 6. The presence of a motorway remains statistically insignificant in all cases.

7.2 Other types of crime

Burglaries might disproportionately occur in areas where there is a high overall crime rate and this might drive the main result because it is not accounted for in the regression. The CSO publishes recorded crime statistics for a range of crime types; see Appendix B for annual statistics. Each of these crime types are used as additional explanatory variables, presented in table 4. The coefficient on connect is robust to the inclusion of all crime types, even the theft rate which is statistically significant at 1%. This provides reassurance that crime persistence is not driving the main result. To note, theft refers to the action of stealing, while burglary refers to breaking an entry with the potential intent to commit a crime, such as theft. A 1 unit increase in the theft rate increases the burglary rate by almost the same amount (0.91). This is an intuitive result as burglary and theft are related crimes.

One might expect that motorways will increase other crimes that require a physical escape, such as theft and vandalism. To test this, other crime types are used as alternative dependent variables and the results are presented in table 5. SD’s connected to the motorway network experience more property damage offences (i.e. vandalism), and the effect is statistically significant at 1%, but new connections have no effect. Drug trade is negatively affected by motorway connections, but the effect is Dublin-specific. A crucial result that reduces endogeneity concerns is that motorway connections do not cause the theft rate. This is important because the theft rate is closely related to the burglary rate in table 5. If there were an omitted variable being captured by connections, this

available at www.breakingnews.ie/ireland/cork-to-limerick-motorway-and-dublin-airport-included-in-115bn-national-development-plan-826540.htm.

This result is robust to different years of opening of postponed junctions.

Kidnap, fraud and weapon related offences are excluded because of low counts.

The presence of a motorway also remains statistically insignificant when other crime types are controlled for in the regression.

This is also true when lags of crime are added as control variables.
would be revealed through connections having a statistically significant effect on other crimes, particularly theft. Conceptually, the uniqueness of the relationship is perhaps because burglary requires the expedient transit of bulky stolen items such as televisions.

7.3 Local economic activity

The SD fixed effect remove unobserved effects that vary over space, and the year dummies remove unobserved effects that vary over time, but neither account for the variables causing the local crime rate that vary over both space and time. Left unaddressed these effects can cause an omitted variable bias because identification rests on spatio-temporal variation. The main culprit is changes in local economic activity e.g. connections to the motorway network might simultaneously raise economic activity and the burglary rate, and in turn the burglary rate might rise with economic activity. As a proxy for local economic activity, the annual number of people registering for Jobseekers Benefit, Jobseekers Allowance and for various other statutory entitlements at individual local offices of the Department of Social Protection is used as a control variable, and the results are presented in table 6\textsuperscript{58}. To note, this proxy is not designed to measure unemployment because it includes part-time, seasonal and casual workers, but it provides a useful indication of the numbers of people entering unemployment at a detailed geographic level. Some welfare offices closed during the period of analysis, so registrations at welfare offices active every year during 2004-15 are used, of which there is 141 spread across the country. The variable ‘register’ is the total number of registrations at the nearest social welfare office, and ‘Δregister’ is the difference between the number of registrations in time t and t-1\textsuperscript{59}. Both variables are scaled to show the effect of 100 registrations. Only the level of registrations is statistically significant and 100 registrations is associated with a small increase in the

\textsuperscript{58} The geographic coordinates of welfare offices are found in Google maps and the distance from the SD’s centroid to welfare offices is used to identify the local number of registrations. Information on the live register is published by the Central Statistics Office in the form of a monthly release available at http://www.cso.ie/px/pxeirestat/Database/eirestat/Live%20Register/Live%20Register_statbank.asp?SP=Live%20Register&rPlanguage=0.

\textsuperscript{59} The live register is also scaled by population e.g. the population size in the SD and the County the office is located in. Although the results on the live register are sensitive to the scaling, the coefficient on motorway connections is not. As the scaling does not affect the main result, and as there is no obvious population to scale by, the live register is left unscaled for ease of interpretation.
Table 4.
The effect of connections to the motorway network on sub district burglary rates (per 10,000 persons), 2004-15

| Independent variables | (1) Burglary rate | (2) Burglary rate | (3) Burglary rate | (4) Burglary rate | (5) Burglary rate | (6) Burglary rate | (7) Burglary rate |
|-----------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| murder rate           | .27* (.15)        | -.08 (.10)        | -.21 (.26)        | -.22 (.31)        | -.02 (.13)        | -.10 (.07)        | .91*** (.10)     |
| drug rate             |                   |                   |                   |                   |                   |                   |                   |
| property damage rate  |                   |                   |                   |                   |                   |                   |                   |
| dangerous acts rate   |                   |                   |                   |                   |                   |                   |                   |
| govt offences rate    |                   |                   |                   |                   |                   |                   |                   |
| public order rate     |                   |                   |                   |                   |                   |                   |                   |
| theft rate            | 5.03*** (1.80)    | 4.65*** (1.65)    | 4.46*** (1.69)    | 4.41*** (1.65)    | 4.84*** (1.71)    | 4.46*** (1.62)    | 4.91*** (1.73)    |

Sub district FE YES YES YES YES YES YES YES
Year dummies YES YES YES YES YES YES YES
Standard errors Clust. Clust. Clust. Clust. Clust. Clust. Clust.
R-squared .94 .94 .94 .94 .94 .94 .94
N 6,744 6,744 6,744 6,744 6,744 6,744 6,744

Notes: See the legend below table 4 for the full title of the crime control variables. ***p<0.01 **p<0.05 *p<0.1. Standard errors are clustered by sub district and are in parentheses. Numbers are rounded to two decimal places where possible.

Table 4 and 5 legend

| murder rate | Attempts/threats to murder, assaults, harassments and related offences |
|-------------|---------------------------------------------------------------------|
| drugs rate  | Controlled drug offences                                             |
| property damage rate | Damage to property and to the environment                             |
| dangerous acts rate | Dangerous or negligent acts                                         |
| govt offences rate | Offences against government, justice procedures and organisation of crime |
| public order rate | Public order and other social code offences                         |
| theft rate | Theft and related offences                                           |
Table 5.  
The effect of connections to the motorway network on sub district crime rates (per 10,000 persons), 2004-15

| Independent variables | Murder rate (1) | Murder rate (3) | Drugs rate (4) | Drugs rate (5) | Drugs rate (6) | Property damage rate (7) | Property damage rate (9) | Dangerous rate (10) | Dangerous rate (11) | Govt offences rate (12) | Govt offences rate (13) | Public order rate (14) | Public order rate (16) | Theft rate (17) | Theft rate (18) |
|-----------------------|----------------|----------------|---------------|---------------|---------------|------------------------|------------------------|-------------------|-------------------|----------------------|----------------------|----------------------|----------------------|---------------|---------------|
| motorway              | 1.60 (1.28)    |                | .82 (2.01)    |                |               | 7.6*** (2.55)         |                       | 1.76 (2.19)       |                   | 1.67 (1.46)        |                      | 8.92 (5.52)         |                     | .11 (0.35)        |               |
| connect               |               | - .78 (1.40)   | -2.36* (1.39) | -2.19 (1.39)  | -1.73 (2.02)  |                       |                       | -1.89 (1.30)      |                   | .58 (.88)           |                      | -3.73 (3.27)        |                     | -.096 (2.40)   |
| Sub district FE       | YES           | YES            | YES           | YES           | YES           | YES                    | YES                    | YES               | YES               | YES                  | YES                  | YES                  | YES                  | YES           |
| Year dummies          | YES           | YES            | YES           | YES           | YES           | YES                    | YES                    | YES               | YES               | YES                  | YES                  | YES                  | YES                  | YES           |
| Standard errors       | Clust.        | Clust.         | Clust.        | Clust.        | Clust.        | Clust.                 | Clust.                 | Clust.            | Clust.            | Clust.               | Clust.               | Clust.               | Clust.               | Clust.             |
| R-squared             | 0.89          | 0.90           | 0.84          | 0.84          | 0.83          | 0.93                   | 0.93                   | 0.78              | 0.78              | 0.84                 | 0.94                 | 0.88                 | 0.88                 | 0.79          |
| N                     | 6,744         | 6,744          | 6,744         | 6,744         | 6,773         | 6,744                  | 6,744                  | 6,744            | 6,744            | 6,744                | 6,744                | 6,744                | 6,744                | 6,744         |

Notes: ‘motorway’ is a dummy variable indicating the presence of a motorway nearby, and ‘connect’ is a dummy variable indicating the year of connection to the motorway network. See the legend below table 4 for the full name of the dependent variables. ***p<0.01 **p<0.05 *p<0.1. Standard errors are clustered by sub district and are in parentheses. Numbers are rounded to two decimal places where possible.
burglary rate (0.82). Although statistically significant, the coefficient on connect remains similar, showing that motorway connections are not capturing changes in local economic activity.

Table 6.
The effect of connections to the motorway network on sub district burglary rates (per 10,000 persons), 2004-15

| Independent Variables | (1) Burglary rate | (2) Burglary rate | (3) Burglary rate | (4) Burglary rate |
|-----------------------|-------------------|-------------------|-------------------|-------------------|
| motorway              | -.35 (1.88)       | -1.52 (2.32)      |                   |                   |
| connect               | 4.50*** (1.70)    |                   | 6.42*** (2.07)    |                   |
| register              | .87** (.40)       | .82** (.39)       |                   |                   |
| Δregister             | 1.20 (1.49)       | 1.18 (1.48)       |                   |                   |
| Sub district FE       | YES               | YES               | YES               | YES               |
| Year dummies          | YES               | YES               | YES               | YES               |
| Standard error        | Clust.            | Clust.            | Clust.            | Clust.            |
| R-squared             | 0.94              | 0.94              | 0.94              | 0.94              |
| N                     | 6,744             | 6,744             | 6,744             | 6,744             |

Notes: ‘motorway’ is a dummy variable indicating the presence of a motorway nearby, ‘connect’ is a dummy variable indicating the year of connection to the motorway network, and ‘register’ denotes the the number of people claiming job-seeking related welfare payments at local welfare offices. ***p<0.01 **p<0.05 *p<0.1. Standard errors are clustered by sub district and are in parentheses. Numbers are rounded to two decimal places where possible.

7.4 Lead and lag of connections

Criminals rely on the properties of the motorway network, such as high speed limits and free flowing traffic. Thus, there should be no effect of motorway connections before the junction opens i.e. the lag values. Lead values of connection might be statistically significant if there is a delayed response of burglars to motorway expansions, or if the increased burglary level persists during the years after connection. Table 7 includes lag and lead values up to three years as separate regressors, alongside the main variable of contemporaneous connections. For example, connect_{t+1} defines the year of motorway connection one year later than the actual opening year. The lead and lagged values are not

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60 Chandra and Thompson (2000) find a run up effect of highway construction on economic activities.
statistically significant, and contemporaneous connections remain significant and of a similar magnitude to the main result in table 2. This confirms that motorway expansion affects burglaries in the year of connection only. To note, this test does not rule out the revisiting of burglars to previously targeted sub districts, as it is likely that they do return (Bernasco and Luykx, 2003). It indicates that the pattern of revisiting is not based on the year of motorway connection, for example, returning 3 years after the year of connection, and thus the pattern of return is not testable in this paper, this discussion is continued in Section 8.

Table 7.
The effect of connections to the motorway network and sub district burglary rates (per 10,000 persons), 2004-15.

| Independent Variables | (1) | Burglary rate |
|-----------------------|-----|---------------|
| connect_{t+3}         | .28 | (2.51)        |
| connect_{t+2}         | .25 | (2.55)        |
| connect_{t+1}         | 2.89| (2.75)        |
| connect_t             | 5.16**| (2.46)       |
| connect_{t-1}         | 2.55| (2.92)        |
| connect_{t-2}         | -.12| (3.51)        |
| connect_{t-3}         | -3.39| (3.07)       |

Sub district FE YES
Year dummies YES
Standard error Clust.
R-squared 0.94
N 6,744

Notes: ‘motorway’ is a dummy variable indicating the presence of a motorway nearby, and ‘connect’ is a dummy variable indicating the year of connection to the motorway network. **p<0.01 *p<0.05 *p<0.1. Standard errors are clustered by sub district and are in parentheses. Numbers are rounded to two decimal places where possible.

61 The lead and lag values are also not significant when used on their own in separate regressions.
7.5 Population

The population in 2011 is used to construct burglary rates but populations do not remain constant overtime and this is not reflected in the burglary rates in the analysis. To alleviate concerns of measurement error, population growth rates for the eight Regional Authorities are used and yearly population estimates each year during 2004-15 are constructed\(^{62}\). For example, in 2011 a SD has a population of 4,809. Between 2011 and 2012, the regional authority experienced a 0.78% decrease in its population. Using this growth rate the 2012 population is calculated as 4,772 persons. Appendix D shows the results when the main analysis in table 2 is repeated, but using the yearly population estimates to construct burglary rates. Connections to the motorway remain statistically significant and the coefficients magnitude is similar to the main result in table 2.

7.6 The border with Northern Ireland

The border between the Republic of Ireland and Northern Ireland is a hard policing border but with free unchecked movement because both countries are in the European Union. Each jurisdictions police force is not legally permitted to continue the chase or make an arrest in the other jurisdiction. From a burglar’s perspective, the probability of apprehension may be smaller closer to the border, because the criminal can flee across the border after committing a crime. If the effect of the border is time invariant, it will be removed in the SD fixed effect, but road changes in Northern Ireland may cause the border effect to vary overtime. It is not possible to include a border dummy variable alongside the SD fixed effect, so SD’s (75) whose centroid is within a \(\leq 30\)km radius of the border are excluded, and the results are shown in Appendix D. Connections to the motorway network remain statistically significant at 1\% and the coefficient is a similar magnitude to the main result. This provides reassurance that the effect of the border on burglary rates is not disrupting the main result.

8. Extension

Before 2016, there was virtually no targeted law enforcement against criminals on motorways. In 2016, a €5 million national anti-crime strategy called ‘Operation Thor’ launched across the country,

\(^{62}\) The Regional Authority is the smallest geographical level available that provides yearly growth rates. The Eight Regional Authorities are: Border, West, Midlands, Mid-East, Dublin, South-East, South-West and Mid-West. The population estimates are available at http://www.cso.ie/px/pxeirestat/Statire/SelectVarVal/Define.asp?maintable=PEA07&PLanguage=0
consisting of high visibility checkpoints near motorways, increased motorway surveillance, covert operations to target known offenders, increased police presence in communities and a national awareness campaign\(^{63}\). In the theoretical framework in Section 3, national police action against burglaries will increase police effectiveness in all SD’s, and thus decreases expected profits everywhere, making burglary less desirable and the result will be a decrease in the supply of burglars. Unsurprisingly, coinciding with the introduction of the policing measures, the number of burglaries dropped nationally by 30% during 2015-16 (see figure 2). All 28 police divisions in Ireland received the new policing measures, but the strength of which varied across divisions. See Appendix E for the delineation of division boundaries. Only those divisions with a motorway received targeted motorway measures, the primary purpose of the strategy. While an awareness campaign was rolled out across all divisions, which if effective will have decreased the demand for burglaries nationally, irrespective of the presence of the motorways. Indeed, in 2016 (see figure 2) both motorway and non-motorway connected regions experience a decrease in burglaries, but the fall is larger in places connected to the motorway network.

A differences-in-differences model is estimated to determine causality between the introduction of the targeted law enforcement at motorways and the fall in burglaries in divisions with a motorway. Equation 8 represents the estimated regression shown in table 10:

\[
burglary_{i,t} = \theta_i + \alpha_t + \beta_1Treat_i + \beta_2Post_{i,t} + \beta_3(Treat*Post)_{i,t} + \epsilon_{i,t} \quad (8)
\]

Quarterly data spanning the 28 police divisions in Ireland during 2014Q1-2016Q4 are used. \(i\) is the division and \(t\) is time\(^{64}\). ‘burglary’ is the burglary rate per 100,000 persons. Treat is equal to one if the division is intersected with a motorway, 0 for disconnected divisions. A motorway intersects 19 divisions, and the remaining 9 divisions are disconnected. Post is equal to 1 in 2016 when the policing measures are launched, and 0 in the periods before 2016. The interaction of post and treat provides the effect of the policy change on the burglary rate in motorway divisions. The targeted enforcement in motorway divisions reduced burglaries by 22.42 on average, and the effect is statistically significant at 1\(^{65}\). The measures did not affect burglaries in Dublin and this complements the main results in table 2 which show that motorway-related burglaries where

\(^{63}\) Details about the National Anti-Crime Strategy are available at: http://garda.ie/Controller.aspx?Page=15036.

\(^{64}\) Available at http://www.cso.ie/en/statistics/crimeandjustice/

\(^{65}\) As a robustness check, other crime types were used as alternative dependent variables and there was no statistically significant decrease among other crime types.
happening outside of the Dublin region. These results provide further weight to the argument that motorways are affecting burglaries.

Since all divisions receive a treatment and a subsequent decrease in burglaries, it is difficult to arrive at a precise estimate of the number of motorway-related crimes the policing measures prevented. Furthermore, media reports outline that burglars reacted to the policing measures at motorways by reallocating some of their activity towards the old primary road network where police presence is less i.e major roads that were downgraded as higher quality roads were built. This indicates that the rise in policing at motorways dispersed some of the existing activity, which provides an explanation as to why the estimated treatment effect is small. Since divisions are large areas, crime can move from the part of the division where there is a motorway towards the part of the division further away from the motorway, theoretically leaving the number of burglaries in the division unchanged\(^{66}\). It is not possible to investigate this further because quarterly data is not available at a lower geographical level. Figure 2 also shows that the number of burglaries increased in Dublin in 2014, while simultaneously decreasing in other motorway counties. This suggests that burglars substituted some part of their previous motorway activity outside of Dublin for Dublin burglaries, in response to increased policing near motorways.

### Table 10.

The effect of the anti burglary campaign on burglary rates in divisions, 2014Q1-2016Q4

| Independent Variables | Exc. County | Dublin |
|-----------------------|-------------|--------|
|                       | (1)Burglary rate | (2)Burglary rate |
| post                  | 114.45***   | -25.87*** |
|                       | (3.52)      | (7.78)  |
| post*treated          | -14.31      | -22.42*** |
|                       | (10.56)     | (7.84)  |
| Division FE           | YES         | YES     |
| Year dummies          | YES         | YES     |
| Standard errors       | Clust.      | Clust.  |
| R-Sq                  | 0.90        | 0.88    |
| N                     | 336         | 312     |

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\(^{66}\) See [https://www.independent.ie/regionals/kerryman/news/operation-thor-sends-crime-gangs-to-kerry-35510971.html](https://www.independent.ie/regionals/kerryman/news/operation-thor-sends-crime-gangs-to-kerry-35510971.html).
Notes: ‘treated’ is a dummy variable indicating counties that have a motorway, and ‘post’ denotes the years of targeted policing at motorways. ***p<0.01 **p<0.05 *p<0.1. Standard errors are clustered by SD and are in parentheses. Numbers are rounded to two decimal places where possible. Population figures are taken from the 2011 Census.

The effectiveness of the targeted action in 2016 occurred after a period of limited motorway growth, there were no expansions during 2011-14, and only three junctions were built in 2015 (table 1). The continuance of motorway-related burglaries during this period shows that criminal’s return to previously targeted areas, and that motorway-related burglaries are not restricted to the year of connection. Most likely, burglars return when police vigilance has lapsed. In the theoretical framework presented in Section 3, this will be represented by a decrease in police effectiveness, and a subsequent rise in expected profits, however there is no discernable pattern to explain when police vigilance falls back to pre-motorway-burglary levels.

9. Conclusion

This paper studies the causal effect of motorway connections on burglary rates using data from Ireland. The spatio-temporal variation in motorway connectivity is exploited in a fixed effects analysis, consisting of crime rates in 562 police sub districts and connections to motorway junctions during 2004-15. Connection to the motorway network causes a 10% rise (5 burglaries) in the number of burglaries in the average sub district. The rise in crime occurs in the year of connection only, and there is no persistent effect on the burglary rate in the years after connection. It is likely that burglars return to previously targeted areas, but the year of return is not patterned with the year of motorway expansion. For this reason, this paper focuses on the immediate aftermath of motorway expansion and it is estimated that motorway expansion caused 12,150 burglaries in recently connected sub districts during 2004-10. The immediate response of burglars to motorway expansions is a novel result and a possible explanation is that the probability of being caught by the police is lowest in areas recently connected to the motorway network, and criminals exploit the fact that the police may not have had sufficient time to increase policing in these areas. The novelty of this paper is to show that major road construction influences the spatial distribution of crime. For policymakers, the findings indicate the need to incorporate crime-externalities into any cost-benefit analysis of future road infrastructure developments. The measure of motorway connections can confidently be thought of as exogenous because the main results are robust to various detailed checks: postponed motorway junctions yield no statistically significant effect on crime, controlling for local economic activity is not disrupting the main result, and no other crime shares this causal relationship with motorways. A
possible explanation for the uniqueness of the effect of motorways on burglary, is that the bulky stolen goods need to be transported from the property as quickly as possible to avoid detection. The national policing action against motorway burglaries launched in 2016 was effective in reducing burglaries, providing further weight to the argument that motorways are affecting the spatial pattern of burglaries.
Appendices

Appendix A

Table 11.
Burglary summary statistics, 2004-15

|                | All SD’s | SD’s with a junction within ≤30km's | SD’s without junction within ≤30km's |
|----------------|----------|-------------------------------------|-------------------------------------|
| Mean           | 48       | 50                                  | 45                                  |
| Min            | 0        | 0                                   | 0                                   |
| Max            | 4,604    | 1,143                               | 4,604                               |
| 25<sup>th</sup> percentile | 19       | 24                                  | 12                                  |
| 50<sup>th</sup> percentile | 33       | 41                                  | 22                                  |
| 75<sup>th</sup> percentile | 57       | 64                                  | 36                                  |
| Number of SD’s | 562      | 387                                 | 175                                 |

Notes: figures are rounded to the nearest whole number

Figure 4.
The change in the number of burglaries each year in Ireland, 2004-16
### Appendix B

**Table 12.**
The number of crimes by type and year, 2004-15

| Year | Burglary/related offences | Attempts and threats to murder/assaults/harassments/related offences | Controlled drug offences | Damage to property/environment | Dangerous/negligent acts | Offences against government/justice procedures and organisation of crime | Public order/other social code offences | Theft/related offences |
|------|--------------------------|---------------------------------------------------------------|------------------------|-------------------------------|------------------------|-------------------------------------------------|--------------------------------------|------------------------|
| 2004 | 24,913                   | 13,277                                                        | 9,863                  | 37,047                        | 12,685                 | 6,453                                           | 47,788                              | 72,201                  |
| 2005 | 26,381                   | 13,687                                                        | 13,316                 | 39,727                        | 14,720                 | 7,792                                           | 55,479                              | 73,076                  |
| 2006 | 24,788                   | 15,454                                                        | 14,219                 | 43,582                        | 19,280                 | 9,482                                           | 56,615                              | 74,494                  |
| 2007 | 23,603                   | 17,665                                                        | 18,553                 | 43,284                        | 21,009                 | 10,997                                          | 60,583                              | 75,187                  |
| 2008 | 24,682                   | 19,150                                                        | 23,404                 | 44,626                        | 19,587                 | 13,255                                          | 61,820                              | 76,861                  |
| 2009 | 26,910                   | 18,353                                                        | 21,982                 | 42,330                        | 15,532                 | 11,898                                          | 57,351                              | 77,031                  |
| 2010 | 25,420                   | 17,703                                                        | 20,004                 | 39,369                        | 12,093                 | 11,396                                          | 54,941                              | 76,826                  |
| 2011 | 27,695                   | 17,062                                                        | 17,695                 | 35,573                        | 9,946                  | 10,172                                          | 49,060                              | 76,974                  |
| 2012 | 28,133                   | 15,710                                                        | 16,450                 | 32,428                        | 9,051                  | 9,445                                           | 43,861                              | 76,402                  |
| 2013 | 26,218                   | 14,502                                                        | 15,372                 | 28,913                        | 7,660                  | 9,187                                           | 36,453                              | 78,737                  |
| 2014 | 27,635                   | 15,164                                                        | 15,915                 | 27,394                        | 7,298                  | 9,765                                           | 32,639                              | 77,697                  |
| 2015 | 26,261                   | 16,976                                                        | 15,090                 | 26,049                        | 7,224                  | 11,438                                          | 33,276                              | 75,864                  |
| 2016 | 18,438                   | -                                                             | -                      | -                             | -                      | -                                               | -                                    | -                      |
Appendix C

Table 13.
The number of SD’s connected to existing and postponed junctions, 2004-15

| Year       | Number of SD’s |
|------------|----------------|
| Connected 2004 | 40             |
| Connected 2005 | 36             |
| Connected 2006 | 5              |
| Connected 2007 | 9              |
| Connected 2008 | 24             |
| Connected 2009 | 41             |
| Connected 2010 | 27             |
| Connected 2011 | 0              |
| Connected 2012 | 0              |
| Connected 2013 | 2              |
| Connected 2014 | 0              |
| Connected 2015 | 0              |

Figure 5.
The location of postponed motorway junctions by proxied year of opening
Appendix D

Table 14.
The effect of motorway connections on sub district burglary rates (per 10,000 persons), using yearly population estimates 2004-15

| Independent variables | (1) Burglary rate | (2) Burglary rate |
|-----------------------|-------------------|-------------------|
| motorway$_i$          | -.004 (.02)       | .05*** (.02)      |
| connect$_i$           |                   |                   |
| Sub district FE       | YES               | YES               |
| Year dummies          | YES               | YES               |
| Standard errors       | Clust.            | Clust.            |
| R-squared             | 0.94              | 0.94              |
| N                     | 6,744             | 6,744             |

Notes: ***p<0.01 **p<0.05 *p<0.1. Standard errors are clustered by sub district and are in parentheses. Numbers are rounded to two decimal places where possible.

Table 15.
The effect of motorway connections on sub district burglary rates (per 10,000 persons), in SD’s >30km’s from the Irish border, 2004-15

| Independent variables | >30km’s from the border |
|-----------------------|-------------------------|
|                       | (1) Burglary rate | (2) Burglary rate |
| motorway              | -.08 (2.09)       | 4.44*** (1.63)   |
| connect               |                   |                   |
| Sub district FE       | YES               | YES               |
| Year dummies          | YES               | YES               |
| Standard error        | Clust.            | Clust.            |
| R-squared             | 0.78              | 0.78              |
| N                     | 5,856             | 5,856             |

Notes: ‘motorway’ is a dummy variable indicating the presence of a motorway nearby, and ‘connect’ is a dummy variable indicating the year of connection to the motorway network **p<0.01 **p<0.05 *p<0.1. Standard errors are clustered by sub district and are in parentheses. Numbers are rounded to two decimal places where possible.
Appendix E

Figure 6.
Police divisions and the motorway in Ireland, 2015
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