Rainfall, Poverty and Crime in 19th Century Germany

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Abstract: We estimate the impact of poverty on crime in 19th century Bavaria, Germany. Rainfall levels are used as instrumental variables for the price of rye to address identification problems found in the existing literature. The rye price was a major determinant of poverty during this period, as grain purchases constituted a large proportion of total household expenditures for the poor. We find large, positive and statistically significant effects of the rye price on property crime: a one standard deviation increase in the rye price increased property crime 8 percent. This result is robust to another poverty measure (the real wage), and when we restrict attention to lagged rainfall measures as instruments (ruling out some possible violations of the exclusion restriction). We also find that higher rye prices lead to significantly *less* violent crime, though, and argue that higher beer prices (caused by higher rye prices) are a likely explanation. We discuss implications for less developed countries today, and for economic theories of criminal behavior.

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1. Introduction

We investigate the impact of poverty on crime in 19th century Bavaria, Germany. Figure 1 graphically

presents the strong correlation between the price of rye – then the staple food of most Bavarians – and

property crime during 1835-1861, and Figure 2 shows the link between real wages and crime.

<div align="center">FIGURE 1 ABOUT HERE.</div>

<div align="center">FIGURE 2 ABOUT HERE.</div>

Striking correlations of this sort have been interpreted as the causal effect of poverty on

crime, but they are potentially subject to bias due to endogeneity and omitted variables. In other

words, does poverty generate crime – or does crime lead to more poverty? Or does some third factor –

say, government institutional performance – affect both simultaneously? To credibly estimate the

impact of poverty on crime, a source of exogenous variation in poverty is needed.

This paper's main innovation lies in using rainfall as a source of exogenous variation in rye

prices – and by extension poverty – in 19th century Bavaria.[1] Using a U.N. Food and Agriculture

Organization (FAO) historical rainfall database, described below, we find that rainfall alone explains

28 percent of variation in the rye price. Excessive rainfall sharply reduces rye yields, both by

interfering with the sowing season for winter grains, as well as ruining the harvest (Baten 2002).

Using an instrumental variable method, we estimate an elasticity of property crime with

respect to the rye price of 0.2 – which implies that a one standard deviation increase in the rye price

increased property crime by 8 percent. The analysis uses von Mayr's (1867) unique historical crime

series for Bavaria. These results are robust across specifications, and to the use of real wage data from

a different historical source (Gømmel 1978) as a proxy for poverty. Ordinary least squares estimates

are twice as large as instrumental variable estimates, and thus if interpreted causally would greatly

exaggerate the effect of poverty on property crime, highlighting the value of our IV approach.

A key remaining issue for econometric identification is the instrumental variable exclusion

restriction: rainfall should not affect crime other than through its effect on the price of rye. One

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[1] Miguel (2003) and Miguel, Satyanath, and Sergenti (2003) employ related econometric strategies in contemporary African settings. It is worth noting that in semi-arid African regions, more rainfall is typically associated with higher crop yields and less poverty, unlike in 19th century Bavaria, where the opposite holds.

concern is that rainfall itself may have a direct effect on crime: heavy rains could reduce criminals'

likelihood of being apprehended by the police (due to flooded roads, say), or might make it more

difficult to guard private property. Another possible channel is psychological: rainfall may affect

people's moods in such a way that they are more likely to commit crimes. If such channels are

present, the IV estimates could be misattributing direct effects of rainfall to poverty. However, these

channels are unlikely to be important in this context. In particular, we find that the main results are

robust to only using lagged rainfall measures, from the previous two years, as instrumental variables

(and not including current rainfall): lagged rainfall affects previous harvests, which in turn affect

current rye prices, but lagged rainfall should not directly affect people's current mood or current

police apprehension capacity, thus helping us rule out these other channels.[2]

In the second main empirical result, we find a strong negative relationship between poverty

and violent crime (Figure 3).

FIGURE 3 ABOUT HERE.

The effect of the rye price on alcohol consumption provides a plausible explanation. Rye prices had a

direct impact on the price of beer during this period (as discussed below), and greater alcohol

consumption has been linked to increased violent crime in both historical and recent studies (Zehr

1976, Markowitz 2000a, 2000b). In interpreting these findings, we argue that it is not the case that

poverty *per se* leads to less violent crime, but rather that in years of scarcity and high rye prices, beer

is also expensive, and this is the channel that leads to less violent crime. The sharp contrast between

the effect of rye prices on property crime versus violent crime highlights the importance of

distinguishing between rational choice theories of crime (such as Becker 1968) versus psychological

explanations for criminal behavior, in which the loss self-control – here due to alcohol consumption –

may play a central role, a point we take up again in the conclusion.

The remainder of the paper is organized as follows. Section 2 provides historical background

on 19th century Bavaria, and Section 3 describes our data sources. The main empirical results are

presented in Section 4, and the final section concludes.

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[2] Note that serial correlation in the annual rainfall measures is small (-0.1) and not statistically significant.

2. Historical Background on 19th Century Bavaria, Germany

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Germany was a predominantly agrarian society during the study period of 1835-1861, lagging far behind the earliest European industrializers, such as Britain and Belgium, and the Kingdom of Bavaria was a laggard even by German standards (Baten and Murray 2000, p. 352). Poverty, malnutrition and poor health were widespread. Sheehan (1989, p. 639) notes that "even in the best of times the poorest families spent most of their income on food; when prices rose they bought less, ate less, and became susceptible to typhus, typhoid, and the other infections that raged throughout these years." More precisely, according to Blackbourn (1997, p. 139), "even in normal times, food accounted for 80 per cent of spending by poor families", a figure comparable to many contemporary less developed countries; for instance, Miguel (2003) finds that 70 percent of expenditures go to food in rural Tanzania. This extreme poverty often bred desperation and criminal activity in Bavaria: when food prices rose Sheehan notes that (p. 640) "on the fringes of society, among those without enough work, savings or marketable skills, the choice was often between stealing, begging or starving."

Rye represented the major staple food for the poor in Bavaria, even more than the potato. Data for total rye and potato production in 1853 from Baten and Murray (2003) corroborates this view: protein intake from bread (derived from rye) was roughly four times that from potatoes.[3] The connection between rye prices and crime in Bavaria was first noted by von Mayr (1867), based on the same data we use. Later, Blasius (1976, 1978) argued that the close connection between rye prices and crime also held for Prussia in 1836-1850. Johnson (1995, p. 138) similarly notes that:

> "During the 1840s, early 1850s … food prices were rising quickly, jobs were scarce – and property offences were rife. But from the mid-1850s on, the general trend in the economy was toward lower prices and improved economic outlook for the majority of Germans, and over most of these years there was a decrease in simple theft offences, which were far and away the most common types of economic crimes and the ones most affected by raw economic hardship."

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[3] The diffusion of potato in Germany started in the late 18ᵗʰ century, but Baten (2003, p. 6) notes that "contemporary sources frequently describe potatoes as being extremely unpopular in the southern part of the country." Rye remained the main German staple even into the 20ᵗʰ century: Gerschenkron (1989 [1943], p. 112) notes that "one of the most seriously considered proposals for the stabilization of the mark in the fall of 1923 was the plan … [that] a "rye-mark" should be created, that is to say, the value of the restored German currency was to be based on the value of rye."

Although most claims by historians rest on anecdotes or simple graphical evidence, several authors also report statistical correlations between food prices and crime. Woytinsky (1929) does so using von Mayr's Bavarian data, Blasius (1978) reports positive correlations between rye bread prices and theft in Prussia, and Zehr (1976) reports strong positive correlations in Germany and France for parts of the 19th century, although he correctly notes that (p. 151) this "in no way proves a cause-and-effect relationship between these variables; it only says that they more-or-less vary together". We are not aware of any existing study that uses more sophisticated econometric techniques to address the fundamental identification problem highlighted in the introduction, as we do in this paper.

3. Data and Measurement

von Mayr (1867) contains information on annual property crime (e.g., theft, street robbery, armed robbery, embezzlement) rates per 100,000 inhabitants, on begging and vagrancy arrests, on violent crime (e.g., assault, gross indecency, loss of liberty / kidnapping, excessive punishment and rape), and on murder. These data are reported cases from Bavarian police records, which von Mayr argued was a better measure of crime than the number of convicted criminals. von Mayr's data are widely considered reliable and consistent over time, as he worked for decades using the same methods.[4] There is complete data for seven of eight Bavarian districts: Upper Bavaria, Lower Bavaria, Upper, Middle, and Lower Franconia, Schwabia, and Upper Palatinate; the sum across all districts is referred to as All Bavaria. (The district with missing data is Palatinate, which is not contiguous with the rest of Bavaria, and we drop it from the analysis.) The descriptive statistics (Table 1, Panel A), show that property crime rates during the study period were roughly comparable to current levels in Spain and Greece, and the murder rate was similar to the United States in the 1990s (UN 1999).

TABLE 1 ABOUT HERE.

The rye price data are from von Mayr as well (Table 1, Panel B). We also employ an additional poverty measure, first, to capture costs of living other than the price of rye, and second to

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[4] Zehr (1976, p. 42) concurs, arguing that among French and German regions during this period "the best [crime] series available is the Bavarian", and Johnson (1995, p. 117) notes that "Bavaria had the most highly developed crime statistics of any German state before 1882". von Mayr had a distinguished career, producing a monumental multi-volume work called *Statistics and Social Sciences*, which includes the volume *Moral Statistics with an element of Criminal Statistics*.

demonstrate the robustness of our results using a different data source. For that purpose we use real wage data from Gømmel (1978), which contains wages for *Bauhandwerker* (roughly translated as craftsmen) in Nuremberg, Middle Franconia. Note that *Bauhandwerker* were often quite poor, but were not considered the poorest of the poor in 19th century Bavaria. Finally, we have annual rainfall in meters for all of Germany from the FAO (2001) historical database, which is derived from rainfall gauges (Table 1, Panel C).[5] Thus while we have annual crime data at the district-level, due to data limitations we have just single annual measures of the rye price and rainfall.

4. Main Empirical Results

4.1 First-Stage and Reduced-Form Specifications

Rainfall from the current year, and from the previous two years, are included as instrumental variables predicting the rye price. Previous harvests may influence the current rye price by affecting the supply of stored grain, as well as the amount available for future sowing. All three coefficient estimates on the rainfall terms are positive (Table 2, regression 1) and we cannot reject the hypothesis that they are equal. One year lagged rainfall has the largest positive effect on prices (coefficient estimate 1.95, standard error 0.82) and is significant at the 95 percent confidence. Forward lags of rainfall – rainfall from future years – are not statistically significant as explanatory variables (regressions not shown), an important specification check. Rainfall alone explains 28 percent of rye price variation (regression 1). The positive first-stage relationship between lagged rainfall and the current rye price is presented graphically in Figure 4.

<div align="center">TABLE 2 ABOUT HERE.</div>

<div align="center">FIGURE 4 ABOUT HERE.</div>

Additional time controls are included to control for secular trends, and for any policy changes made in response to the food crisis of the late 1840s and the failed German revolution of 1848. As expected, violent crime shows a sharp increase in 1848, the year of the failed revolution (Figure 3).

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[5] Climate data derived from tree ring thickness (Briffa, Jones and Schweingruber 1988) did not strongly predict rye prices (regressions not shown). One reason may be that greater tree ring thickness reflects both higher rainfall and higher temperatures, and that, while excessive rainfall damages the rye harvest, warm weather typically works in the opposite direction.

Blackbourn (1997, p.138) notes that "revolution in Germany was a result of several superimposed crises. At the economic level, an old style crisis of harvest failure in 1845-7 … had important and cumulative effects throughout society. … Crop failure also doubled the price of basic foodstuffs like rye and potatoes, causing widespread distress among those living on the edge of subsistence". The rainfall data corroborate this, indicating that there were several consecutive years of heavy rains during 1843-1846, after which climatic conditions largely returned to normal.[6] The food crisis "eroded trust in 'complacent' governments, placing a question mark against their competence and their very legitimacy" (Blackbourn 1997 p. 140), and forcing them to respond aggressively; German states did so by a variety of means after 1848, including increased grain purchases and distribution, price controls, and limits on grain exports, and market intervention in Bavaria was particularly active.

To account for the effects of these policy shifts, linear and quadratic time trend terms, an indicator variable for the post-1847 period, and interactions between the post-1847 indicator and the time trend terms are included as controls; these time controls, together with the rainfall measures, capture 83 percent of variation in rye prices (Table 2, regression 2). Note the drop in rye prices after 1847, in part reflecting the government intervention described above. Lagged rainfall from the previous year again has the strongest effect on current rye prices. Not including current rainfall as an explanatory variable leaves the point estimates on the two lagged rainfall terms basically unchanged, with one-year lagged rainfall still significant at 99 percent confidence and two-year lagged rainfall significant at 95 percent confidence (regression not shown). Using the panel data from the seven Bavarian districts – in a framework that includes district fixed effects, and clusters disturbance terms by year – yields nearly identical point estimates and slightly smaller standard errors (regression 3).

Analogous regressions using the real wage of *Bauhandwerker* as the dependent variable broadly confirm our main result – that excessive rainfall reduces real income – although, perhaps not surprisingly, the effect of rainfall on wages is somewhat weaker than its impact on rye prices (Table 2, regression 4). Note that this probably understates the impact of rainfall on the real income of the

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[6] While historians have claimed that the 1845-47 food crisis generated popular support for the 1848 revolution, it is interesting to note that the return to normal rainfall in 1847 and 1848 might have also dampened enthusiasm for the revolution, leading to its ultimate failure.

poorest Bavarians – those most likely to resort to criminal activity in hard times – since rye consumed a larger share of the income of the poorest than of the working class.

The link between rainfall and rye prices also depends on transport costs and trade restrictions on grains. The railroad spread rapidly throughout Germany during the 1840s and 1850s (Carr 1991)[7], and this development facilitated inter-regional and even international trade in grains, thus potentially weakening the link from German rainfall to rye prices over time. Looser trade regulations could also weaken this link. The German Customs Union (*Deutscher Zollverein*) came into being in January 1834, embracing eighteen states (including Bavaria) with a total population of 23 million, and during the mid-19th century trade restrictions across states were gradually relaxed. By 1865 – just after our study period – "Germany had completely free trade in grains" (Gerschenkron 1943, p. 42).

To investigate if improved infrastructure and the expanding Customs Union weakened the link between rainfall and rye prices, interactions between rainfall and the time controls were included in the main specification (analogous to Table 2, regression 2), but we found no statistically significant effects on any of the interaction terms (regression not shown). One plausible explanation is that climatic variables and rye harvests are quite highly correlated throughout Germany, limiting the scope for trade as a moderating force in prices in the absence of large-scale international trade in grain.

In a reduced-form specification, estimating the impact of rainfall on property crime, lagged rainfall is associated with higher crime at over 90 percent confidence in the All Bavaria specification including time controls (Table 2, regression 5), and results are robust to other specifications (not shown) – our first hint that poverty increases property crime, the focus of the next sub-section. This relationship is presented graphically is Figure 5.

FIGURE 5 ABOUT HERE.

The analogous reduced-form coefficient estimates on one-year lagged rainfall are -0.66 (standard error 0.28, statistically significant at 95 percent confidence – regression 6) when the log of violent crimes is the dependent variable, and -0.55 (standard error 0.32) for the log of murders (regression not shown), evidence that higher rainfall reduces violent crime, the focus of sub-section 4.3 below.

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[7] See Ritschl (2003) for an account of this chapter in German economic history.

4.2 Rye Prices and Property Crime

The estimated elasticity of the rye price on property crime is 0.29 and statistically significant at 99

percent confidence in the OLS specification without time controls (Table 3, regression 1), and 0.41

when time controls are included (regression 2).[8]

<p style="text-align:center">TABLE 3 ABOUT HERE</p>

To address bias caused by endogeneity and omitted variable bias, we use an instrumental

variable two-stage least-squares (IV-2SLS) approach, where current rainfall, one-year lagged rainfall,

and two-year lagged rainfall are the instrumental variables for the rye price. In a specification with

time controls, this results in an estimated elasticity of 0.20 (Table 3, regression 3) which is

significantly different than zero at 95 percent confidence, and using crime data for the seven Bavarian

districts in a panel framework yields nearly identical results (regression 4). These estimates imply that

a one standard deviation increase in the rye price increases property crime by 8 percent. Note that this

is only half the magnitude of the analogous OLS estimate (0.41), suggesting that the bias in the OLS

regression is large and positive, leading to potentially misleading interpretations.

The historical evidence provides a possible explanation for the divergence between OLS and

instrumental variable estimates. Blackbourn (1997, p. 145) notes that social protest "triggered by

particular local circumstances" often resulted in direct action: "Peasants, rural labourers, journeymen

and workers demanded redress of their grievances and engaged in direct action", including "attacking

grain stores", and industrial sabotage, in some cases. In other words, property crime may directly

affect the price of rye when it includes the destruction of grain stores (as social protest), leading to

endogeneity in simple OLS specifications attempting to estimate the impact of rye prices on crime.

To address potential violations of the exclusion restriction (discussed in Section 1 above),

rainfall from the current year is not included as an instrumental variable in the first stage, and instead

only the lagged rainfall measures are used. The resulting point estimate on the rye price increases

slightly, to 0.26, in the All Bavaria specification and remains highly statistically significant (Appendix

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[8] When time controls are included, the Durbin-Watson statistic increases from 1.3 to 2.1, thus eliminating all
serial correlation in the residuals, and a similar result holds in all subsequent regressions. There is no significant
autocorrelation in the residuals in a number of other regressions where lagged price and crime measures are also
included as explanatory variables (not shown).

Table A1, regression 2), indicating that the IV-2SLS estimates are not driven by the direct effect of current rainfall on property crime.

The effect of real wages for *Bauhandwerker* (craftsmen) on property crime is somewhat stronger than the rye price results: the IV-2SLS elasticity of -1.00 (Table 3, regression 7) implies that a one standard deviation decrease in the real wage increases property crime by 15 percent, and once again this result is highly statistically significant and robust to alternative specifications.

The results with arrests for begging and vagrancy further suggest that rye prices were a major determinant of poverty during this period. In an IV-2SLS specification for All Bavaria including time controls, the elasticity of rye prices with begging and vagrancy is 0.60, again highly statistically significant (Appendix Table A2, regression 1). This implies that a one standard deviation increase in the rye price increases begging and vagrancy arrests by a very large 22 percent.

TABLE 4 ABOUT HERE

Some economic historians have claimed that the link between rye prices and crime in Germany broke down during the course of the 19th century, due to rising incomes, nascent industrialization, and the diffusion of the potato – which is less sensitive to climatic fluctuations than rye; if extreme poverty fell, and if crime was to a large extent driven by poverty, one might expect the impact of the rye price on crime to decrease over time. For instance, Zehr (1976, p. 138) claims that "the relationship between basic subsistence costs and both violent and property crime loosened as the century progressed due, seemingly, to rising standards of living". However, this claim remains contested, with other authors, including Gømmel (1978), finding that real wage levels were practically unchanged during our study period (although year-to-year fluctuations were often quite large). To test this claim, we include the interaction of the rye price and time trend terms (and instrument for these with interactions between rainfall levels and the time trend), and do not find support for the hypothesis that the effect of the rye price on property crime weakened during the period: none of the coefficient estimates on the interaction terms are statistically significant (results not shown).

4.3 Rye Prices and Violent Crime

Violent crime displays a strong negative association with the price of rye. In an OLS specification, the elasticity of violent crime (excluding murders) is -0.48, significant at 99 percent confidence (Table 4, regression 1). The IV-2SLS specification yields a somewhat smaller elasticity of -0.42 (regression 2), which is also significant at 99 percent confidence, and utilizing the panel of districts yields a similar estimate (regression 3). The results are robust to using only lagged rainfall as instruments for the rye price (regressions not shown), and are similar, though somewhat weaker, when the real wage is the endogenous variable (not shown). Murder is also strongly negatively associated with the rye price in the IV-2SLS specification, with a point estimate similar to other violent crimes (elasticity -0.31, significant at 95 percent confidence – regression 5).

The finding that violent crime is consistently negatively associated with rye prices is puzzling at first glance, given the strong positive impact of the rye price on property crime (Table 3). After all, violent crime is normally though to increase with poverty, as emphasized in Bonger's (1916) classic contribution on criminality and economic conditions, as well as in more recent contributions (see Fajnzylber, Lederman and Loayza 2002 and Miguel 2003).

The most compelling explanation for this result in 19th century Bavaria is that higher rye prices led to higher beer prices, and that the resulting drop in alcohol consumption in turn reduced violent crime. Using Nuremberg beer price data from Gømmel (1978), the correlation coefficient between the logs of rye and beer prices was 0.76, and highly statistically significant, during the study period. If the contemporaneous beer price is included as the endogenous variable, instead of the rye price, we find that the beer price also leads to significantly less violent crime (regression not shown); however, due to the fact that rainfall is the only source of exogenous variation, and that rye and beer prices are so highly correlated, we are unable to discriminate between the effect of beer prices versus the effect of rye prices – and, by extension, real wages – on violent crime. The impact of rye prices on violent crime is best understood as working through these two offsetting channels, and the results suggest that the negative effect of higher beer prices on violent crime far outweighed any positive impact of lower real wages.

Several other authors have found a strong correlation between alcohol consumption and violence. Markowitz (2000a, p. 1) notes that "the positive association between alcoholic beverage

consumption and violence is well documented, as is the negative relationship between the quantity of alcohol consumed and its price", and, using U.S. National Crime Victimization Survey data, she finds that higher beer taxes across U.S. states lead to a lower incidence of assault during the 1990s (Markowitz 2000b). Similar violent crime patterns were found in France for the 19th century, where according to Zehr (1976, p. 98) "the correspondence between peaks and troughs in wine consumption and in assault before 1870 was excellent – almost perfect." [9]

Finally, we also analyze the relationship between the rye price and total reported crime – including property crime, violent crime, and murder, as well as vandalism and rare violations such as perjury – and find a weak association: the coefficient estimate is 0.08 (standard error 0.08) in the All Bavaria IV-2SLS specification with time controls (Appendix Table A2, regression 5). This finding highlights the importance of looking beyond aggregate crime measures in empirical studies, as these may obscure interesting and heterogeneous underlying patterns across different crime categories.

5. Conclusion

We estimate the causal effect of high rye prices on crime in 19th century Bavaria, Germany using rainfall levels as instrumental variables for the rye price, and find that the effect of poverty on property crime is large and significant. Yet higher rye prices led to a sharp drop in violent crime, and we argue that this is due to a rise in the price of beer (due to higher rye prices).

The study lends support to the notion that economic conditions affect crime. Becker (1968) developed these ideas theoretically, and our finding on property crime is probably best understood within his rational-choice framework: higher rye prices decrease real income from legal employment, and this makes theft relatively more attractive. However, the violent crime findings are not as obviously accommodated in a Beckerian framework. The link from real income and alcohol prices to alcohol consumption, and from alcohol consumption to violence, could of course reflect a rational choice calculus: if people temporarily "lose control" when they drink, they might simply take this loss of control into account when deciding whether to drink in the first place. However, a more realistic (in

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[9] Zehr (1976) speculates that this was also the case for Germany, but notes that before 1870 (p. 102) "the lack of good alcohol consumption indexes for Prussia and Bavaria does not allow this possibility to be tested."

our view) understanding of alcohol use and violence is likely to be found in recent Psychology and Economics research. Risky behaviors like drinking may result, in part, because people systematically underweight the future consequences of their current actions during decision-making – especially if there are immediate utility benefits to the activity, as is the case for drinking alcohol – and because of errors of "over-confidence" about the ability to regulate future self-control problems (see O'Donoghue and Rabin 2001 for a discussion of these issues). Thus while property crimes in 19th century Bavaria appear to be "crimes of poverty", violent "crimes of passion" are less easily understood in terms of economic conditions and rational choice calculations.

The results may also have implications for policymakers in present-day less developed countries, which are at income levels similar to 19th century Bavaria. The elimination of agricultural price controls and subsidies may yield the efficiency gains traditionally emphasized by economists, but if these reforms – which often lead to higher and more variable food prices – exacerbate poverty, they may trigger outcomes not typically considered by economists, including crime waves and social instability.

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7. Tables and Figures

Figure 1: Rye prices and property crime in Bavaria
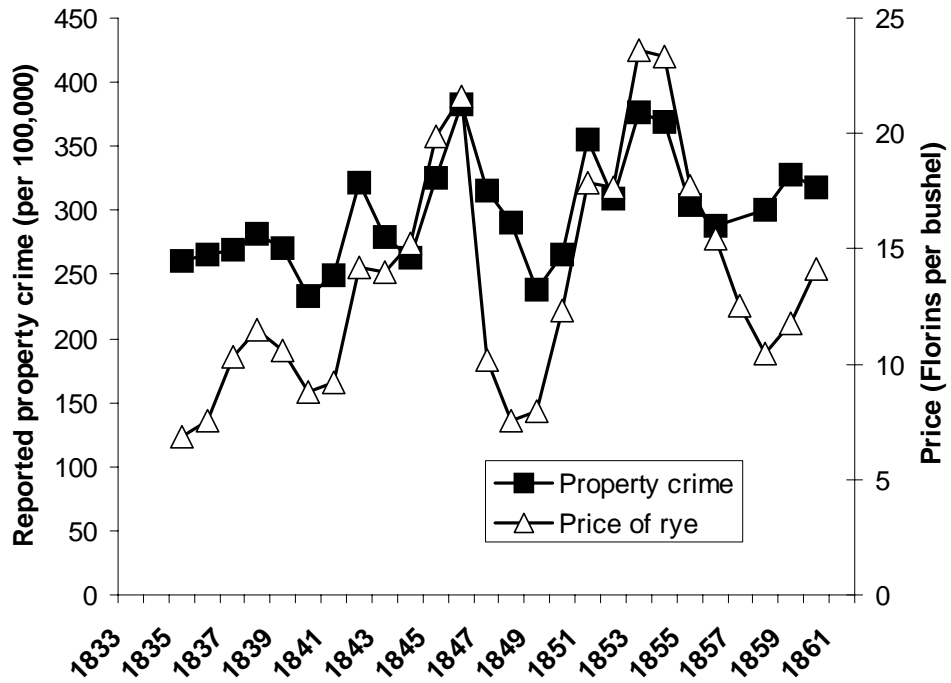

Figure 2: Real wage and property crime in Bavaria
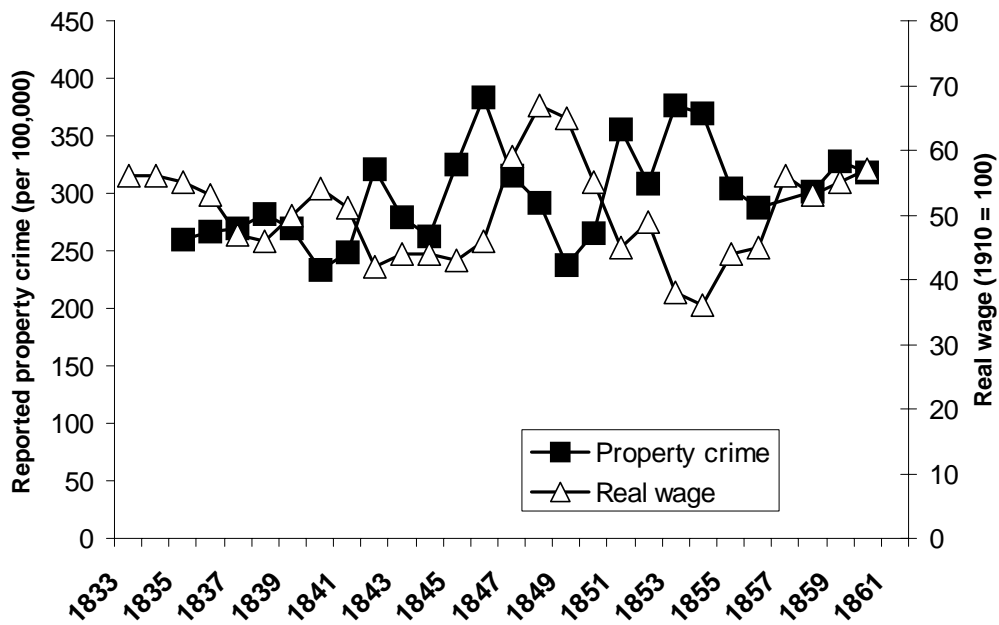
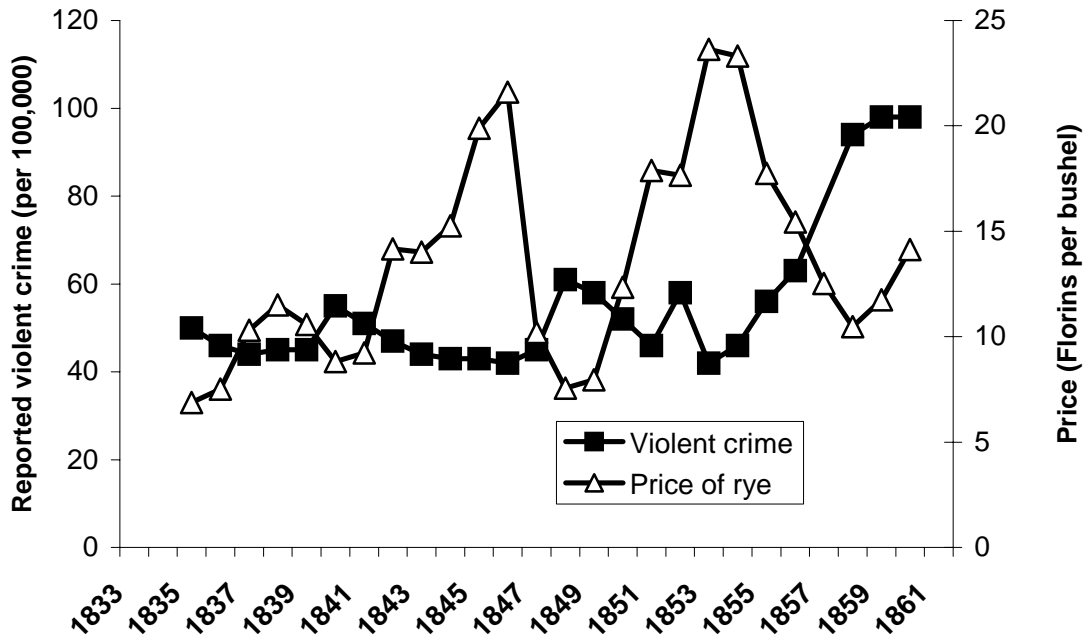**Figure 3:** Rye prices and violent crime in Bavaria

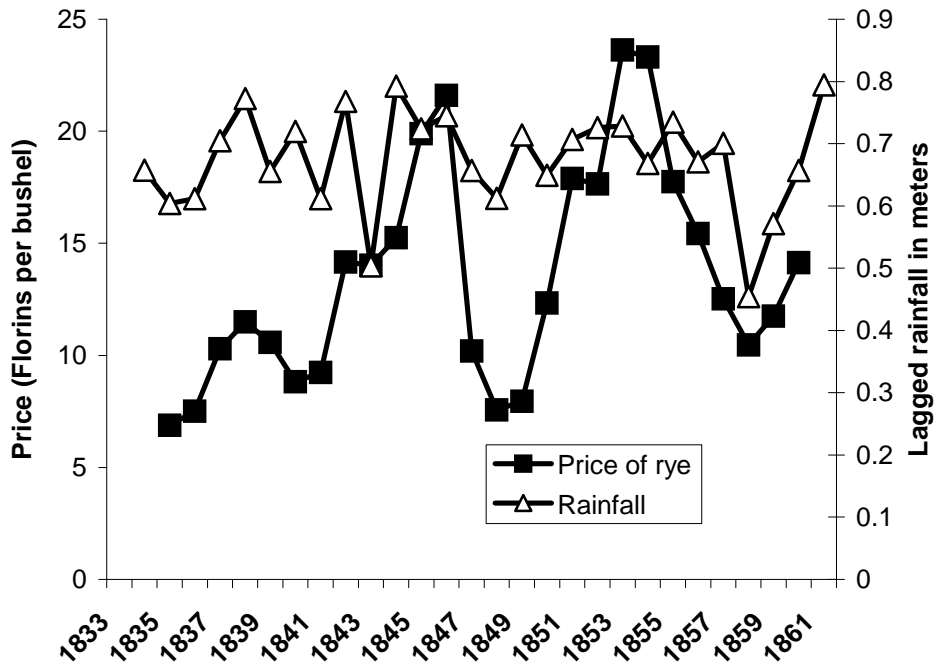**Figure 4:** Rye prices and rainfall in Bavaria
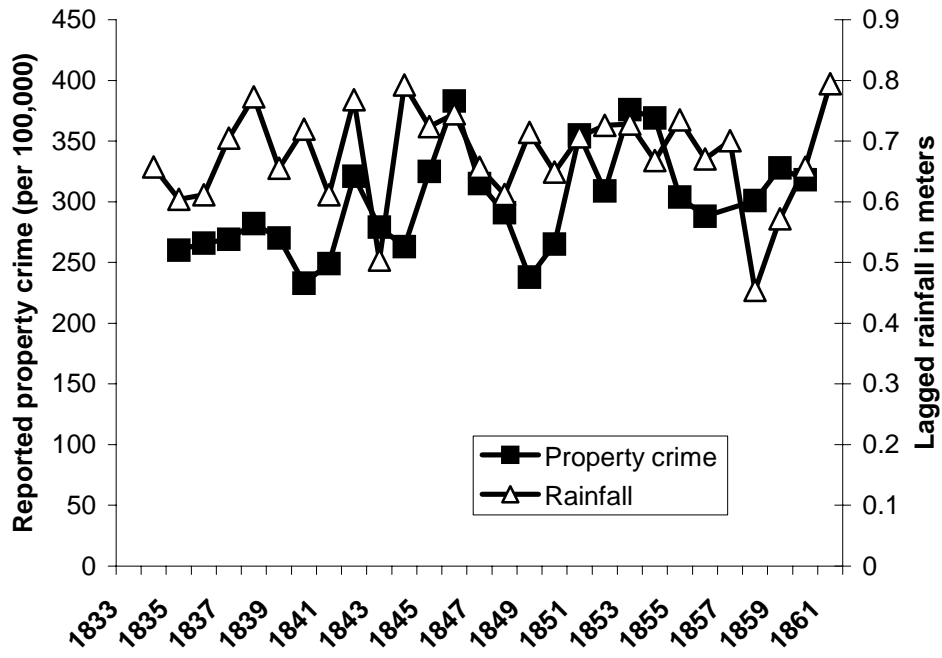
Figure 5: **Property crime and rainfall in Bavaria**

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Table 1: Descriptive Statistics

	All Bavaria			Bavarian States		
	Mean	std dev.	Obs.	Mean	std dev.	Obs.
Panel A: Crime measures						
Property crime (annual, per 100,000 population)	298	41.8	25	290	78.8	179
Ln (Property crime)	5.69	0.14	25	5.64	0.26	179
Violent crime (annual, per 100,000 population)	54.9	16.9	25	54.4	22.6	179
Ln (Violent crime)	3.97	0.26	25	3.93	0.36	179
Murders (annual, per 100,000 population)	8.16	1.18	25	8.04	2.4	179
Ln (Murders)	2.09	0.13	25	2.04	0.28	179
Total crime (annual, per 100,000 population)	418	61.3	25	408	92.8	179
Ln (Total crime)	6.02	0.14	25	5.99	0.22	179
Begging, vagrancy arrests (annual per 100,000 pop.)	1934	528	25	1744	676	179
Ln (Begging, vagrancy arrests)	7.54	0.25	25	7.37	0.48	179
Panel B: Economic measures						
Rye price (Florins per bushel)	13.6	5.0	25	13.6	4.9	179
Ln (Rye price)	2.55	0.37	25	2.54	0.36	179
Real wage (1910 = 100)	49.7	7.7	25	49.9	7.5	179
Ln (Real wage)	3.90	0.15	25	3.90	0.15	179
Panel C: Rainfall measures						
Rainfall (m), year t	0.69	0.070	25	0.68	0.076	179
Rainfall (m), year t-1	0.67	0.082	25	0.67	0.080	179
Rainfall (m), year t-2	0.67	0.082	25	0.67	0.080	179

Notes for Table 1:

All crime and rye price data are from von Mayr (1867). The data are from seven of eight Bavarian districts: Upper and Lower Bavaria, Upper, Middle and Lower Franconia, Schwabia, and Upper Palatinate. The sum of these is referred to as All Bavaria. The eight district is Palatinate (which is not geographically contiguous with the rest of Bavaria, and has missing data). For price and crime variables, the year runs from 1 November (of the previous year) to 31 October. For the rainfall and wage variables, the year runs from 1 January to 31 December.

Property crime: Reported property crime per 100,000 inhabitants per year. Property crime includes petty larceny (e.g., theft of wood, charcoal, turf), grand larceny, street robbery, armed robbery, embezzlement, and other property crimes.

Violent Crime: Reported violent crime per 100,000 inhabitants per year. Violent crime includes assault, gross indecency, loss of liberty / kidnapping, excessive punishment and rape. It does not include murder.

Murder: Reported murders per 100,000 inhabitants per year.

Total crime: Includes all property crimes, violent crimes, and murders, as well as vandalism, perjury and various other minor crimes. This measure does not include arrests of beggars and vagrants.

Begging and Vagrancy: Arrests of beggars and vagrants per 100,000 inhabitants per year.

Price of Rye. Measured in Bavarian Florin (Guilder) per Bavarian bushel.

The real wage data are from Gømmel (1978). This index is 100 in 1910. It is calculated using the officially regulated wage for builder craftsmen, corrected for a cost of living index.

The rainfall data are meters per year for Germany, FAO (2001).

Table 2: First-stage and Reduced-form Results

	Dependent variable:					
	Ln (Rye price)			Ln (Real wage)	Ln (Property crime)	Ln (Violent crime)
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS
Rainfall variables						
Rainfall, year t	1.04	0.61	0.83**	-0.05	-0.16	-0.36
	(0.83)	(0.51)	(0.40)	(0.29)	(0.33)	(0.27)
Rainfall, year t-1	1.95**	1.71***	1.66***	-0.41*	0.38*	-0.66**
	(0.82)	(0.47)	(0.34)	(0.22)	(0.20)	(0.28)
Rainfall, year t-2	1.20	1.08**	1.02**	-0.33	0.42	-0.50
	(0.82)	(0.49)	(0.40)	(0.25)	(0.36)	(0.30)
Time controls						
Time trend		-0.002	-0.002	-0.022	-0.0590*	0.039
		(0.050)	(0.043)	(0.030)	(0.033)	(0.028)
(Time trend)^2		0.0056	0.0056	-0.0007	0.0059**	-0.0031
		(0.0035)	(0.0030)	(0.0023)	(0.0024)	(0.0020)
Post-1847		-4.20**	-4.15***	3.21***	-0.34	1.94
		(1.61)	(1.39)	(1.01)	(0.73)	(1.26)
Time trend*Post-1847		0.46**	0.45***	-0.31**	0.085	-0.26*
		(0.17)	(0.14)	(0.11)	(0.084)	(0.13)
(Time trend)^2*Post-1847		-0.016***	-0.016***	0.0073	-0.0062*	0.0098**
		(0.0051)	(0.0044)	(0.0034)	(0.0031)	(0.0037)
R^2	0.28	0.83	0.83	0.71	0.51	0.87
Root MSE	0.33	0.18	0.15	0.10	0.12	0.11
Observations	25	25	179	25	25	25
Mean dependent variable	2.54	2.54	2.54	3.9	5.69	3.97

Table 2 Notes: Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. Regressions (1)-(4) are First stage results, and regressions (5)-(6) are the Reduced-form. The hypothesis of no first-order autocorrelation cannot be rejected (using the Durbin-Watson test statistic) in the specifications that include time controls. In the specification with district-level data (regression 3), disturbance terms are allowed to be correlated across states in a given year, and district fixed effects are included.

Table 3: Poverty and Property Crimes

	(1) OLS	(2) OLS	(3) IV-2SLS	(4) IV-2SLS	(5) OLS	(6) OLS	(7) IV-2SLS	(8) IV-2SLS
Dependent variable: Ln(Property crime)								
Ln (Rye price)	0.29***	0.41***	0.20**	0.22**				
	(0.05)	(0.08)	(0.09)	(0.09)				
Ln (Real wage)					-0.46***	-0.88**	-1.00**	-0.93**
					(0.15)	(0.14)	(0.47)	(0.36)
Time controls	No	Yes	Yes	Yes	No	Yes	Yes	Yes
District fixed effects	No	No	No	Yes	No	No	No	Yes
R^2	0.60	0.78	-	-	0.26	0.76	-	-
Root MSE	0.09	0.08	0.09	0.15	0.12	0.08	0.08	0.14
Observations	25	25	25	179	25	25	25	179
Mean dependent variable	5.69	5.69	5.69	5.64	5.69	5.69	5.69	5.64

Table 3 Notes: Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. The hypothesis of no first-order autocorrelation cannot be rejected (using the Durbin-Watson test statistic) in the specifications that include time controls. In both specifications with district-level data (regression 4, 8), disturbance terms are allowed to be correlated across states in a given year. The instrumental variables are rainfall in the current year, in the lagged year (t-1), and two years earlier (t-2).

Table 4: Poverty and Violent Crimes and Murder

	Ln(Violent crime)			Ln(Murder)		
	(1) OLS	(2) IV-2SLS	(3) IV-2SLS	(4) OLS	(5) IV-2SLS	(6) IV-2SLS
Dependent variable:						
Ln (Rye price)	-0.48***	-0.42***	-0.37***	-0.25**	-0.31**	-0.25**
	(0.05)	(0.08)	(0.08)	(0.10)	(0.14)	(0.12)
Time controls	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	No	No	Yes	No	No	Yes
R^2	0.95	-	-	0.63	-	-
Root MSE	0.07	0.07	0.19	0.09	0.09	0.20
Observations	25	25	179	25	25	179
Mean dependent variable	3.97	3.97	3.93	2.09	2.09	2.04

Table 4 Notes: Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. The hypothesis of no first-order autocorrelation cannot be rejected (using the Durbin-Watson test statistic) in the specifications that include time controls. In both specifications with district-level data (regression 3, 6), disturbance terms are allowed to be correlated across states in a given year. The instrumental variables are rainfall in the current year, in the lagged year (t-1), and two years earlier (t-2).

Appendix

<u>Appendix Table A1</u>: Poverty and Property Crimes – using only lagged rainfall as instruments

	Dependent variable: <u>Ln(Property crime)</u>					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV-2SLS	IV-2SLS	OLS	IV-2SLS	IV-2SLS
Ln (Rye price)	0.41***	0.26**	0.24**			
	(0.08)	(0.09)	(0.11)			
Ln (Real wage)				-0.88***	-1.05*	-1.06*
				(0.14)	(0.50)	(0.58)
Time controls	Yes	Yes	Yes	Yes	Yes	Yes
District fixed effects	No	No	Yes	No	No	Yes
R^2	0.78	-	-	0.76	-	-
Root MSE	0.08	0.08	0.15	0.08	0.12	0.14
Observations	25	25	179	25	25	179
Mean dependent variable	5.69	5.69	5.64	5.69	5.69	5.64

<u>Table A1 Notes</u>: Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. The hypothesis of no first-order autocorrelation cannot be rejected (using the Durbin-Watson test statistic) in the specifications that include time controls. In both specifications with district-level data (regression 3, 6), disturbance terms are allowed to be correlated across states in a given year. The instrumental variables are rainfall in the lagged year (t-1), and two years earlier (t-2), not in the current year.

<u>Appendix Table A2</u>: Poverty versus begging and vagrancy and major crime categories

	Dependent variable:				
	Ln (Begging, vagrancy)	Ln (Property crime)	Ln (Violent crime)	Ln (Murder)	Ln (Total crime)
	(1)	(2)	(3)	(4)	(5)
	IV-2SLS	IV-2SLS	IV-2SLS	IV-2SLS	IV-2SLS
Ln (Rye price)	0.60***	0.20**	-0.42***	-0.31**	0.08
	(0.11)	(0.09)	(0.08)	(0.14)	(0.08)
Time controls	Yes	Yes	Yes	Yes	Yes
R^2	-	-	-	-	-
Root MSE	0.07	0.09	0.07	0.09	0.08
Observations	25	25	25	25	25
Mean dependent variable	7.54	5.69	3.97	2.09	6.02

<u>Table A2 Notes</u>: Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. The hypothesis of no first-order autocorrelation cannot be rejected (using the Durbin-Watson test statistic) in the specifications that include time controls. The instrumental variables are rainfall in the current year, in the lagged year (t-1), and two years earlier (t-2).