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 is used as an instrumental variable for grain (rye) prices to address econometric identification problems in the existing literature. The rye price was a major determinant of living standards during this period. The rye price has a positive effect on property crime: a one standard deviation increase increased property crime by 8%. OLS estimates are twice as large as instrumental variable estimates, highlighting the value of our empirical approach. Higher rye prices lead to significantly less violent crime, though, and we argue that higher beer prices, caused by the higher rye prices, are a likely explanation.

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1. Introduction

This paper uses a new empirical approach to estimate the causal impact of poverty on crime. We study both property crime and violent 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 property crime.

FIGURE 1 ABOUT HERE.

FIGURE 2 ABOUT HERE.

Striking correlations of this sort have been interpreted as the causal effect of poverty on property crime by historians, but they are potentially subject to bias due to endogeneity and omitted variables, and we are not aware of economic history research that addresses the key identification issues. In other words, does poverty generate crime – or does crime lead to more poverty? Or does some third factor – say, government institutional performance, a certain public policy reform, or political instability – affect both simultaneously? To credibly estimate the impact of poverty on crime, a source of exogenous variation in real income is needed. Although our aim is to apply this approach in economic history, it may also be extended to some present day less developed countries.

This paper's main innovation lies in using rainfall as a source of exogenous variation in rye prices, and by extension the cost of living, in 19th century Bavaria, where rye was the main staple.[1] This empirical strategy is viable in poor largely agrarian societies, like 19th century Bavaria or contemporary less developed countries, where rainfall shocks have a major impact on real income. Using a United Nations Food and Agriculture Organization (FAO) historical rainfall database described below, we find that rainfall alone explains 28% of total variation in rye prices. Excessive rainfall sharply reduces rye yields, both by interfering with the sowing season for winter grains, as

[1] Miguel [29] and Miguel et al. [30] 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 held. Oster [33] shows that extreme precipitation and temperatures were associated with witch hunts in 16th-18th century Europe and North America.

well as by ruining the harvest (Baten [2]). High rye prices led to lower real incomes for urban workers and rural farm laborers in Bavaria, and also for farmers whose crop was destroyed by floods.

The analysis uses von Mayr's [27] unique historical crime series for Bavaria. 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 a moderate 8%. The magnitude is similar to recent findings on the impact of unemployment and wages on property crime in the contemporary United States (Levitt [23]). These results are robust across several specifications. The finding is also robust to the use of the real wage for skilled workers (from a different historical source, Gømmel [19]), as a second proxy for the standard of living.

Ordinary least squares estimates are twice as large as instrumental variable estimates. A partial explanation for this simultaneity bias may be the historical observation (Galius [17]) that social tensions in Bavaria during this period sometimes took the form of property crime that directly affected the price of rye, for instance, destruction of grain stores. The OLS estimates overstate the effect of poverty on property crime, highlighting the value of the IV approach we develop. These econometric methods have not before, to our knowledge, been applied in the economic history literature on the causes of crime.

The main limitations of the empirical analysis are the relatively small sample of only 25 years,[2] and the fact that there is only a single Bavarian rye price series during this period (due to extensive local grain market integration in southern Germany). While both the data on the rye price and on rainfall vary only across time in our sample (i.e., there is a single series for all Bavaria), there are separate district-level time series for crime. We exploit this variation in some specifications using district fixed effects, and find that the main instrumental variable result is indeed robust. However, the lack of district-specific rye price and rainfall data limits the informational value of the district-level analysis beyond what is learned in the main regression specification.

A key issue for econometric identification is the instrumental variable exclusion restriction: rainfall should only affect crime through its impact on living standards. One concern is that rainfall

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

itself may have a direct effect on crime, if heavy rains reduce criminals' likelihood of being apprehended by the police (due to flooded roads, for example), or 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, or rainfall may make it more or less pleasant to commit crimes. If such channels are present, IV estimates could misattribute the direct effects of rainfall to poverty. However, these channels are unlikely to be important in the context we study. In particular, the main empirical results are robust to using only lagged rainfall measures (from two earlier years) as instrumental variables. Lagged rainfall affects previous harvests, which in turn affect current rye prices and living standards, but lagged rainfall should not directly affect people's current mood, current police capacity, or the ability to protect private property, thus helping us rule out these other channels. This serves as an important validation of the empirical strategy.

The second main empirical finding focuses on our other major crime category, violent crime. We find a strong *negative* relationship between rye prices and violent crime (Figure 3).

FIGURE 3 ABOUT HERE.

The effect of the rye price on alcohol consumption provides a plausible, though admittedly speculative, explanation. High rye prices led to high beer prices during this period, reducing demand, and lower alcohol consumption has been linked to less violent crime in both historical settings and recent studies (Zehr [41], Markowitz [25], [26]). In interpreting these findings, we argue that it is not the case that poverty *per se* leads to less violent crime, but rather that beer is also expensive in years of high rye prices and the resulting reduction in beer consumption is the likely channel that reduces violent crime.

Taken together, these findings support the view that economic conditions affect crime. Becker [6] developed these ideas theoretically, and our property crime findings are probably best understood within his rational choice framework: higher rye prices reduced real income from legal labor market activities, and this made theft relatively more attractive for the Bavarian poor.

However, 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 Beckerian calculations. The link from 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. A more realistic (in our view) understanding of alcohol use and violence, however, is likely to be found in recent Psychology and Economics theory. Risky behaviors like drinking may result in part because people systematically fail to consider the future consequences of their current actions – especially if there are immediate utility benefits, as is often the case for drinking alcohol (see O'Donoghue and Rabin [32]). Our violent crime findings are also consistent with "projection bias" (Loewenstein et al. [24]), the notion that people in a given "state" – for instance, when sober – systematically make faulty predictions about their behavior in another state (when drunk), and this may lead them to drink excessively and commit "too many" violent crimes.

The remainder of the paper is organized as follows. Section 2 provides historical background on 19th century Bavaria, and Section 3 describes the data sources. The main empirical results are presented in Section 4, and the final section concludes.

2. Historical Background on 19th Century Bavaria, Germany

Germany was a predominantly agrarian society during the study period of 1835-1861, lagging far behind the earliest European industrializers Britain and Belgium, and the Kingdom of Bavaria was a laggard even by German standards (Baten and Murray [1], p. 352). Poverty, malnutrition and poor health were widespread. Sheehan ([37], 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 ([7], 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.[3] For instance, Miguel [29] finds that 70% of expenditures go to food in rural Tanzania. Ten percent of Bavarian household income went for beer purchases alone (Gømmel [19]). 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

[3] Of course, food accounted for a smaller budget share for wealthier Bavarian households.

skills, the choice was often between stealing, begging or starving." Land reforms associated with the end of serfdom further increased rural poverty in the 19th century by stripping away feudalism's limited remaining safety nets (Baten [4]).

Rye represented the major staple food for the Bavarian poor, much more than potato, wheat or other crops. Data for total rye, potato and wheat production in 1853 from Baten and Murray [1] indicate that protein intake from bread (derived from rye) was roughly four times that from potatoes and six times that derived from wheat.[4] Thus the price of rye was a key determinant of living standards in 19th century Bavaria.

The connection between rye prices and crime in Bavaria was first noted by von Mayr [27], based on the same data we use. Later, Blasius ([8], [9]) argued that the close connection between rye prices and crime also held for Prussia in 1836-1850. Johnson (21], 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."

Although most claims by historians rest on anecdotes or simple graphical evidence (like Figures 1 and 2 above), several authors also report statistical correlations between food prices and crime. Woytinsky [40] does so using von Mayr's Bavarian data, Blasius [9] reports positive correlations between rye bread prices and theft in Prussia, and Zehr [41] 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 historical study that uses more credible econometric methods to address the identification problems highlighted in the introduction, as we attempt to do in this paper.

[4] The diffusion of potato in Germany started in the late 18th century, but Baten ([3], 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 ([18], 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."

The impact of rainfall shocks and rye prices on real income differed for distinct segments of the Bavarian population. For the growing numbers of urban workers, high rye prices unambiguously led to lower living standards. The same likely held for landless rural farm laborers, whose pay did not keep up with rising food prices. These two groups taken together constituted a substantial share of the Bavarian population by the mid-19th century, although exact population figures are difficult to establish.

For farmers with considerable land holdings, however, the relationship between rye prices and poverty is theoretically ambiguous. Higher rye prices led to higher income for farmers who were net sellers of grain, ceteris paribus. Yet to the extent that the cause of these high rye prices was flooding, which reduces – and may even destroy – farm production, then many farmers could also have experienced incomes drops during extreme rainfall years. Since prices rise but production falls in flood years, the relationship between rye prices and income could go either way for net grain sellers. Nonetheless, the theoretically ambiguous relationship between rye prices and real incomes for well-off farmers is not a major concern for our purposes, since this relatively prosperous group likely accounted for only a small share of total criminal activity, and the elasticity of crime with respect to their income was probably smaller than for poorer segments of the population.

3. Data and Measurement

Despite being a laggard in terms of industrial development, Bavaria was a leader in legal reform: in 1813, Bavaria became the first German state to adopt a modern penal code (based on the 1810 French code) and this Bavarian code served as a model for the national German penal code of 1872 (Johnson [21], p. 24). Bavaria also had the most comprehensive crime statistics in Germany prior to 1882 when the standard national crime reporting system was established: the mid-19th century Bavarian reports have crime categories familiar to us today (p. 117). von Mayr [27] presents information on annual crime rates per 100,000 inhabitants. The main crime categories are property crime (mostly theft of wood, charcoal and turf, but this also includes more serious crimes like armed robbery and embezzlement), violent crime (e.g., assault, gross indecency, kidnapping, excessive punishment, and rape), and murder. There is also data on the numbers of begging and vagrancy arrests. These data are

reported cases from Bavarian police records, which von Mayr rightly argued was a better crime measure than the number of arrests, investigations, or convictions. The data cover both rural and urban areas, and are widely considered reliable and consistent over time.[5]

There is complete crime data for seven of the eight Bavarian districts: Upper and Lower Bavaria, Upper, Middle, and Lower Franconia, Schwabia, and Upper Palatinate; the sum across all seven districts is referred to as All Bavaria. (The district with missing crime data is Palatinate, which is not contiguous with the rest of Bavaria, and we drop it from the analysis.) Bavaria had a total population of 4.5 million inhabitants in 1850 (Baten [3]). The descriptive statistics (Table 1, Panel A) show that Bavarian 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 [39]), a period of rapid decline in the U.S. murder rate from its peak in the 1980s.

TABLE 1 ABOUT HERE.

While there is annual crime data at the district level, there is just a single annual measure of the rye price and a single rainfall measure. The rye price data are from von Mayr [27], as well (Table 1, Panel B). von Mayr found that grain prices were essentially identical across the seven Bavarian study districts, and he thus only recoded one price series for them. For Palatinate, the non-contiguous district located to the west of the Rhine river, von Mayr collected a separate rye price series. The correlation coefficient between annual rye prices in Palatinate and the study districts is very high at 0.94, and this suggests a high degree of grain market integration in southern Germany.

A second poverty measure, the real wage, is employed to capture changes in the cost of living through all channels, including channels other than rye prices, and to demonstrate the robustness of the main results using a different data source. For that purpose, we use real wage data for *Bauhandwerker* (roughly translated as construction workers) in Nuremberg, Middle Franconia from Gømmel [19]. Given that rye products constituted a large portion of overall consumption, the two proxies for living standards are highly correlated. Major components of *Bauhandwerkers*'

[5] Zehr ([41], p. 42) argues that among French and German regions during this period "the best [crime] series available is the Bavarian". von Mayr had a distinguished career, producing a monumental work called *Statistics and Social Sciences*, which includes the volume *Moral Statistics with an Element of Criminal Statistics*.

consumption basket included grain products (50% of overall consumption, and this includes rye products), meat and dairy products (20%), potatoes (7%), and housing expenditures (10%), among other items. Note that these real wage figures take into account the local price of grains, including rye. Although *Bauhandwerker* were often quite poor, they were not considered the poorest of the poor in 19th century Bavaria. Even though the rye price may be the best available poverty proxy, it is of some interest to see if the main results extend to poverty as proxied by real wages, even if these are not available for the poorest segments of society.

Finally, there is annual rainfall in meters for all of Germany from the FAO [16] historical database, which is derived from a dozen rainfall gauges throughout Germany, though there are none within Bavaria during the study period (Table 1, Panel C).[6] Using recent data from 1991-2003 (Deutscher Wetterdienst [14]), we find a correlation of 0.80 between monthly rainfall in 13 Bavarian weather stations and 22 non-Bavarian stations, suggesting that Bavarian rainfall patterns are highly correlated with the rest of Germany, thus justifying the use of the all Germany FAO series.

4. Main Empirical Results

The first part of this section (4.1) focuses on the instrumental variable first-stage and reduced-form specifications. We then present the property crime (section 4.2) and violent crime (4.3) results in turn.

4.1 First-Stage and Reduced-Form Specifications

Rainfall from the current year and from the previous two years are included as instrumental variables for 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 at traditional confidence levels (not shown). This first specification uses data for All Bavaria, with a sample size consisting of 25 year observations; some later regressions use the district-year as the unit of observation (with 179 district-year observations)

[6] Climate data derived from tree ring thickness (Briffa, Jones and Schweingruber [12]) 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.

and include district fixed effects. 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% 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% of rye price variation (regression 1). The positive first-stage relationship between lagged rainfall and current rye price is presented graphically in Figure 4.

TABLE 2 ABOUT HERE.

FIGURE 4 ABOUT HERE.

Time controls are included to capture secular trends and policy changes made in response to the food crisis of the late 1840s and the failed German revolution of 1848. To account for the effects of these policy shifts, an indicator variable for the post-1847 period, linear and quadratic time trend terms, and interactions between the post-1847 indicator and the time trend terms are included as controls. As expected, violent crime shows a sharp increase in 1848, the year of the failed revolution (Figure 3). Blackbourn ([7], 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 FAO rainfall data corroborate this, indicating that there were consecutive years of heavy rain during 1843-1846, after which climatic conditions largely returned to normal.[7] The food crisis "eroded trust in 'complacent' governments, placing a question mark against their competence and their very legitimacy" (Blackbourn [7], p. 140), and leading many 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.

[7] While some 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 at a critical juncture, leading to its ultimate failure.

The time controls, together with the rainfall measures, capture 83% of variation in rye prices (Table 2, regression 2). Note the drop in rye prices after 1847, which in part reflects the government intervention described above. One-year lagged rainfall again has the strongest effect on current rye prices, and the three rainfall terms are jointly significant and reasonably strong instruments (F-statistic = 7.9), and this at least partially addresses small sample IV estimation concerns (Staiger and Stock [38]). 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% confidence and two-year lagged rainfall at 95% (regression not shown).

Using panel data from the seven Bavarian study districts – in the framework that includes district fixed effects and clusters disturbance terms by year – yields nearly identical point estimates and slightly smaller standard errors (Table 2, regression 3). The variation in the key rainfall variables here is still of course entirely driven by time series variation in the aggregate German annual rainfall measure, and thus results differ only slightly from the previous specification. Recall that the rye price is identical across the seven Bavarian districts in the sample. Thus even if rainfall data disaggregated by Bavarian district were to exist (and we have been unable to locate it), this data would not substantially improve the precision of IV estimates since there is minimal variation in the endogenous variable – the rye price – across the districts in a given year, presumably due to grain market integration in southern Germany.

Analogous regressions using the real wage of *Bauhandwerker* as the first stage dependent variable broadly confirm the main result – that excessive rainfall reduces real income – although, perhaps not surprisingly, the first-stage relationship between rainfall and wages is weaker than its impact on rye prices (the F-statistic in Table 2, regression 4 is only 1.8). Note that this may understate the impact of rainfall on the real income of Bavarians even poorer than the *Bauhandwerker*, since rye purchases likely constituted an even larger share of their income.

The link between rainfall and rye prices should also depend on transport costs and grain trade restrictions. The railroad spread rapidly throughout Germany during the 1840s and 1850s (Carr [13])[8],

[8] See Ritschl [36] for an account of this chapter in German economic history.

and this development facilitated inter-regional and even international trade in grain, 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 restrictions across German states were gradually relaxed. By 1865, just after the study period, "Germany had completely free trade in grains" (Gerschenkron [18], 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 there are no statistically significant effects on any of the interaction terms (regression not shown). This implies that the impact of rainfall on Bavarian rye prices did not change significantly during this period. A plausible explanation is that the climatic variables and rye harvests are quite highly correlated throughout Germany, as we discussed above, limiting the scope for trade within Germany to serve as a moderating force in grain prices in the absence of extensive international trade.

In a reduced-form specification estimating the impact of rainfall on property crime, lagged rainfall is associated with higher crime at over 90% confidence in the All Bavaria specification including time controls (Table 2, regression 5), and results are robust to other specifications (not shown), a first hint that poverty increases property crime, the focus of the next sub-section.[9] This reduced form 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% confidence – regression 6) when the log of violent crimes is

[9] An alternative model where crime is driven by contemporaneous rainfall rather than by poverty seems unlikely. We examine a specification similar to Table 2 regression 5 but which excludes the lagged rainfall terms and includes the log of rye prices as an additional explanatory variable. The point estimate on the log of rye prices in that specification is large, positive and statistically significant at over 99% confidence, while the point estimate on current rainfall is actually somewhat negative, which goes in the "wrong" direction in terms of explaining property crime patterns (regression not shown). It is thus certainly not the case that including the rye price and current rainfall simultaneously leads to a positive and significant coefficient estimate on the current rainfall measure. We thank the Editor for suggesting this discussion.

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.

4.2 Rye Prices and Property Crime

The estimated elasticity of the rye price on property crime is 0.29, statistically significant at 99% confidence, in the OLS specification without time controls (Table 3, regression 1) and 0.41 when time controls are included (regression 2).[10] An OLS specification using crime data for the seven Bavarian districts in a panel framework yields very similar point estimates (regression not shown, estimate 0.47, standard error 0.08).

TABLE 3 ABOUT HERE.

An instrumental variable two-stage least-squares (IV-2SLS) approach is employed to address potential bias caused by endogeneity and omitted variable bias, 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% confidence, and using data for Bavarian districts in the panel framework yields nearly identical results (regression 4). The panel specification uses a considerably larger sample size (179 district-year observations), partially addressing sample size concerns in IV estimation, although recall that the key rainfall measure is still the single annual FAO series, and we view this specification principally as a robustness check. These estimates imply that a one standard deviation increase in the rye price increases property crime by 8%. Note that this is only half the magnitude of the analogous OLS estimate (0.41) – and we can reject that the OLS and IV estimates are equal at over 90% confidence – suggesting that bias in the OLS regression is large and positive. Thus simple correlations between rye prices and crime appear potentially misleading.[11]

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[10] When time controls are included, the Durbin-Watson statistic increases from 1.3 to 2.1, thus nearly 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).

[11] Standard errors on the main regression coefficient estimate (on the rye price term) increase in IV specifications, but these increases are often relatively small – at least in part due to the strength of the first stage relationship presented in Table 2. The increase in standard errors is greater when the real wage is the endogenous variable, consistent with the weaker first stage for wages.

The historical evidence provides one possible explanation for this significant divergence between OLS and instrumental variable estimates. Blackbourn ([7], p. 145) notes that social protest "triggered by particular local circumstances" often resulted in property crime: "Peasants, rural labourers, journeymen and workers demanded redress of their grievances and engaged in direct action", such as "attacking grain stores." Galius ([17], p. 181) discusses how especially those rural workers not bound to landlords by contract "carried out large food raids attacking large fortified estates in what often resembled a perpetual social war". In the towns, the confrontations came "in particular with those engaged in the production, manufacturing, and sale of foodstuffs." Main targets were Jewish grain traders and bakers. In other words, 'the perpetual social war' sometimes took the form of property crime that directly affected the price of rye, leading to endogeneity in simple OLS specifications that regress crime on the rye price. This is likely to account for at least part of the difference between OLS and IV estimates. We have no way, however, to conclusively establish how much of the bias in OLS specifications comes from this sort of social unrest versus other sources. Nonetheless, the difference between OLS and IV estimates illustrates the importance of finding a source of exogenous variation in living standards when estimating the effect of poverty 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 as instruments. The resulting point estimate on the rye price increases slightly, to 0.26, in the All Bavaria specification and remains highly statistically significant (Appendix Table A1, regression 2), indicating that the IV-2SLS estimates are not driven by the direct effect of contemporaneous rainfall on property crime. As a further robustness check, we applied the limited information maximum likelihood (LIML) method developed by Moreira [31] to a specification analogous to Appendix Table A1, regression 2, and find that the main point estimate on the rye price remains unchanged at 0.26 and is statistically significant at nearly 95% confidence (standard error 0.13, regression not shown). Applying LIML to a regression analogous to Table 3 regression 3 yields similar but somewhat weaker results (estimate 0.15, standard error 0.14 – regression not shown).

The effect of *Bauhandwerker* (construction worker) real wages 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%, and once again this result is highly statistically significant and robust to alternative specifications. The similarity between OLS and IV estimates when the real wage is the endogenous variable may be due in part to the fact that rainfall is a relatively weak instrument for wages, which is likely to bias instrumental variable results toward the OLS estimate, especially when using a small sample (Bound et al. [11]), as in this study.

We next examine the impact of rye prices on begging and vagrancy arrests. In the 19th century Bavarian context these arrests are interesting since they constitute a reasonably direct manifestation of poverty. Begging arrests often involved children and can hardly be characterized as serious crimes, but begging was illegal at the time and they thus enter into police records. The main finding here is 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 (Table 4, regression 1). This implies that a one standard deviation increase in the rye price increases begging and vagrancy arrests by a very large 22%.

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, a crop less sensitive to climatic fluctuations than rye. If extreme poverty fell, and crime were 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 ([41], 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 [19], finding that average real wage levels were practically unchanged during our study period (although year-to-year fluctuations were often large). To test this claim, we include the interaction of the rye price and time trend terms – and instrument these with interactions between rainfall levels and the time trend terms – but do not find support for

the hypothesis that the effect of the rye price on property crime weakened during the study period: none of the coefficient estimates on the interaction terms are statistically significant at conventional confidence levels (results not shown).

4.3 Rye Prices and Violent Crime

In contrast to property crime, violent crime displays a strong negative association with the price of rye. The elasticity of violent crime (excluding murders) is -0.48, significant at 99% confidence in an OLS specification (Table 5, regression 1). The IV-2SLS specification yields a somewhat smaller elasticity of -0.42 (regression 2), which is also significant at 99% confidence, and utilizing the panel of districts yields a similar estimate (regression 3). The similarity of the OLS and IV estimates may result from the absence of an endogeneity channel for violent crime comparable to the one described above for property crime (running from social unrest and destruction of grain to higher rye prices).

TABLE 5 ABOUT HERE.

The violent crime results are robust to using only lagged rainfall as instruments for the rye price, and are similar, though somewhat weaker, when the real wage is the endogenous variable (regressions not shown). The rye price is also strongly negatively associated with murder in the IV-2SLS specification, with a point estimate similar to other violent crimes (elasticity -0.31, significant at 95% confidence – Table 5, regression 5). The estimated IV-2SLS elasticity for rape – a crime not usually thought to have economic motives, unlike the property crimes and perhaps some of the violent crimes (e.g., kidnapping) – is similarly large and negative, at -0.30 (regression not shown).

The finding that violent crime is consistently negatively associated with rye prices is puzzling at first glance given the robust 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 [10] classic contribution on criminality and economic conditions as well as in more recent contributions (Fajnzylber et al. [15], and Miguel [29]; see Krueger and Maleckova [22] for a different perspective). However, several recent studies on crime and economic conditions in the contemporary United States find a pattern similar to our findings, namely, a moderate positive correlation between local economic distress – typically proxied by unemployment and low wages – and property crime, but a much

weaker, and sometimes negative, relationship with violent crime (Levitt [23], Gould, Weinberg and Mustard [20], Raphael and Winter-Ebmer [35]).

The most compelling explanation for this result in 19th century Bavaria in our view is that higher rye prices led to higher beer prices, and that the resulting drop in alcohol consumption in turn reduced violent crime.[12] Using Nuremberg beer price data from Gømmel [19], the correlation coefficient between the logs of rye and beer prices was 0.76 during the study period, and this is highly statistically significant. 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 living standards – on violent crime. The impact of rye prices on violent crime in Bavaria during this period is best understood as working through these two distinct, and possibly offsetting, channels. The results thus 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 also found a strong correlation between alcohol consumption and violence. Markowitz ([25], 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 [26]). Similar violent crime patterns were found in France for the 19th century, where according to Zehr ([41], p. 98) "the correspondence between peaks and troughs in wine consumption and in assault before 1870 was excellent – almost perfect."

Zehr [41] speculates that this was also likely 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

[12] Levitt [23] makes a related point: "To the extent that activities that are associated with increased levels of either offending or victimization are normal goods – like alcohol consumption, frequenting night clubs, and owning a car – the link between economic activity and crime is theoretically ambiguous."

possibility to be tested." As a substitute for alcohol consumption data, we have attempted to obtain historical production records from present-day Bavarian brewers (including Spaten-Löwenbrau and others). However, large-scale industrial beer manufacturing began only in the 1850's in Bavaria with the adoption of more sophisticated production processes, hence existing production records do not cover most of the study period. It is also worth mentioning that we unsuccessfully searched for 19th century Bavarian data on alcohol-related crimes – for instance, public drunkenness and disturbing the peace – in an effort to provide more direct evidence on the hypothesized alcohol channel. However, as a result of the historical data limitations, the alcohol consumption channel linking high rye prices to violent crime remains much more speculative than the link between rye prices and property crime.

Finally, there is a weak association between the rye price and total reported crime, including all crime categories (property crime, violent crime, and murder, as well as vandalism and rare violations such as perjury): the coefficient estimate is 0.08 (standard error 0.08) in our preferred specification, the All Bavaria IV-2SLS specification with time controls (Table 4, regression 5). This finding highlights the importance of looking beyond aggregate crime measures in empirical studies, as these may obscure heterogeneous patterns across crime categories.

5. Conclusion

This paper illustrates the potential payoffs of applying micro-econometric methods to the study of economic history. 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 moderate but significant. The effect is not as large as simple OLS estimates would suggest, however, highlighting the importance of using IV methods to address bias due to endogeneity and omitted variables. This result is robust to a second proxy for poverty, the real wage, and to a variety of specification checks. Yet higher rye prices led to a sharp drop in violent crime, which we argue is possibly due to a rise in the price of beer and resulting drop in alcohol consumption. The results provide support for both rational choice and psychological theories of crime.

Beyond improving our understanding of 19th century European economic history, the results may also have implications for policymakers in present-day less developed countries, many of 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 lead to higher or more variable food prices, and exacerbate poverty among some workers, they may also trigger outcomes not typically considered by economists, including crime waves and political unrest (as argued in Bates [5], Miguel et al. [30], and Mehlum et al. [28]). When taking such social externalities into account, optimal policy design may differ from one based solely on productive efficiency grounds.

Acknowledgments

We are grateful to Statistics Finland and Statistics Norway for hunting down the original von Mayr (1867) publication, to Statistics Bavaria for answering questions on data issues, to Anne Kjersti Uhlen for discussions on rye production and climate, to Terje Thun for discussions on tree rings, and to the Editor Jan K. Brueckner, David Card, Brad DeLong, Steve Levitt, two referees, and seminar participants at the Norwegian University of Science and Technology, University of Bergen, and University of California, Berkeley for helpful suggestions.

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Tables and Figures

Figure 1: Rye prices and property crime in Bavaria

Figure 2: Real wage and property crime in Bavaria

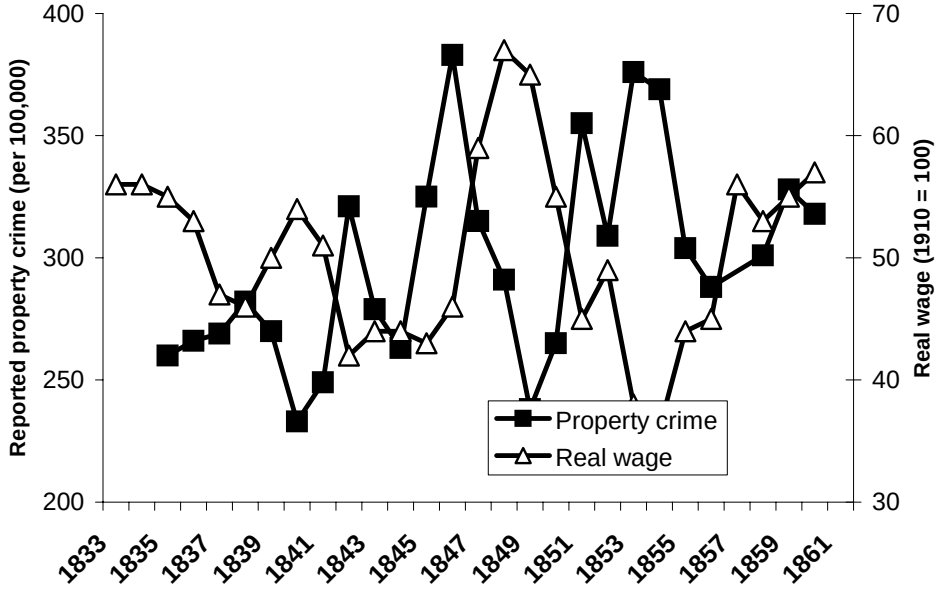

Figure 3: Rye prices and violent crime in Bavaria

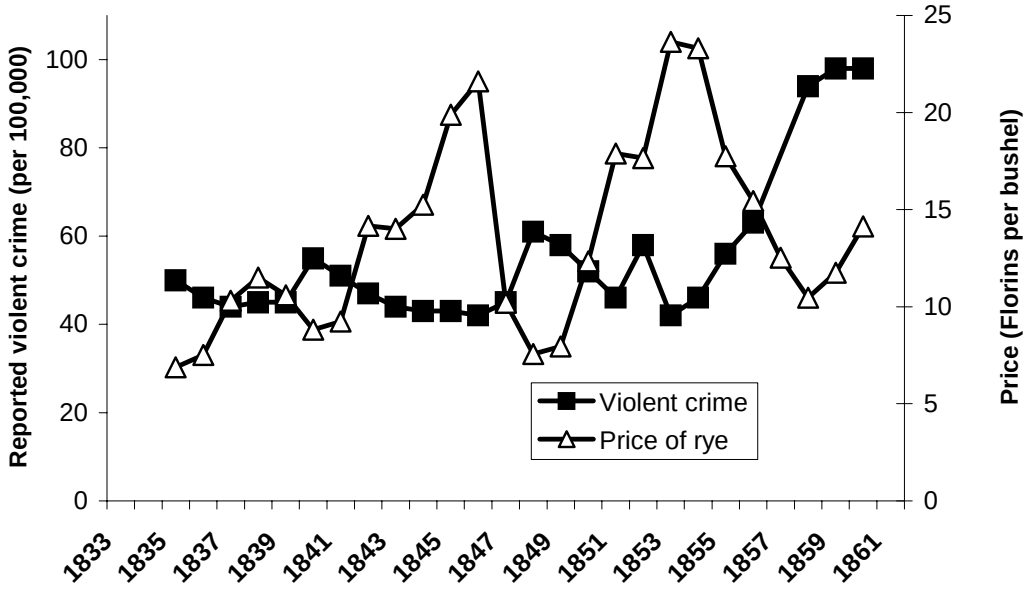

Figure 4: Rye prices and lagged rainfall in Bavaria

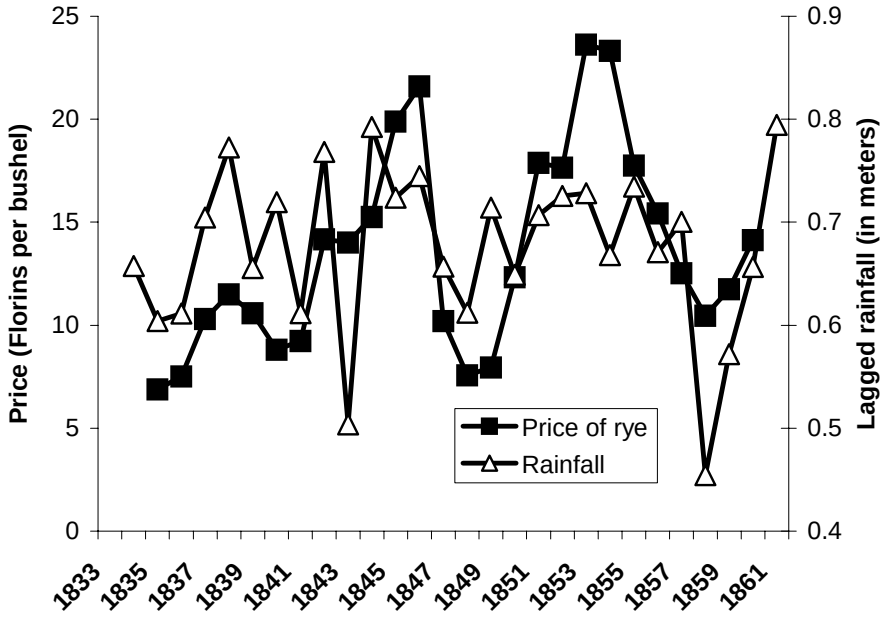

Figure 5: Property crime and lagged rainfall in Bavaria

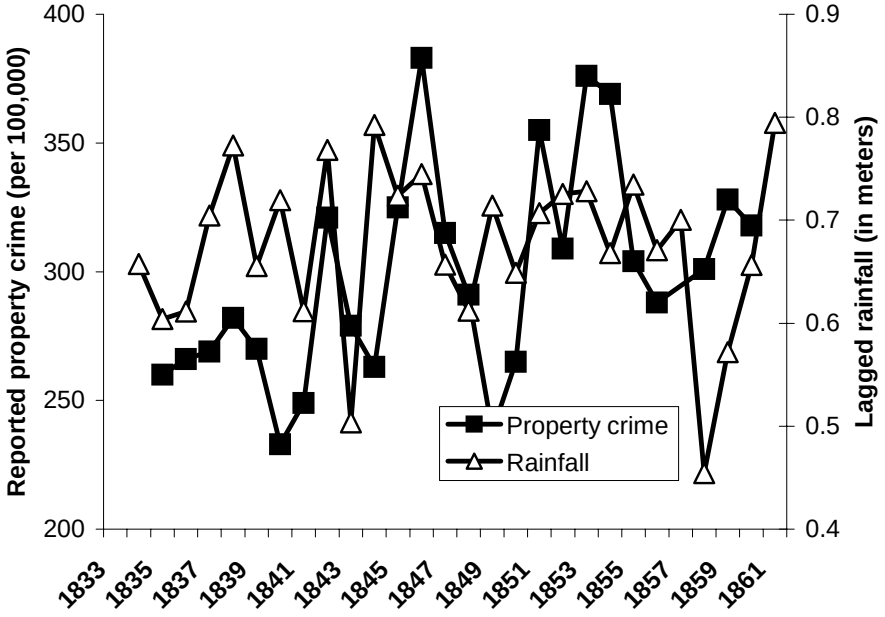

Table 1
Descriptive Statistics

	-------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)	8.2	1.2	25	8.0	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

Table 1 Notes:
All crime and rye price data are from von Mayr [27]. 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, kidnapping, excessive punishment, and rape. (It does not include murder or robbery).

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 per Bavarian bushel.

The real wage data are from Gømmel [19]. 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 [16].

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 of dependent variable	2.54	2.54	2.54	3.9	5.69	3.97
F-stat., H_0: coefficient estimates on all rainfall measures = 0	2.4	7.9	14.1	1.8	1.3	4.3

Table 2 Notes:
Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) % 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. Violent crime excludes murder here.

Table 3
Poverty and Property Crimes

	Dependent variable: Ln (Property crime)							
	(1) OLS	(2) OLS	(3) IV-2SLS	(4) IV-2SLS	(5) OLS	(6) OLS	(7) IV-2SLS	(8) IV-2SLS
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 of 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 (*) % 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) in addition to time controls and district fixed effects when appropriate (e.g., district fixed effects are included in regression 4, 8).

Table 4
Poverty 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 of dependent variable	7.54	5.69	3.97	2.09	6.02

Table 4 Notes:
Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) % 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), in addition to the time controls. Violent crime excludes murder here.

Table 5
Poverty and Violent Crimes and Murder

	Dependent variable:					
	-------Ln (Violent crime) -------			-------Ln (Murder) -------		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV-2SLS	IV-2SLS	OLS	IV-2SLS	IV-2SLS
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 of dependent variable	3.97	3.97	3.93	2.09	2.09	2.04

Table 5 Notes:
Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) % 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) in addition to time controls and district fixed effects when appropriate (e.g., district fixed effects are included in regression 3, 6). Violent crime excludes murder here.

Appendix

Appendix Table A1
Poverty and Property Crimes – using only lagged rainfall as instruments

	Dependent variable: Ln (Property crime)					
	(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 of dependent variable	5.69	5.69	5.64	5.69	5.69	5.64

Table A1 Notes:
Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) % 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, in addition to time controls and district fixed effects when appropriate (e.g., district fixed effects are included in regression 3, 6).