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The Effects of a Move Towards Cashlessness: A Cross-National-Time-Series Study of Money Supply and Acquisitive Crime Rates

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ABSTRACT

Cash is an important medium of exchange in most countries, but criminological theories suggest it carries a positive impact on acquisitive crime. Previous research has verified this relationship. This paper will build on the previous research and test if these theories hold empirically in a cross-national-time-series analysis with theft, robbery, burglary and homicide as dependent variables and a money supply-based operationalization of cashlessness: the electronic share of money, as the main explanatory variable. Using fixed effects regressions, we found significant positive effects of cash on theft, burglary and domestic burglary. We performed several sensitivity analyses and concluded that the results from the fixed effects regressions were heavily biased. Therefore, a stationary analysis was performed. With detrended data we found no significant results, indicating that there are no gains in the form of reduced acquisitive crime from incremental moves towards cashlessness.

Keywords: Cash, Electronic money, M0, M1, Acquisitive crime

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Introduction

Cash has been the main form of currency used in transactions for a long time. It is a great medium of exchange and historically it has reduced transaction costs and thereby increased economic efficiency. However, the IT-revolution has brought with it new improved ways of conducting transactions, and in many western economies they have already bypassed cash as the main medium of exchange. Cash transactions are by nature hard to trace and are therefore great for conducting illegal transactions. Cash also requires next to no trust between parties, further facilitating use in criminal circles (Warwick, 1993). This paper will examine how the revolution in payment systems, away from cash, affects crime rates in a cross-country-time-series analysis.

A reduction in the use of cash could potentially reduce several different kinds of crime. Most direct should be the impact on acquisitive crimes: theft, robbery and burglary, because the ultimate goal of such crimes is to acquire wealth in the form of cash. Prevalence of cash could also have effects on drug related crimes since they too are facilitated by cash as a medium of exchange. Further, by potentially reducing drug trafficking and robbery, a move towards cashlessness could impact homicide rates indirectly, since homicides may occur when robberies go bad or drug crews fight for territory. For the purpose of this paper, acquisitive crimes will be the main focus, but the relationship with homicide will be explored as well. A range of research predicts a positive relationship between cash and crime in theory (Warwick, 1993), and some studies have confirmed the relationship empirically (Pridemore et al., 2018, Wright et al., 2014, Army et al., 2014). By running regression analyses with acquisitive crimes as dependent variables and a new and potentially superior operationalization of cashlessness as independent variable this relationship and those theories will be tested empirically in this paper.

The research question for this paper is thus: theory predicts a positive relationship between cash and crime. Do these theories hold empirically?

Theory

Warwick, 1993 writes in some length about the potential benefits of a cashless society. He lays out the properties of cash that makes it the number one target for many acquisitive crimes, either as a direct target itself or as an instrumental second step after selling stolen goods. Cash is by nature anonymous and requires next to no trust to be used in transactions. It is liquid and sometimes the only possible medium of exchange in underground economies (Naylor, 2004; Schneider & Enste,

2013; Wright et al., 2014). It also retains value over time (unless very high inflation dilutes the value) and can therefore be stored. This is especially useful when a criminal need to lay low after committing a crime as to not draw attention.

There are three main criminological theories that attempt to explain crime, that might be impacted by changes in the degree of cashlessness. These are: self-control theory, routine activities theory and rational choice theory. (Pridemore et al., 2018)

Self-control theory holds that crime is opportunistic, often ill planned or not planned at all, and that opportunity is a catalyst for crime. People with poor self-control develop it during childhood as a result of parents not teaching them self-control (Hirschi & Gottfredson, 1990). From the perspective of this theory, a move towards cashlessness would decrease crime rates by making opportunities less common and worth less. If fewer people walk around with cash on hand there would be less of an opportunity to rob them, and if fewer people store cash in their homes there would be less gain from burglary. Stealing goods and converting them to cash would also be harder, as fewer members of society wish to perform transactions using physical currency. Converting stolen goods to other forms of untraceable currency, such as cryptocurrency, requires planning and technical knowledge that people with low self-control might not possess. Any measure that makes committing crime harder will have effects according to self-control theory and reducing the societal dependence on cash for transactions is one such measure. (Pridemore et al., 2018)

Routine activities theory was developed by Felson & Cohen in 1979. For acquisitive crimes, it holds that criminals are motivated and look for easy targets. Targets are protected by guardians such as police or bystanders. If in a situation there are offenders and targets, but no guardians, crimes occur. The crime rate then becomes an "equilibrium" between easy targets available and offenders. Reducing the amount of people walking around with cash would reduce potential targets. There would also be a breaking point when herd immunity is reached, meaning that the people who do carry cash are protected by those who do not (Pridemore et al., 2018). This is similar to vaccinations: if a sizable portion of a population is immune to a certain decease, the ones that are not immune will be protected because the disease would be unable to spread to them. In the same vein, when a certain portion of people have stopped walking around with cash, the ones that still do would be protected since there is no way for the criminals to tell whether a person is a profitable target or not. Interestingly, other types of crime such as fraud might increase with moves towards

cashlessness, as criminals substitute one activity for another (Pridemore et al., 2018). According to this theory, crime is not so affected by poverty and unemployment.

Rational choice theory treats crime as an economic decision. The theory was first developed by Becker in 1968 in the paper *Crime and Punishment: an economic approach*. It holds that individuals calculate the potential benefits and costs of crime and then make their choice. The benefit is the expected utility that comes from the value acquired. Costs are potential fines and imprisonment and the disutility of those would be multiplied by the chance of getting caught. One could also include the disutility of acting immorally in the costs of this equation. A reduction in the amount of cash in a society would impact both the benefits and costs of acquisitive crime. Benefits from robbery and theft would be lower since fewer people would have cash on hand (and less of it), and by increasing the difficulty of converting stolen goods to money. The costs would be greater since the risk of getting caught while fencing increases when not using anonymous cash in transactions but instead recorded electronic transactions. There are ways to make electronic transactions anonymous for example by using cryptocurrencies, but that requires effort and technical knowledge. That increased effort required is a cost for the purpose of this equation. If governments or law enforcement lag behind in legislation and knowledge about electronic currencies, new crimes such as fraud might increase with a move towards cashlessness as the chance of getting caught could be lowered.

Our hypothesis is that the causal relationship between cash and acquisitive crime is not entirely linear, but instead that significant reductions in crime will occur when certain thresholds of cashlessness are reached. We argue that there are two such thresholds. The first one appears when herd immunity greatly reduces benefits of robbery and pickpocketing. Before and after this, incremental moves towards cashlessness should have a smaller impact on crime until a new higher threshold at 100% cashlessness is reached. When cash is completely eliminated, fencing becomes much harder, unless a new way of performing untraceable transactions becomes widespread. This would greatly reduce the benefits of acquiring goods through all forms of acquisitive crime, resulting in a sizeable reduction in the amount of acquisitive crimes. In the area between the thresholds, cash is still in use, so organized criminal circles will be able to conduct transactions with it. However, previous research indicates that there is continuous crime reduction from incremental moves towards cashlessness. Some of the countries in our study may have passed the first threshold of herd immunity within the relevant timespan, but no countries have yet reached complete

cashlessness. If our theory holds, weak results could indicate that the countries studied have not reached either threshold or are between them.

Current state of knowledge

There is limited prior research on the topic of cash and crime.

While there is a commonly accepted intuition that cash impacts crime and governments actively encourage their citizens to use electronic payment systems (Sunstein, 2014), there have been few empirical studies conducted. The difficulty of finding and generating reliable data on crime combined with a predilection for cash in many countries such as Germany and the US might be reasons for why this topic is fairly unresearched. Three main empirical studies have been conducted: Wright et al., 2014, Armey et al., 2014 and Pridemore et al., 2018.

Pridemore et al., 2018 runs a cross-national OLS analysis on over 50 different countries with an operationalization of cashlessness focusing on government benefits payouts. Their focus is on the poorest 40% of the population in each country. This approach is sound because the poorest 40% are the main perpetrators and victims of acquisitive crimes as well as the main benefactors of government payouts. The explanatory variable they use is a form of government based cashlessness: the share of the population aged 15+ years that has received an electronic direct deposit from the government. They find significant negative effects of cash on robbery, but not on burglary or homicide. They only examine between-nation variation and the reliability of reported crime can vary widely between countries. That in combination with the impossibility of controlling for all drivers of crime, results in several control variables having coefficients in the opposite direction of what the theory would suggest.

Wright et al., 2014 also focuses on government cashlessness. They take advantage of a natural experiment in Missouri, where some counties started government payouts with debit cards rather than cash-redeemable checks. They found significant crime reduction from the cashless program for robbery, burglary and auto theft. The argument for using government based cashlessness is that in poor neighborhoods where acquisitive street crimes are more common than anywhere else, a significant portion of all cash in circulation comes from government benefits. Using a natural experiment is perhaps the optimal way of studying the effects of cash on crime, as issues caused by unreliable data, spurious correlation caused by time trends, as well as omitted variable bias

disappear. The downside of a natural experiment and difference in difference methods is that it is not as generalizable as a cross-national-time-series regression would be.

Armey et al., 2014 runs a cross-national-time-series analysis with 70 countries and 6 years with point of sale devices per capita as their operationalization of cashlessness and main explanatory variable. This is a form of commercial cashlessness, compared to the government cashlessness of Wright et al., 2014 and Pridemore et al., 2018. In our opinion, this operationalization is a suitable now, but might lose relevance in the future, for example when smartphone-based payments become dominant. Armey et al., 2014 find significant effects of commercial cashlessness on robbery and burglary. This study uses fixed effect regressions to minimize data reliability issues and is the one most similar to the one we are conducting.

Research design

This study aims to answer the question: does cash impact crime; do the theories that hold this proposition to be true hold, in an empirical study? To do this we collected secondary data for 19 countries for four types of acquisitive crime: theft, robbery, burglary, domestic burglary, as well as homicide. The countries were selected on the basis of data availability and reliability. We will do a cross-national-time-series analysis because the results from such regressions would be the most generalizable. Below follows a description of the variables, regressions and data.

Dependent variables

Our dependent variables are yearly reported theft, robbery, burglary, domestic burglary and homicide. Using reported crime statistics is not optimal due to potential differences in unrecorded statistics between countries. However, in the absence of actual crime data, this is our only choice.

Explanatory variable

Our main explanatory variable is a money supply operationalization of cashlessness that we have dubbed the *electronic share of money*, or EM/M1. It is the percentage of the perfectly liquid money stock that is electronic, or not cash. We follow money supply measures defined as:

- M0: the amount of cash in circulation outside banks and MFIs, i.e. physical currency held by the public.
- M1: equal to M0 + perfectly liquid electronic money deposits

M1 might include other elements, such as cheques, for some countries, but their prevalence is negligible during the relevant timeframe. These inconsistencies are discussed in the data section below.

The component of our measure, EM (short for electronic money) is defined as:

$$EM = M1 - M0$$

EM is divided by M1 to give the electronic share of money (EM/M1): our operationalization of cashlessness that will be used as the main explanatory variable.

All components of M1 serve the same purpose as a medium of exchange in transactions. A wider definition of the money supply would include deposits that are not equivalent to cash (less liquid) for our purpose. EM/M1 should serve well as an approximate for how cashless a society is. Other researchers such as Armey et al., 2014 used commercial operationalization of cashlessness, such as number of point of sale devices per 1000 capita. We believe our "macroeconomic" measure is a more valid operationalization of the theoretical definition of cashlessness. It is more general than the government based cashlessness of Pridemore et al., 2018. It will also remain valid in the future, whereas the operationalization of cashlessness used by Armey et al., 2014 (point of sale devices per 1000) might lose relevance, for example if smartphone-based payments become dominant.

If the narrow money supply consists only of physical currency (cash), the EM/M1 variable would assume the value of 0. If electronic money is half of the liquid money stock the value would be 0.5 and if no cash is in use it would assume the value of 1. The interpretation of the beta-coefficient against a logarithmic crime variable then becomes: X percent more/less crimes will be committed if a country uses only electronic money as compared to only cash.

Control variables

This study attempts to build on previous research by contributing with a new explanatory variable as operationalization of cashlessness: EM/M1. The control variables used in this paper closely follows the previous research. Unemployment, GDP/Capita, percentage of population living in urban areas and number of police officers per 1000 citizens are all used in the Armey et al., 2014 study.

Unemployment serves as a good proxy for variation in motivation or reason to commit crime. It should therefore capture cyclical elements of crime caused by the economic situation, if there are any. According to both self-control theory and rational choice theory there should be more crime when unemployment is higher. GDP/Capita will be used as a compliment to unemployment and should capture variation in crime stemming from differences in wealth, with the assumption being that individuals who are rich (because they are living in rich countries) have less reason to commit acquisitive crimes. The potential benefits and alternative costs of acquisitive crime could also be affected by it. GDP/Capita could also proxy stronger judicial systems or technological advancement, factors which might impact crime rates. Further, the percentage of people living in urban areas will be used as a control variable, because crimes should increase according to all three theories if this variable increases: in the routine activities theory as a result of more offenders and victims being grouped together in the same spot, in the rational choice theory because the cost of finding targets would be lower in dense areas, and in self-control theory since there are more targets close by as well. This variable comes with some problems though; mainly that poorer countries will be more agrarian and thus the variable could be negatively correlated with GDP/Capita, which could lead to problems of multicollinearity. Number of police officers per 1000 citizens is problematic as it could capture a positive correlation between police and crime and incorrectly arrive at the conclusion that more police causes more crime. We will run the regressions with and without the urban and police variables to see if the results differ.

Regressions

As mentioned above, unrecorded statistics seem to differ widely between countries, resulting in the inability to use a method that exploits between panel variation. Fixed effect regressions capture country specific time independent factors. The different levels of unrecorded statistics are one of those. Other country specific factors such as culture will also be captured by the fixed effects, as long as they are time invariant. The assumption that must hold to exploit within variation is that the national share of unrecorded statistics stays the same over time. We will use the dummy variable form of the fixed effects method, meaning a dummy variable for each country will be included. Further, time specific country independent factors will also be captured by including a dummy variable for each year.

Additionally, a stationary analysis will be performed. When examining the data presented in the appendix, common time trends between our dependent variables and our main explanatory variable became apparent. This, in combination with a lack of data on variables that would have been

relevant to control for, prompted us to make the data immune to spurious correlation by detrending it. Detrending the data forces it to be stationary, and that guarantees that the explanatory variables will not be biased by a lurking third variable that affects both the dependent and one or several independent variables. As the data displayed close to linear, rather than exponential or cyclical trends for most countries, linear detrending was used for all dependent and independent variables separately by each country. The detrended observations for each country and each variable then become the deviation from the national time trend in the variable in question. We will run OLS regressions with these residuals as well.

Further, both the fixed effects and the detrended OLS regressions will be run using EM/M1 for the current year and the previous year, for a total of four types of regressions for each crime. A one-year lag will be included in two of the models, meaning crime this year is tested to be related to EM/M1 last year. If potential perpetrators of crime need time to adapt to new levels of cashlessness, we should see significant results for the lagged variable. Since all variables have yearly values, and EM/M1 is averaged over every year, a six-month response time or more would warrant a one-year lag in the regressions. What the response time on changes in cash would be is not determined by theory, so we will test both with and without lag to see if the results differ. According to theory there are no good reasons to lag the control variables, as the response time on these should be very fast. Potential perpetrators of crime should immediately adapt to new circumstances with regards to their employment, police activity in their vicinity, or economic situation.

Data

The countries making up our dataset are presented in Table 1. All countries that are members of either the OECD or EU were included in the dataset given that the necessary data was available. We chose OECD and EU countries because we believe the data reliability of these nations to be high. With less divergence between nations the overall variation in the data might be smaller, but data on useful control variables is more readily available. The necessary data was reported for 19 out of 41 total OECD and EU countries. Criminological data was available for 13 years (2003–2015), resulting in 247 observations in the dataset. Data was sporadically missing for some of the control and dependent variables, leading to different numbers of observations for the different regressions. The number of observations for each regression is reported together with its results.

Table 1: List of nations

Belgium	Lithuania
Bulgaria	Mexico
Canada	Netherlands
Czech Republic	Poland
Denmark	Portugal
Finland	South Korea
Germany	Sweden
Greece	Switzerland
Hungary	United Kingdom
Japan	

Money supply data was collected from EIKON Reuters DataStream database (which, in turn, lists the corresponding central bank as the source of the data for each country), crime and police data was collected from the United Nations Office of Drugs and Crime (UNODC) and the data for the control variables were collected from the World Bank.

For our operationalization of cashlessness to be effective, all money supply data must follow the same definition, i.e. that M0 consists of cash in circulation (all physical currency held by the public) and M1 consists of cash in circulation, demand deposits and other checkable deposits. To assure this, all data was collected from a centralized database (EIKON Reuters DataStream) following the same specification across countries. We also checked that the data was consistent with the same information collected directly from the corresponding central banks' databases for a handful of countries and found no abnormalities. The average of the monthly data across all months was used as the yearly money supply measure.

All variables that do not represent percentages, police officers per 1000, crime per 100 000 and GDP/Capita were logarithmized. Variables that are percentages, EM/M1, % of population living in urban areas and unemployment were not logarithmized. This was done for ease of interpretation.

Results

Results for the five outcome variables using all four of our types of regressions are presented below in Tables 2–5. The presented *p*-values correspond to two-sided tests.

Fixed effects regressions

The results from the regular fixed effects dummy variable regressions are provided in Table 2. Our operationalization of cashlessness was negatively associated with theft, burglary and domestic burglary offending rates and statistically significant at the 5%, 1% and 5% level respectively. The estimated effects on robbery and homicide rates were positive and statistically insignificant.

The results from the fixed effects dummy variable regressions with lagged EM/M1 are provided in Table 3. EM/M1 with one-year lag was negatively associated with theft, burglary and domestic burglary offending rates and statistically significant at the 1%, 1% and 10% level respectively. In contrast to the regular fixed effect regression, the main explanatory variable is positively associated with homicide and statistically significant at the 10% level. The estimated effect on robbery rates was negative and statistically insignificant.

For the fixed effect regressions without lag the interpretation of the coefficients is the following: for each nation the case is that having only electronic money as liquid currency stock would result in crime rates being 85.4%, 115.5% and 81.5% lower for theft, burglary and domestic burglary respectively, than if that society would have only cash. A 0.01 move upwards in the variable, in other words a one percent more cashless society would then result in a 0.854%, 1.155%, and 0.815% reduction in the crimes respectively. The only non-significant coefficients are for robbery and homicide.

With a one-year lag the same interpretation holds (with the numbers from Table 3), but now for crime in the next year instead of the current year. With lags, robbery is once again not significant and homicide is surprisingly significant in the opposite direction of what the theory would predict.

Detrended OLS regressions

The results from the detrended regressions without lag are presented in Table 4 and the results from the detrended regressions with lag are presented in Table 5. In contrast to the previous regressions, none of our parameter estimates are statistically significant for any one of the detrended OLS regressions. As none of the results are significant, the interpretation of the detrended regressions is that yearly deviations from trend in our operationalization of cashlessness do not cause a deviation in crime for that year or the next.

Table 2: Result from fixed effects dummy variable regressions (Dummy variables for countries and years omitted)

	Ln Theft			Ln Robbery			Ln Burglary			Ln Domestic b.			Ln Homicide		
	β	SE	p	β	SE	p	β	SE	p	β	SE	p	β	SE	p
EM/M1	-0.854	0.342	0.013	0.089	0.514	0.862	-1.155	0.419	0.006	-0.815	0.411	0.049	0.368	0.394	0.352
Ln GDP/Capita	0.808	0.284	0.005	-2.243	0.316	0.000	-1.421	0.385	0.000	-1.428	0.326	0.000	-1.164	0.277	0.000
Unemployment	0.036	0.005	0.000	0.005	0.007	0.480	0.000	0.008	0.960	-0.003	0.007	0.655	-0.008	0.005	0.105
% Urban	-0.027	0.010	0.006	-0.022	0.015	0.153	-0.052	0.017	0.002	-0.053	0.024	0.027	-0.025	0.012	0.033
Ln Police	0.119	0.154	0.438	0.614	0.210	0.004	0.044	0.172	0.800	0.380	0.201	0.061	0.433	0.148	0.004
Constant	2.121	2.999	0.480	26.927	3.608	0.000	27.390	4.388	0.000	24.443	3.810	0.000	11.970	3.360	0.000
n		220			211			202			198			211	
F		0.000			0.000			0.000			0.000			0.000	
R^2		0.981			0.983			0.970			0.968			0.974	

Table 3: Result from fixed effects dummy variable regressions with 1 year lag (Dummy variables for countries and years omitted)

	Ln Theft			**Ln Robbery**			**Ln Burglary**			**Ln Domestic b.**			**Ln Homicide**		
	β	SE	p	β	SE	p	β	SE	p	β	SE	p	β	SE	p
EM/M1 lag	-1.109	0.388	0.005	-0.330	0.556	0.554	-1.423	0.437	0.001	-0.849	0.480	0.079	0.732	0.376	0.053
Ln GDP/Capita	0.832	0.327	0.012	-2.356	0.355	0.000	-1.507	0.409	0.000	-1.561	0.375	0.000	-1.274	0.331	0.000
Unemployment	0.034	0.005	0.000	-0.003	0.007	0.720	-0.005	0.009	0.535	-0.007	0.007	0.283	-0.009	0.005	0.088
% Urban	-0.034	0.012	0.005	-0.030	0.018	0.092	-0.067	0.017	0.000	-0.072	0.024	0.004	-0.020	0.013	0.139
Ln Police	0.193	0.177	0.277	0.783	0.231	0.001	0.247	0.170	0.148	0.640	0.200	0.002	0.415	0.158	0.009
Constant	1.974	3.419	0.564	28.230	3.854	0.000	28.787	4.643	0.000	26.265	4.140	0.000	12.547	3.842	0.001
n		207			199			192			190			200	
F		0.000			0.000			0.000			0.000			0.000	
R^2		0.981			0.984			0.972			0.970			0.976	

Table 4: Result from detrended OLS regressions (Dependant and independent variables have been linearly detrended)

	Ln Theft			**Ln Robbery**			**Ln Burglary**			**Ln Domestic b.**			**Ln Homicide**		
	β	SE	p	β	SE	p	β	SE	p	β	SE	p	β	SE	p
EM/M1	-0.313	0.302	0.301	0.070	0.381	0.854	-0.074	0.581	0.899	0.032	0.347	0.926	-0.679	0.430	0.116
Ln GDP/Capita	0.403	0.280	0.151	0.603	0.358	0.093	-0.149	0.361	0.681	-0.207	0.322	0.520	-0.371	0.378	0.327
Unemployment	0.015	0.005	0.006	0.015	0.007	0.036	0.011	0.008	0.166	0.003	0.006	0.583	-0.012	0.007	0.096
% Urban	-0.016	0.053	0.768	0.015	0.066	0.825	0.039	0.073	0.588	0.041	0.066	0.536	-0.029	0.073	0.688
Ln Police	0.147	0.158	0.352	1.130	0.202	0.000	0.301	0.197	0.128	0.494	0.183	0.007	0.409	0.212	0.055
Constant	-0.001	0.006	0.858	0.002	0.008	0.826	0.002	0.008	0.826	0.001	0.007	0.905	0.003	0.008	0.725
n		220			211			202			198			211	
F		0.039			0.000			0.095			0.043			0.106	
$\mathbf{R^2}$ / $\boldsymbol{Adj.R^2}$		0.053	0.031		0.143	0.122		0.046	0.022		0.058	0.033		0.043	0.020

Table 5: Result from detrended OLS regressions with 1 year lag (Dependant and independent variables have been linearly detrended)

	Ln Theft			**Ln Robbery**			**Ln Burglary**			**Ln Domestic b.**			**Ln Homicide**		
	β	SE	p	β	SE	p	β	SE	p	β	SE	p	β	SE	p
EM/M1 lag	-0.197	0.369	0.593	0.644	0.457	0.161	0.029	0.608	0.962	0.278	0.412	0.501	-0.261	0.472	0.580
Ln GDP/Capita	0.436	0.326	0.182	0.316	0.408	0.438	0.193	0.412	0.640	0.032	0.363	0.930	-0.409	0.418	0.329
Unemployment	0.016	0.006	0.012	0.014	0.008	0.064	0.014	0.008	0.086	0.009	0.007	0.178	-0.012	0.008	0.127
% Urban	0.011	0.061	0.860	0.007	0.075	0.921	0.030	0.074	0.686	0.013	0.068	0.850	0.021	0.079	0.790
Ln Police	0.159	0.174	0.364	1.201	0.219	0.000	0.394	0.205	0.056	0.531	0.193	0.006	0.389	0.223	0.083
Constant	-0.002	0.007	0.735	0.006	0.008	0.464	-0.002	0.008	0.815	0.000	0.007	0.971	0.002	0.009	0.857
n		207			199			192			190			200	
F		0.075			0.000			0.125			0.040			0.318	
$\mathbf{R^2}$ / $\boldsymbol{Adj.R^2}$		0.048	0.025		0.156	0.134		0.045	0.019		0.061	0.035		0.030	0.005

Diagnostics and robustness of the research

There is a potential problem of reverse causality when examining the link between cashlessness and acquisitive crime. If acquisitive crime increases, people might carry less cash, and if crime decreases people would feel more comfortable in carrying more cash again. Had the results indicated that more cash reduces acquisitive crime it is likely that the reverse relationship held true. As this is not the case, reverse causality is deemed to be a non-issue.

Fixed effects regressions

The fixed effect regressions suffer from several issues. They are run with robust standard errors because heteroskedasticity was present in the data. The VIFs (variance inflation factors) test for multicollinearity were alarmingly high at around 25 for our main explanatory variable, and extremely high at above 100 for several dummy variables, Urban and Ln Police, for both the regular and lagged specifications. When removing Urban and Ln Police, the significance levels of the parameter estimates of EM/M1 decreased for every dependent variable, and the VIFs for EM/M1 were still very high at around 20. Additionally, the Woolridge tests for autocorrelation concludes that there is autocorrelation with 1% significance for all crimes in both the regular and lagged specifications. These test results seriously discredit the regressions.

The R-squared values are very high in both regressions because of how the model is specified. While using fixed effects dummy variable regression, the R-squared values reflects the time-varying variation in the dependent variable that is explained by the time-varying variation in the independent variable. In our case though, they are unusually high which could be a symptom of spurious correlation.

It is likely that this model specification results in spurious regressions due to the nature of the data. Both the dependent and independent variables are non-stationary and display time trends. This introduces the risk of lurking omitted variables that drive both cash dependence and crime downwards. E.g. better video surveillance, forensic testing and other technological factors might impact crime, and the same underlying technological advancements might simultaneously drive a nation towards cashlessness. Because of the non-stationarity and the symptoms of spurious correlation we ran the detrended regressions.

Detrended OLS regressions

After detrending, the data becomes well behaved for both the regular and lagged models. There is no heteroskedasticity for any of the crimes when performing a Breusch-Pagan / Cook-Weisberg test for heteroskedasticity, except for burglary at the 1% significance level. Neither is there any multicollinearity, all VIFs are below 2.5 for all explanatory variables in all of our models. There is still the potential issue with autocorrelation. The Woolridge test for autocorrelation could reject the hypothesis that there was no autocorrelation, at the 5% level for homicide and at the 1% level for all other crimes. When excluding the urban and police variables, results stayed roughly the same for both specifications.

To check whether the parameter estimates would become more significant and if the residuals differed systematically among countries, we also ran the regressions with country specific fixed effects. Our results were unaffected and the dummy variables for each country were insignificant, indicating that the residuals did not differ systematically and the detrending was successful.

As the diagnostics of the detrended regressions are solid, we are confident in the result that they produce.

Discussion

We do not find any consistent significant relationship between our operationalization of cashlessness and crime of any sort across our model specifications.

Fixed effects regressions

As noted in the diagnosis, our significant results from the two types of fixed effects regressions are likely due to spurious correlation. The presence of time trends in both the dependent and explanatory variables indicate the presence of one or multiple lurking variables that causally affect both crime, the electronic share of money and other control variables. In our opinion this is evidenced by the inconsistent directions of the estimated effect of GDP/Capita (positive for theft, negative for other crimes), the negative significant effect of unemployment on homicide, and the negative significant effect of urbanization on all types of crime.

Therefore, to infer that cashlessness has a causal, negative effect on acquisitive crime, we would also have to conclude that GDP/Capita has a causal, positive effect on theft, that increased unemployment reduces homicide, and that increased urbanization reduces all types of crimes explored in our analysis.

These flaws have been remedied somewhat by the use of fixed effects dummy variables and controlling for common time trends through the inclusion of yearly dummy variables. Without these, our result would have been even less reliable. Evidently, however, the models still suffer from irredeemable problems and no causality can be established.

Detrended OLS regressions

Our stationary analysis does not suffer from the problems of spurious correlation and its result are therefore more reliable.

According to theory and given that linear relationships hold between cashlessness and crime rates, a positive deviation from trend in the electronic share of money would cause a negative deviation from trend in acquisitive crime. We find no such correlation or causation in our results. This indicates that the effect is not incremental and there is no linear, causal relationship between the electronic share of money and acquisitive crime.

However, these results do not rebut the theories that predict a causal relationship between cashlessness and crime rates. There may still exist causal relationships that are not linear to the degree that deviations from trends correlate strongly.

Conclusion

Our results serve as evidence against incremental effects on acquisitive crime from reduced cash use. A non-linear relationship consistent with the theories could still exist. As long as cash exist in a society, fencing is still viable. For example, in the framework of rational choice theory, costs might not incrementally increase with cashlessness, since stealing goods and fencing them is still possible. In fact, it might be that a majority of the spoils of theft, robbery and burglary are in the form of goods rather than cash in many societies. In that case the threshold for herd immunity would not exist as goods are as good a target as cash for robbers and thieves. Thus, the major gains

from a cashless society would come only at complete cashlessness, when fencing anonymously becomes an impossibility. This is an example of how causal non-linear effects might exist.

Although our results indicate that there is no linear relationship, we can neither confirm nor disprove the theories that predict a negative relationship between cashlessness and crime. Our results are in contrast to previous research that found this relationship to hold empirically. There are several potential explanations for why this is the case. It might be that our operationalization of cashlessness is too general and lacks importance or precision for street level cash use. The reverse could also be true, that our operationalization is the most accurate so far and that the theories actually do not hold. Another explanation could be that we have too few observations or are lacking data for important control variables. The main cause of the differing results though is that we forced our data to be stationary, something previous research has not done. The stationary analysis helps mitigate spurious correlation and omitted variable bias. Our fixed effects regressions did predict significant reductions in theft, burglary and domestic burglary, consistent with theory and previous research, but we believe that the reason for the significant results is flawed regressions suffering from spurious correlation. Armey et al., 2014 recognized the issue of spurious correlation with their similar regressions and made a point of the fact that their explanatory variable of point of sale devices per 1000 did not have significant effects on homicide or rape. Their argument is that if the regressions had caught an omitted variable that biased their main explanatory variable, that would have happened for homicide and rape as well, but it did not. This is true for our fixed effects regressions without lag as well. With lag however, homicide was significant in the wrong direction. We do not believe that that line of reasoning is enough to dismiss the possibility of spurious correlation, hence why a detrended analysis was performed as well. The results from those regressions indicate that the results from the fixed effects regressions were biased.

In conclusion, our main contribution to the research on the topic is the evidence against perfectly linear relationships between cashlessness and acquisitive crimes. Had this paper found significant effects of cashlessness on crime we could have proposed policy changes aiming at reducing crime rates through moves towards cashlessness. Now we can only encourage further research on the topic.

Future research

Researchers should continue to investigate the relationship between cash and crime, but with lack of reliable crime statistics and sufficient data for good control variables, conventional linear regression might not be the optimal method. We recommend instrumental variable estimation or natural experiments for future research.

With access to or the possibility to produce data on better control variables and more reliable crime statistics one could continue to build on our research, that of Pridemore et al., and Armey et al., by running regression analysis. We believe that several control variables that we were not able to find data on could be useful. The first one is drug consumption, as drug addicts are common offenders of these kinds of crime (Wright et al., 2014). Other potential control variables could be personal computers per 1000, if abortions were legal one generation before every year, wealth inequality, and percentage of population born in another country (cultural homogeneity).

As our results speak against linear effects, we recommend trying to locate thresholds of significant crime reductions and study the effects at that threshold. This could be done by constructing dummy variables for different levels of an operationalization of cashlessness and testing if their parameter estimates are negative and statistically significant. When a country takes the final step to outlaw cash that country should be studied immediately as well.

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Appendix

Appendix I: Sources for control variables:
GDP per capita, Purchasing Power Parity (2011 international $): World Bank, International Comparison Program database.

Unemployment (% of total): World Bank, ILOSTAT database

Urban population (% of total): World Bank, United Nations Population Division. World Urbanization Prospects

Appendix II: Changes to the data:
Yearly M0 and M1 measures are the average of the monthly data for the current year (January to December).

Crime statistics for the UK are the average of the separately reported data of England, Wales and Scotland.

The logarithmized data was used as the basis for the detrended data for all variables, except for EM/M1, unemployment and urban population.

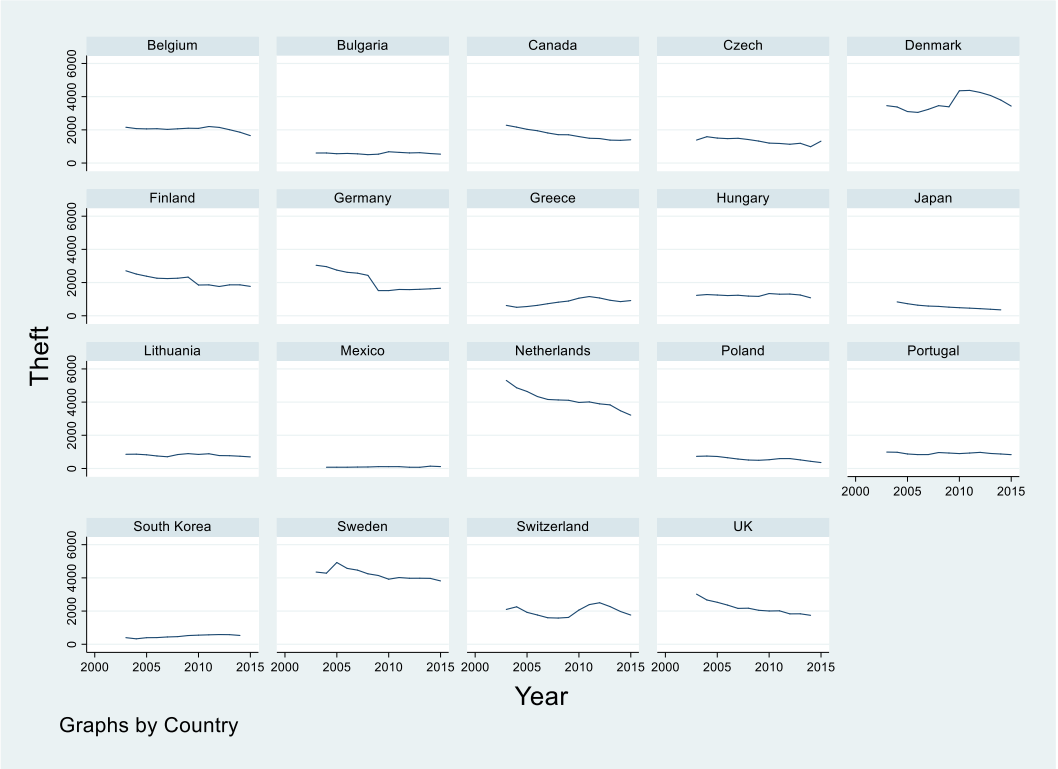
Appendix III: Deleted data:
M0 and M1 data for Switzerland 2012–2015 due to inconsistent values.

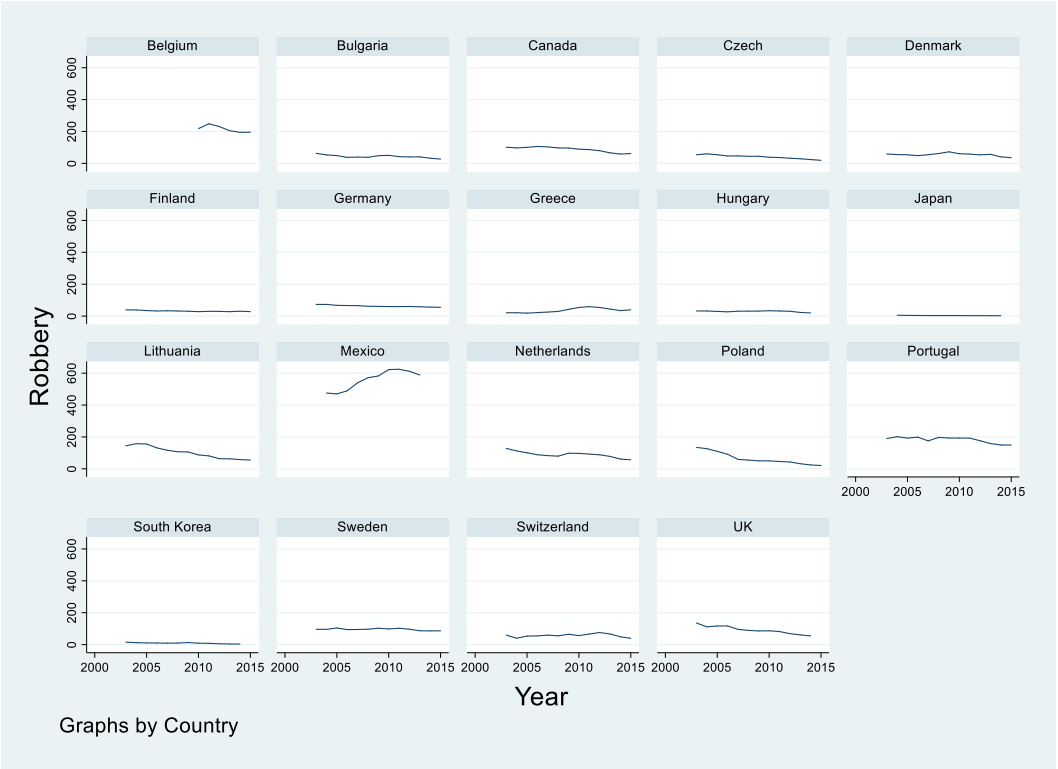
Robbery data for Mexico 2014 and 2015 due to a large jump in the data (likely due to a change of definition).

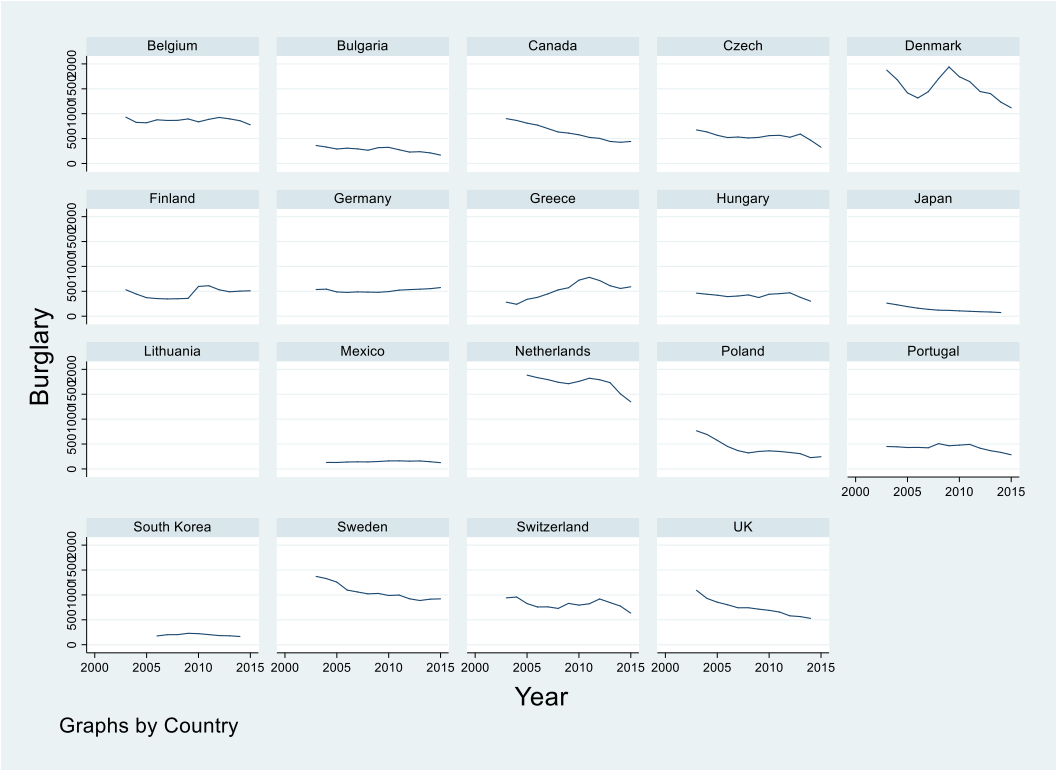
Robbery data for Belgium 2003–2009 due a large jump in the data (likely due to a change of definition).

Appendix IV: Plots of crime and EM/M1 data by year and country

Data sources covered in the data section. Diagrams by the authors.



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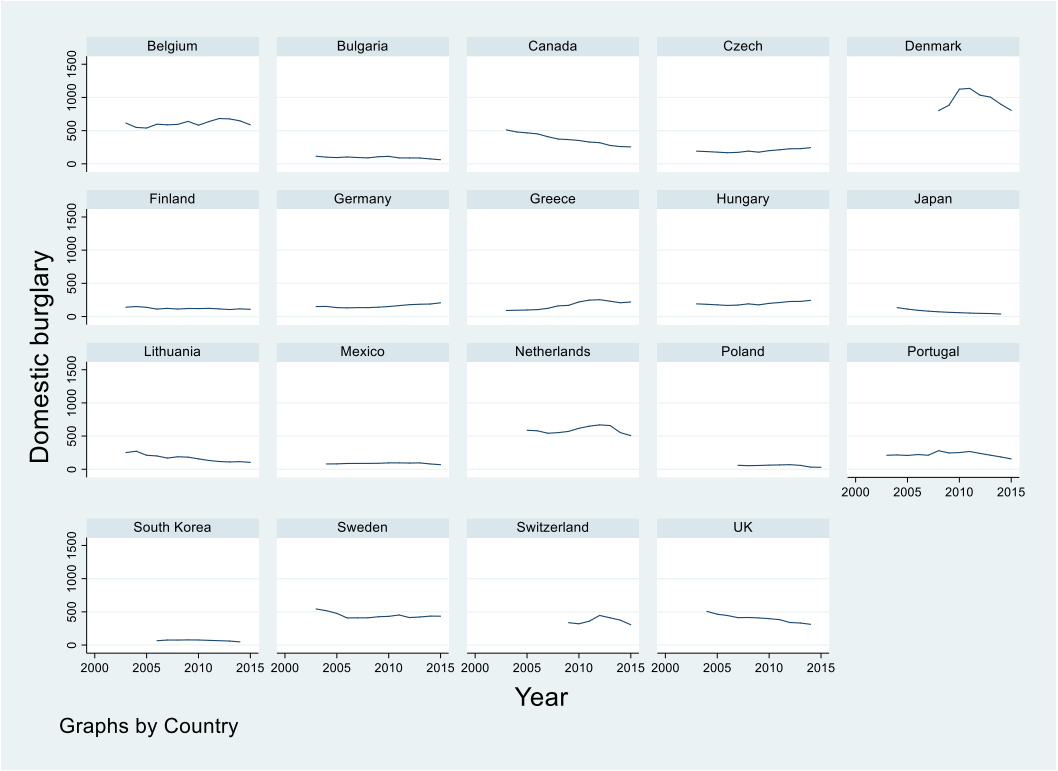
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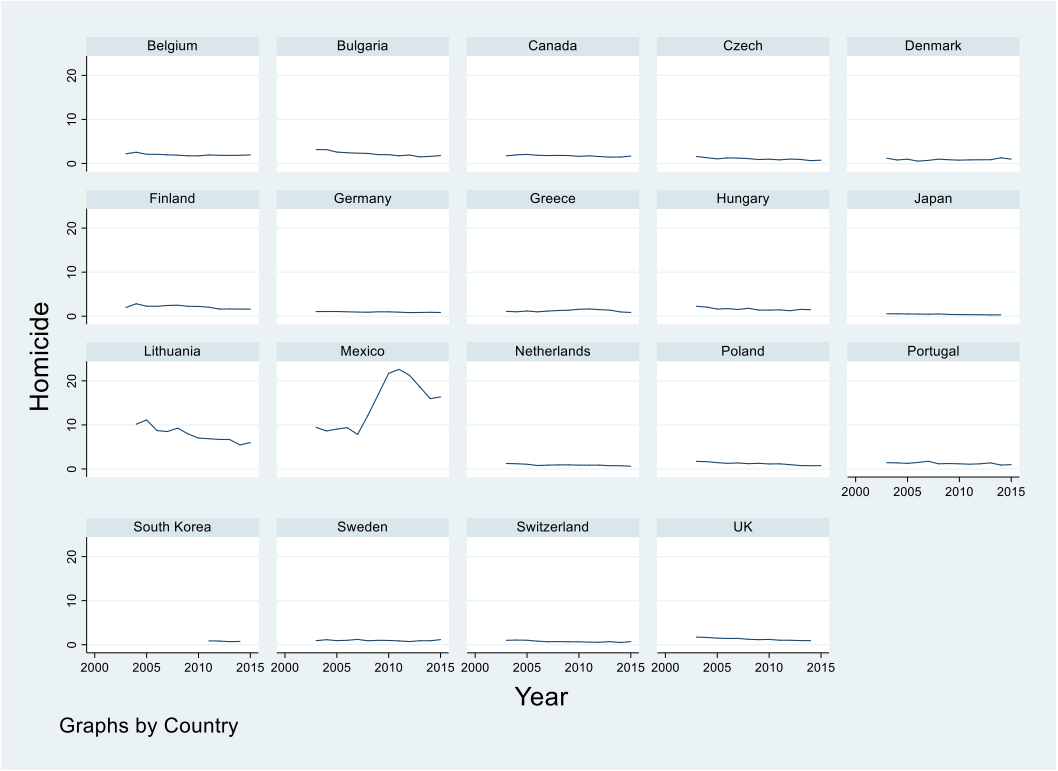
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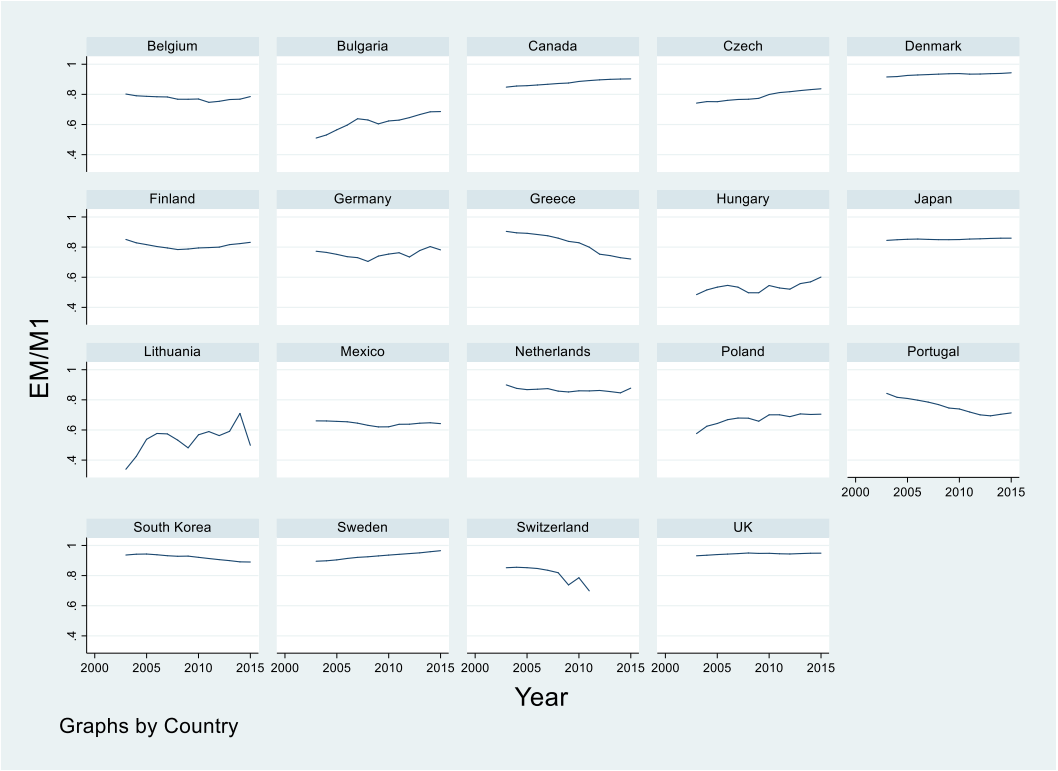
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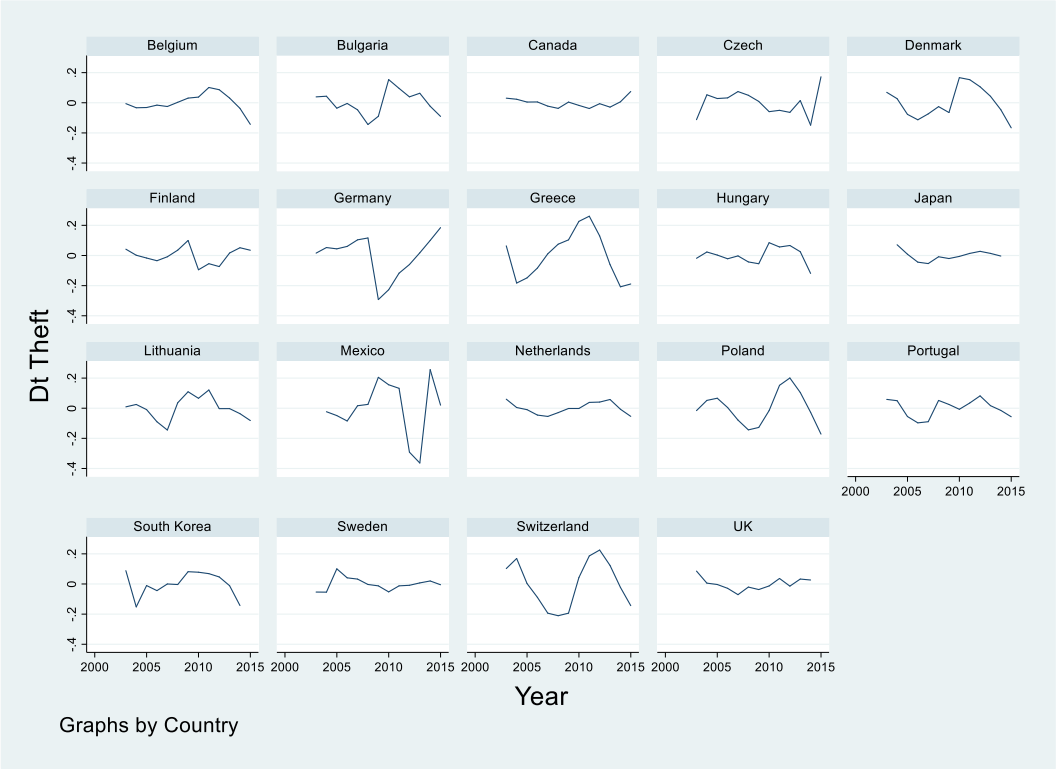
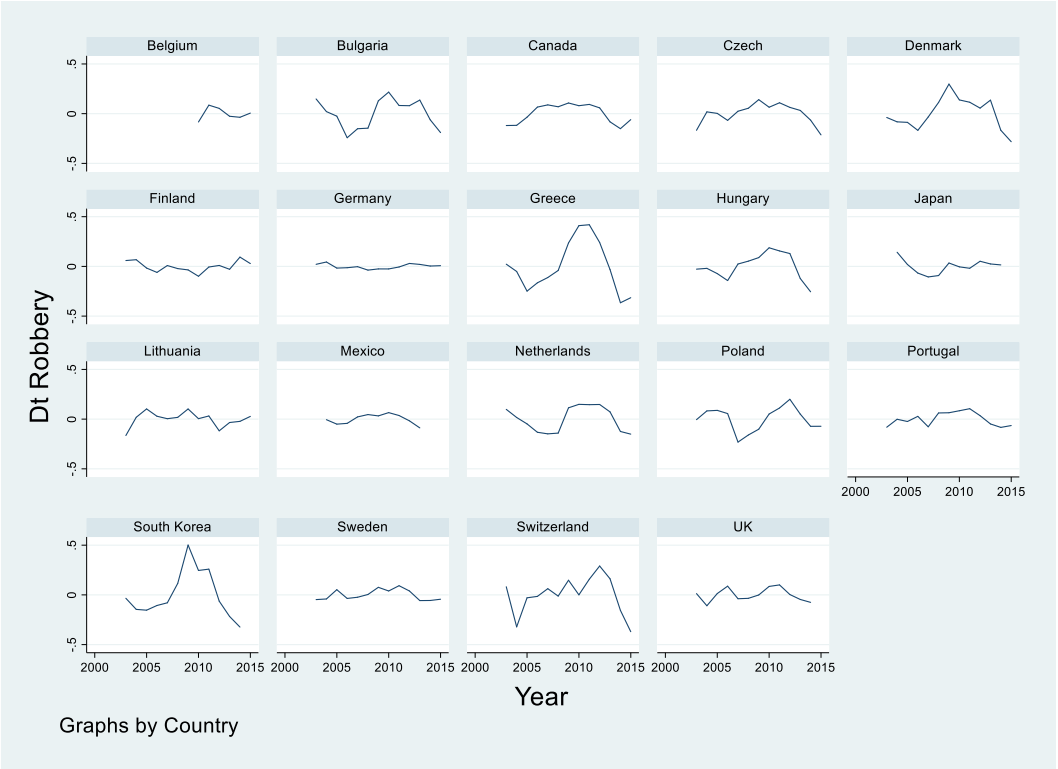
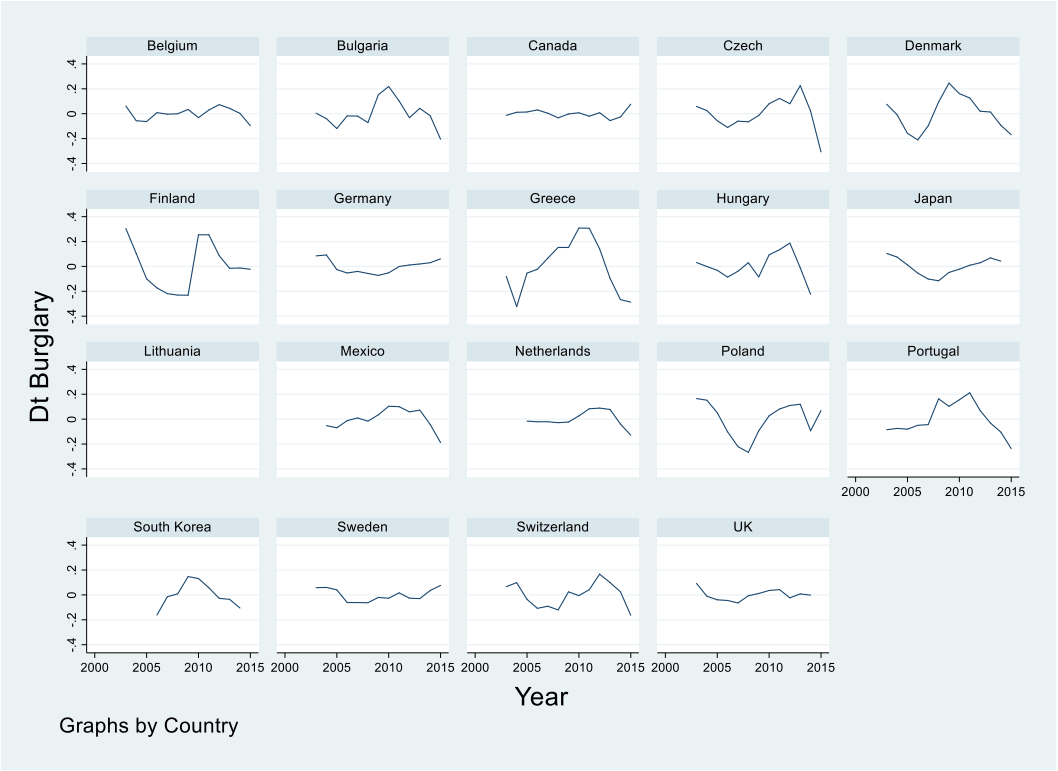
Appendix V: Plots of detrended crime and EM/M1 data by year and country

Data sources covered in the data section. Diagrams by the authors.



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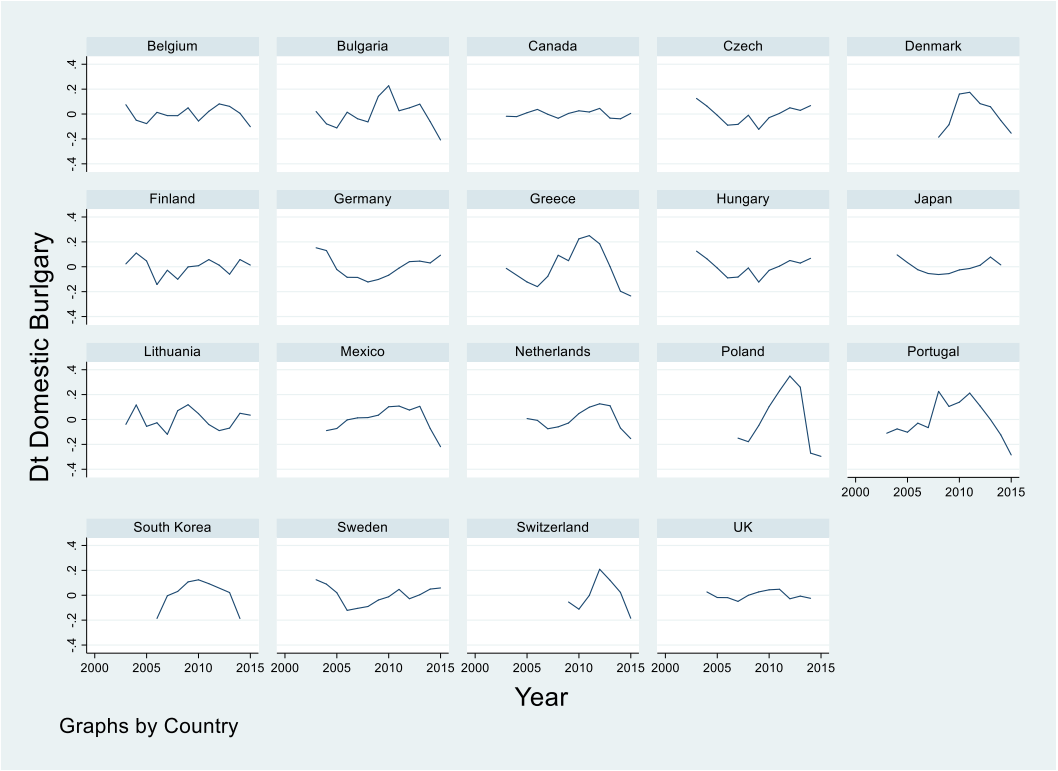
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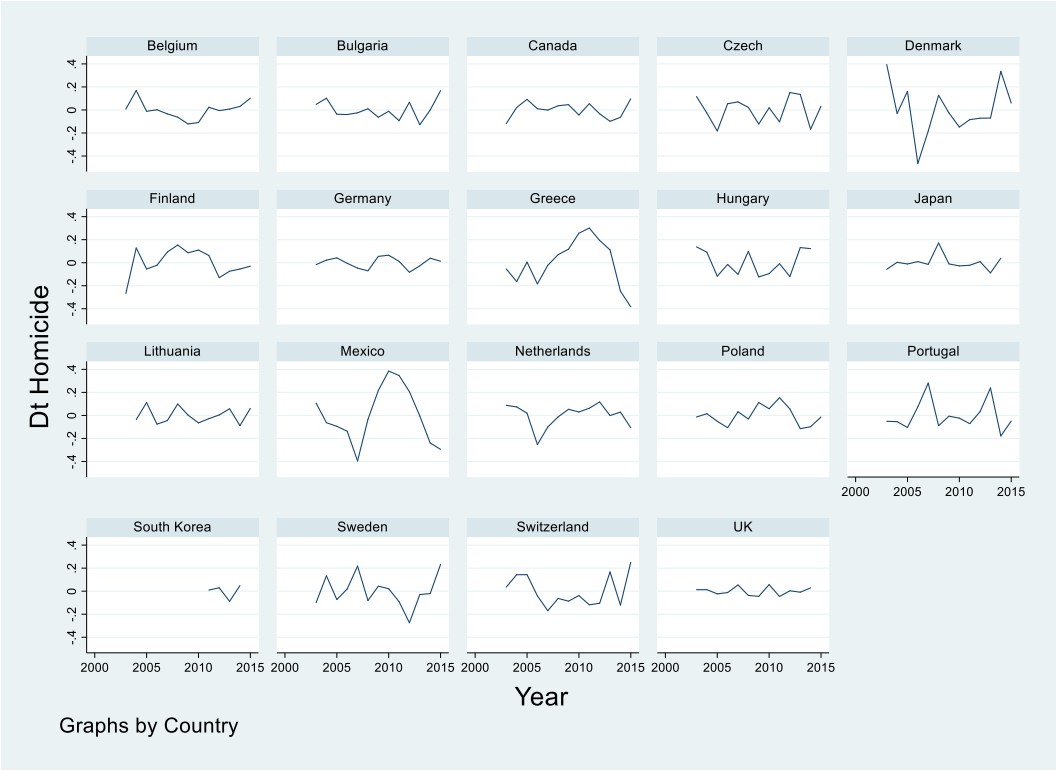
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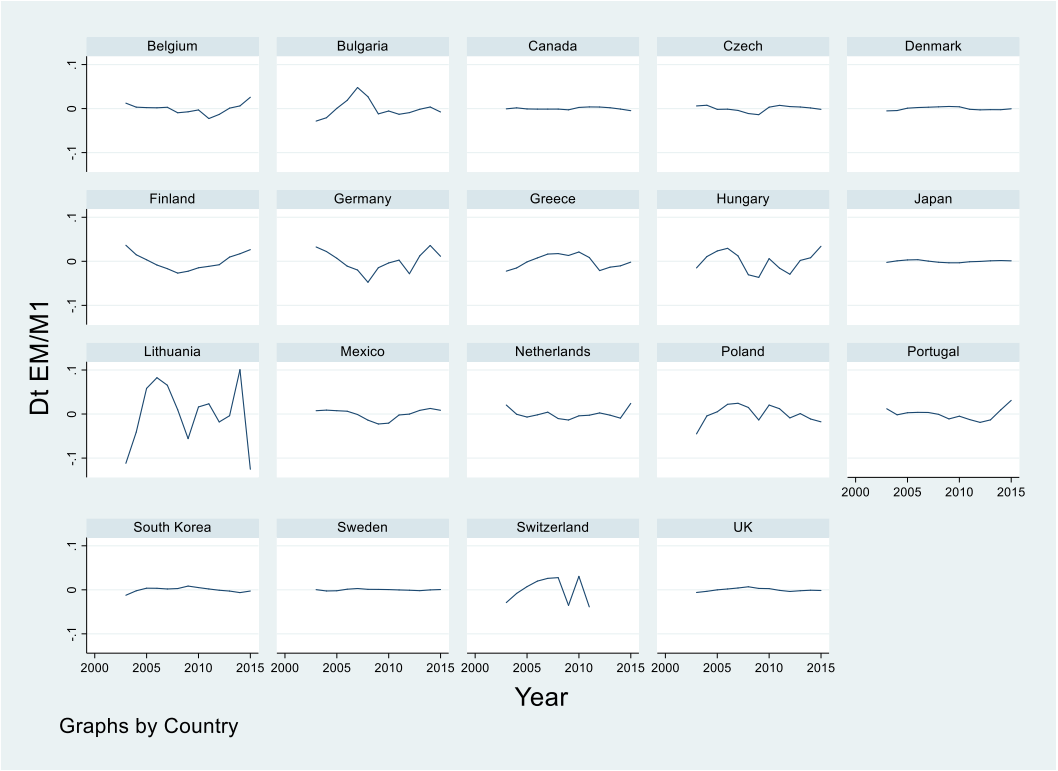
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