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**RAGE AGAINST THE MACHINES:
LABOUR-SAVING TECHNOLOGY AND
UNREST IN ENGLAND, 1830-32**

Hans-Joachim Voth and Bruno Caprettini

**DEVELOPMENT ECONOMICS,
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Abstract

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JEL Classification: P16, J21, J43, N33

Keywords: Labor-saving technology; social instability; riots; welfare support; agricultural technology; factor prices and technological change.

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RAGE AGAINST THE MACHINES: LABOR-SAVING TECHNOLOGY AND UNREST IN ENGLAND, 1830-32^{*}

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Is new technology a mixed blessing? From the invention of steam engines to the IT revolution, the vast increase in living standards over the last 200 years owes a great deal to new technology (Mokyr 1992). Over the same period, labor-saving technologies have also destroyed the majority of jobs then in existence. Spinners and weavers were made redundant by steam-powered textile mills; more recently, computers have replaced phone operators, bookkeepers and other workers performing routine jobs (Autor, Levy, and Murnane 2003). This has put downward pressure on low-skilled workers' wages (Acemoglu and Autor 2011), and driven up the demand for highly-skilled workers operating the new equipment (Autor, Katz and Krueger 1998; Acemoglu and Restrepo 2016).

Classical economists long predicted that technological unemployment would lead to social and political instability. Marx (2010) argued that technological change would depress wages to such an extent that workers would revolt, overthrowing the established political and economic order. Both Keynes (1931) and Leontief (1952) were skeptical that new jobs could be created at a rate sufficient to compensate for technological job losses. And yet, while there is ample evidence that labor-saving technical change can adversely affect workers' employment and wages, its social and political consequences have received less attention.¹ This is surprising in light of a burgeoning literature on the economic determinants of conflict. Exogenous variation in commodity prices or rainfall suggests that adverse economic conditions make civil war and unrest more likely (Miguel, Satyanath and Sergenti 2004), creating a 'window of opportunity' for political change (Brückner and Ciccone 2011).

In this paper, we combine these two perspectives and examine whether and when the introduction of labor-saving technology can lead to social instability and political unrest. In addition, we analyze the consequences of technology-induced unrest on subsequent innovative activity. We do so by looking at one famous historical episode – the 'Captain Swing' riots in 1830s England. These constitute the largest wave of political unrest in English history, with more than 3,000 cases of arson, looting, attacks

¹ Autor *et al.* (2016) is one recent exception.

on authorities, and machine-breaking across 45 counties. Only armed repression quelled the unrest. The riots had lasting consequences, ushering in a period of institutional reform (Aidt and Franck 2015).

The ‘Captain Swing’ riots have variously been attributed to the Poor Laws (an early form of income support), the immigration of Irish laborers, failed harvests, technological change, and the return of soldiers and sailors after the end of the Napoleonic Wars (Hobsbawn and Rudé 2014; Griffin 2012). While all of these may have contributed to the outbreak of unrest, recent scholarship has cast doubts on the role of machinery as a prime cause of unrest (Mokyr, Vickers and Ziebarth 2015).

Using newly-collected historical data on the diffusion of threshing machines, we show that labor-saving technology was a key factor behind the riots. First, we collect advertisements of farms for lease or sale from dozens of English local newspapers that list mechanical threshers as part of the farm inventory. We then compare this data with the pattern of unrest. Figure 1 shows the main result: In parishes where the technology was not adopted, the riot probability was 13.6%; in places where threshing machines had spread, it was 26.1% – twice as high. Newly digitized data from the 1832 Poor Law survey also demonstrate that unemployment was systematically higher in parishes with threshers. Machine-breaking in response to technological unemployment was a key part of the riots, but importantly, it also spilled over into other forms of unrest, such as arson, blackmail, and attacks on Poor Law administrators.

We argue that the link between new technology and wider unrest is causal. Threshing machines were cheaper to operate using water power. In addition, threshing machines were initially useful to process only wheat. Soil suitability for wheat cultivation strongly predicts adoption. The confluence of these two geographical characteristics – enough running water to drive a water mill and wheat suitability – is a strong predictor of both machine adoption and riots, even after controlling for each instrument separately. This suggests that the effects of labor-saving technology on unrest are causal.

Next, we examine mechanisms behind our results. Proximity to a manufacturing city dampens the link between machines and riots. In contrast, enclosure of common land exacerbated the effect of machines on riots. There is also suggestive evidence that the Poor Laws reduced the effect of threshers on riots. Finally, the effects of the riots lingered after they were quelled: in the most-affected areas both machine adoption and patenting rates were markedly lower for decades *after* the riots.

We contribute to two main literatures – one on labor markets effects of new technology, the other on the economic determinants of conflict. A growing literature in labor-economics has demonstrated that the IT revolution has disadvantaged less educated workers (Acemoglu 1998; Autor, Katz and Krueger 1998), and replaced workers performing tasks that are easy to codify (Autor, Levy and Murnane 2003).² There is also good evidence that new agricultural technologies can drive workers out of agriculture (Bustos, Caprettini and Ponticelli 2016). However, what is unclear is whether such labor-saving technological change can create political instability and social unrest.

Most of the theoretical work on the link between political instability and economic conditions begins with the observation that low-income countries are more prone to civil conflict than richer countries (Fearon and Laitin 2003; Collier and Hoeffler 2004; see Blattman and Miguel 2010; Ray and Esteban 2017 for reviews). It is tempting to explain this correlation with lower opportunity costs of organizing a rebellion, but Fearon (2008) notes that the effect of income on unrest is ambiguous, because in low-income countries potential loot is also small. Chassang and Padró i Miquel (2009) show that temporary negative shocks increase revolt frequency, while permanent shocks have an ambiguous effect.

Much of the recent empirical literature on social unrest has focused on exogenous income shocks and their effects on conflict. Miguel, Satyanath and Sergenti

² During the Industrial Revolution, new technologies may have been more skill-replacing than skill-biased (James and Skinner 1985; Mokyr 1992). The direction of technical change itself may be endogenous to factor prices (Acemoglu 2002; 2007). This is in line with the early adoption of coal engines in England (Allen 2009) and the introduction of new machines for treating non-U.S. cotton during the U.S. Civil War (Hanlon 2015).

(2004) find that adverse weather shocks significantly predict civil conflict in Africa, while Bohlken and Sergenti (2010) present similar results for Hindu-Muslim riots in India. Brückner and Ciccone (2010) show that downturns in international prices of the main commodity exported by Sub-Saharan countries lead to higher chances of civil war. Ponticelli and Voth (2011) look at cross-country evidence for period 1919 to 2008 and argue that fiscal consolidation lead to social turmoil. These results support the predictions of the model of Chassang and Padró i Miquel (2009) about the effects of temporary income shocks. Relatedly, Autor *et al.* (2016) show that adverse trade shocks have led to more political polarization in U.S. constituencies.

We also contribute to the historical literature on the ‘Swing’ riots. Systematic analysis began with the Parliamentary Inquiry that followed the unrest (Checkland 1974). It largely blamed the riots on the Poor Law’s failings. The Hammonds (1920) famously attributed unrest to laborers’ growing immiserization. Hobsbawn and Rudé (2014) argued that they were largely driven by the adverse effects of technological change. Stevenson (2013) emphasized that the riots were often aimed at Irish migrant workers, and not technology (see also Mokyr, Vickers and Ziebarth 2015). Hobsbawn and Rudé’s database was extended by Holland (2005), and updated by Griffin (2012). Aidt and Franck (2015) have recently argued that the riots facilitated passage of the 1832 Reform Act. Finally, Aidt, Leon and Satchell (2016) analyze how riots spread across England during the two years of unrest, and argue that ‘contagion’ played a significant role.

Relative to the existing literature, we make the following contributions: First, we unify the literatures on technological change and on the economic determinants of conflict, by providing evidence for an additional channel – the distributional effect of the new technology. The current literature on income and conflict overwhelmingly focuses on negative shocks. New technologies represent a positive shock to output but create distributional effects that may affect some groups adversely. Threshing machines are labor-saving and reduce the share of output going to labor; this lowered rural

workers' opportunity cost of revolt.³ Second, we focus on a massive, rapid dislocation in the labor market driven by technological change. Threshing was the main income source for agricultural laborers for many months of the year. Mechanical threshing largely eliminated winter earnings for agricultural laborers, who constituted the relative majority of the labor force in most English counties (Shaw-Taylor *et al.* 2010). This is in contrast with more recent cases of technological change, which involve relatively gradual changes affecting a smaller part of the labor force (such as telephone operators or secretaries). Third, threshing machines were skill-replacing, not skill-using. While threshing is not a complex task, threshing machines replaced experienced men with capital, as well as women and boys. This is in contrast with more recent cases of technology adoption, which typically increase demand for high-skilled jobs (Autor, Katz and Krueger 1998).

1 Historical background

Threshing is a key agricultural activity. It loosens the grains from the husks (threshing), and then separates the husks from the grains (winnowing). Threshing is a laborious process. Hand-threshing used flails swung overhead and provided winter employment, when labor demand was low. In 1786, Andrew Meikle invented the first threshing machine (Macdonald 1975). In this section, we describe English agriculture in 1800, and discuss the link between threshing machines and the 1830 riots.

a. Agriculture in early 1800 England

English agriculture by 1800 was relatively efficient and highly commercialized. Estate owners rented their land to farmers-tenants (Hobsbawm and Rudé 2014). These used advanced techniques such as crop rotation, improved the soil by drainage, fertilized

³ The importance of distributional effects of income shocks is central to the theory of Dal Bó and Dal Bó (2011). Dube and Vargas (2013) show evidence consistent with this theory looking at the conflict in Colombia. Berman *et al.* (2017) present results from African conflicts that speak to similar mechanisms. Other papers that have investigated the relationship between distribution and conflict are Esteban and Ray (1999; 2011) Mitra and Ray (2014) and Morelli and Rohner (2015).

their fields, and hired day laborers during harvest time (Crafts 1985; Overton 1996; Allen 1999; Rahm 1844). Almost all output was sold on the market.

Agricultural laborers were often illiterate and owned few assets. They also increasingly lost access to common lands as a result of enclosures (Allen 1992; Neeson 1996; Mingay 2014). By the 18th century, many agricultural laborers were hired by the day, the week, or the season (Thompson 2013). During winter, when agricultural work was scarce, many worked as threshers.⁴ The Poor Laws made income support available to the poor:⁵ Under this system, parishes had to support local residents seeking relief, but had no obligation towards outsiders (Marshall, 1977; Boyer 1990). This discouraged migration even over short distances (Redford, 1976).⁶

Threshing machines spread slowly in the beginning because they were relatively expensive (Hobsbawm and Rudé 2014; Macdonald 1975). However, when Great Britain and France went to war in 1803, the British Army and the Royal Navy recruited many rural workers (Colley 2009). As labor became scarce, farmers adopted a number of labor-saving technologies, including threshing machines (Dickson and Stevenson 1815). Productivity gains depended on the specific type of machine (Appendix B.1). Threshing machines operated by horses or water increased productivity by a factor of 5 and 10 respectively. Whenever available, water power was preferred.⁷ Machines were not only more efficient; they were also faster and caused less wastage (Hobsbawm and Rudé 2014, Hammond and Hammond 1920). After 1815, Britain discharged most of its soldiers and rural labor became relatively abundant again. Nonetheless, threshing

⁴ The Hammonds cite a landowner from Canterbury as saying that in his parish, "...where no machines had been introduced, there were twenty-three barns... in these barns fifteen men at least would find employment threshing corn up till May." (Hammond and Hammond 1987). Clark (2001) estimates that threshing accounted for up to 50 percent of winter income of rural laborers.

⁵ Elisabeth I introduced the Poor Law in 1601 with the "Acte for the Reliefe of the Poore" (Marshall 1977). The basic framework remained in place until 1834 (Boyer 1990, Clark and Page 2008).

⁶ Boyer (1990) argues that the Poor Law did not slow down aggregate rural-urban migration. His conclusion does not exclude the possibility that the Poor Laws prevented rural-rural migration, and Landau (1995) presents evidence that the "Laws of Settlement" systematically limited migration across parishes in the 18th century.

⁷ The "threshing machines" entry of *Farmers' Encyclopedia* states: "Where the locality admits the use of a water wheel, this power is most economical and easily managed; but the advantage is limited to peculiar situations." (Johnson 1844).

machines continued to spread as their productivity had increased (Hobsbawn and Rudé 2014).

b. Captain Swing riots

The first ‘Swing’ riots broke out in August 1830, in Kent.⁸ They quickly spread across the country. More than 3,000 riots occurred across 45 counties. Almost all took place in rural areas, and all rioters were either rural workers or local craftsmen (Hobsbawn and Rudé 2014; Stevenson 2013). Unrest took several forms. Arson attacks were common (Tilly 1995); in many parishes rioters forced the overseers of the poor out. Between September and November 1830 alone, 529 threshing machines were attacked (Holland 2005). Wage demands were also important; many farmers agreed to a minimum wage (Griffin 2012; Hammond and Hammond 1920). Threatening letters – signed by the mythical ‘Captain Swing’ – were sent to farmers and by October 1830, *The Times* began to call the wave of riots ‘Swing’ (Griffin 2012). Unrest simmered for more than two years, until the winter of 1832.

After a slow response, the government adopted a hard line and ordered the army and local militias to quell the protests. It also set up a special commission which passed 252 death sentences. Many of these sentences were eventually commuted, mostly to overseas transportation (Hobsbawn and Rudé 2014).

Several factors contributed to the wave of riots in 1830-32. Hobsbawn and Rudé (2014) emphasize how bad weather, a poor harvest and the prospect of a cold winter aggravated the rural workers’ situation. News of the French and Belgian revolutions may have contributed to initial unrest in Kent (Archer 2000; Charlesworth 1979). Domestic politics was tense too: discussions of electoral reform had come to naught under the Duke of Wellington’s Tory government. Eventually, the Great Reform Act of 1832 would be passed – but only after Wellington’s government fell during the peak of the riots (Aidt and Franck 2015).

⁸ Hobsbawn and Rudé (2014) place the start of the riots on the 28th of August 1830, when a gang of people smashed a threshing machine in Lower Hardres, Kent. Recently, Griffin (2012) demonstrated that riots began 4 days earlier, when 20 men destroyed the first threshing machine in Elham, Kent.

Whatever the immediate causes of the riots, rural workers' increasing immiserization prepared the ground for unrest. Enclosures had deprived rural workers of access to common lands, effectively transforming them into a "landless proletariat, relying almost exclusively on wage-labor" (Hobsbawm and Rudé 2014; Hammond and Hammond 1920). Additionally, bringing in the harvest in cereal-producing areas required a large workforce – but employment opportunities were scarce during the rest of the year. The Poor Laws could sustain agricultural laborers year-round, but it came under increasing strain as the population grew and cottage industries declined (Stevenson 2013; Thompson 2013).

The new threshing machines increasingly deprived rural laborers of their main source of income during the winter. Unemployment was on average 5.5 percent higher in winter than in summer. Where threshing machine had spread, this difference grew by an additional 2.1 percentage points.⁹ While enclosures, poor laws and mechanization appear in almost any account of the Swing riots, there is so far no hard evidence to establish their effect. Thompson (2013) and Royle (2000) emphasize the role of enclosures and the loss of access to land. The Parliamentary enquiry, set up after the 1830-32 riots, largely blamed the "Old Poor Law" – soon to be reformed thoroughly. Finally, Hobsbawm and Rudé (2014) underline the importance of new machines.

2 Data

We combine data on the Swing riots with hand-collected data on threshing machine adoption during the period 1800-30. In addition, we use information from the 1801 crop returns, the 1821 British Census and the 1832 Poor Law Commission Report. Finally, we use data on local geographic and soil conditions. Here, we describe each of these sources (further details are in Appendix A).

⁹ We combine data on threshing machine diffusion in 1800-1830 (described in the next section), with information on rural unemployment in 1834 (Checkland 1974). Summer unemployment was essentially unaffected by machines ($\beta = -0.001$, $p = 0.868$). Columns 1-3 of Table C1 show that the positive association between threshing machines and winter unemployment survives the inclusion of controls.

The Family and Community Historical Research Society compiled detailed data on the Swing riots (Holland 2005).¹⁰ The main underlying source are judicial records; in addition, they use newspaper accounts of the time. The database contains date, parish, and type of crime perpetrated by rioters.¹¹ Figure C1 reports the total number of Swing riots over time, differentiating between attacks on machines and the rest. Figure 2 shows the geographical distribution of these incidents.

Two separate sources provide information on threshing machine adoption. The first are advertisements from 60 regional newspapers. The second are the *General Views of Agriculture*, a collection of surveys analyzing English agriculture between 1790 and 1820. Some 118,758 newspaper issues were published between January 1800 and July 1830. We search them for the exact string ‘threshing machine.’ The ads we find either announce that a farm with a threshing machine is available for lease or sale, or that a manufacturer of threshing machines invites interested farmers to see them at work at one of their customers in the vicinity (see Figures C2 and C3 for examples). From 549 advertisements, we find evidence of adoption for 466 parishes: Figure C4 shows the number of threshing machine adverts during the thirty years prior to the Swing riots.

We complement this list with information from the *General View of Agriculture*. These surveys were sponsored by the Board of Agriculture. Each volume covers a single county. The first surveys appeared in the 1790s and were followed by second editions during the 1810s. There are few references to threshing machines in the early editions. By 1810, however, threshing machines were so widespread that there is a chapter on them in each volume. Surveyors discuss technical characteristics, including productivity, and provide information on the owner and location of the machine. Figure C5 shows the geographical distribution of threshing machines.

To explain threshing machines adoption, we use two geographical characteristics: availability of water power and soil suitability for wheat cultivation. To quantify the former, we use accumulation flow (Lehner, Verdin and Jarvis 2008), which captures the

¹⁰ Aidt and Franck (2015) use the same data in their study of the political consequences of Swing riots.

¹¹ Holland (2005) builds on Hobsbawm and Rudé (2014), adding a further 1642 riots to their original list of 1475 incidents.

amount of upstream area that drains into each cell of a global, 15 seconds grid. Higher values strongly predict the presence of rivers. Figure C6 illustrates accumulation flows in England. The FAO's Global Agro-Ecological Zones database (FAO-GAEZ) reports the potential output in each area by crop type. It is based on soil characteristics, historical weather records and an agronomic model.¹² Data are available for grid cells of about 9.25×9.25 kilometers. We use it to compute the average yield attainable in every parish (Figure C7).

We also collect new data from the Poor Law Commission Report (Checkland 1974). For a subsample of parishes, this publication records poor rates and population size (Figure C8). We define generosity of poor relief by dividing the poor rates in 1803 by the 1801 population. In this way, generosity is measured before threshing machines became widespread. On average, parishes collected just under 14 shillings per capita, with substantial variation – parishes at the 90th percentile collected 5 times more than those at the 10th.

In addition, we use the 1821 British population census (Southall *et al.* 2004) to reconstruct demographic and sectoral composition of each parish, the 1801 corn returns (Turner 1982) to calculate the acreage cultivated with different crops at the beginning of 1800, the tables in Gonner (1912) to measure enclosures before 1820, and the data in Luterbach *et al.* (2004) and Pauling *et al.* (2006) for historical weather data. Finally, we calculate distances using parish centroids, based on an 1851 map of parishes (Burton *et al.* 2004). Table 1 reports summary statistics for our variables and Appendix A.2 describes each variable.

3 Empirical analysis

This section presents our main empirical findings as well as our identification strategy.

¹² FAO-GAEZ calculates potential output under three different assumption of input use: 'low,' 'intermediate' and 'high.' We use the measure of potential output calculated with intermediate input because it is likely to represent well the technologies available to 1800s British farmers. See Bustos, Caprettini and Ponticelli (2016) for a discussion about the different technological levels used in FAO-GAEZ measures.

a. Threshing machines and riots

Panel A of Figure 1 illustrates our main finding. We divide English parishes into two groups – those with and without evidence of threshing machine adoption. More than one out of four parishes with threshing machines saw at least one riot – almost twice the rate of parishes with no machines. This basic relationship holds in a setting with a richer set of controls. We estimate variations of the following regression:

$$Riot_p = \beta_0 + \beta_1 Machines_p + \beta_{pop} Pop1821_p + \beta_X X_p + \theta_r + e_p \quad (1)$$

where $Riot_p$ is the number of riots in parish p during 1830-32, $Machines$ is the number of threshing machines, $Pop1821$ is the (log of the) total population living in the parish in 1821, and X is a vector of additional controls including area, share of agricultural families, male-female ratio, and distance to closest newspaper town and Elham, the village of the first riots.

In the most demanding specification, we include θ_r , fixed effects for the 4 macro-regions of England plus Wales. We define these regions based on Caird (1852), who divides England along two lines: one running North-South and another East-West. The North-South line separates pastoral areas (in the West) from arable land (in the East). The East-West line divides areas with high and low agricultural wages. The macro regions are geographical units with relatively homogeneous agricultural systems.

Table 2 presents our baseline results. The dependent variable is always the number of Swing riots. When we control only for population, the coefficient on *Machines* is positive and highly significant. Adding other parish-level controls in column 2 reduces the point estimate marginally and does not affect significance. Column 3 adds the 5 region fixed effects. The point estimate falls slightly and significance remains high – the correlation between machine adoption and riots is strong even within each agricultural regions.

In the last two columns of Table 2 we consider two alternative explanations for the Swing riots – adverse weather and enclosures.¹³ We construct 3 historical weather

¹³ Hobsbawn and Rudé (2014) note that the years 1828-30 had wet summers and poor harvests. Additionally, the autumn of 1830 was cold and they report stories of people being “afraid of the winter.”

variables: abnormal precipitation in spring and summer of 1830, and abnormal temperature in the fall of 1830. In addition, we add the share of land enclosed before 1820 (available for 7,000 parishes). Column 4 of Table 2 reports the estimates with additional controls, and column 5 adds region fixed effects. In both cases the coefficient on threshing machines remains positive and significant.¹⁴

There is a strong and positive correlation between riots and adoption of the new machines. The strength of the association is noteworthy because our measure of technology adoption is noisy. It is likely that we mis-classify parishes where threshing machines were in operation but were not mentioned in newspapers or surveys. This will bias our estimates downwards (Deaton 1997).

b. Identification

There are three reasons why the OLS estimates may not reflect accurately the relationship between threshing machine adoption and unrest. First, landlords and farmers may be less inclined to adopt labor-saving technologies where the risk of protest is high. Anecdotal evidence from the period suggests that this is a valid concern.¹⁵ This would bias estimates downwards. Second, there may be omitted variables that affect both the adoption of labor-saving technologies and the likelihood of rural protest. While the inclusion of observed characteristics does not affect point estimates in Table 2, it is still possible that other, unobserved characteristics correlate with technology adoption and riots. This could also affect our estimates. Third, measurement error in technology adoption is likely to bias coefficients downward, because we do not observe all threshing machines in use between 1800 and 1830.

To address these issues we need plausibly exogenous variation in the adoption of threshing machines. In the early 19th century, there were several types of threshing

These observations suggest that weather shocks may have contributed to the outbreak of the riots in 1830. Thompson (2013) and Royle (2000) emphasize how enclosures impoverished rural workers in the decades leading to the riots.

¹⁴ The number of Swing riots in a parish is a count variable and almost 86 percent of the parishes do not experience unrest during 1830-32. Thus, a linear model may not be appropriate. Table C2 in the appendix shows that results are robust to alternative estimation methods.

¹⁵ For instance Caird (1852) talks of an Oxfordshire farmer who “had so many hands thrown upon him, that he resorted to spade husbandry, being the best means in which they could be employed.”

machines. In particular, three different sources of power were commonly used: man-power, horses, and water-mills.¹⁶ We focus on the diffusion of water-powered threshing machines. While they represented only a small share of all threshing machines in 1830,¹⁷ there are three reasons to focus on them: First, whenever available, water power was cheap. Second, water-powered threshers generated greater labor savings than either man- or horse-powered machines (Figure B1). Therefore, we also expect them to have a greater impact on riots.¹⁸ Third, the possibility to install a water-mill was determined by conditions outside the control of local farmers — which makes them a good instrument, exogenous to equation (1). Average accumulation flow in a parish predicts the adoption of water-powered threshing machines. It captures the strength and the direction of streams and rivers — essential for powering water mills.¹⁹

Our second instrument is soil suitability for wheat, which measures how much wheat an area can produce. We expect it to predict thresher adoption because wheat was the only grain suitable for mechanical threshing.²⁰ We measure wheat suitability with FAO's potential yield data, based on intermediate inputs.

To instrument for adoption, we use the interaction of accumulation flow and wheat suitability, controlling for the two variables separately. Controlling for accumulation flow and wheat suitability separately is important because either of these two variables may affect riots through channels different from machine adoption. For example, the possibility to install a water-mill may promote economic development overall, which may have a direct effect on unrest. Similarly, wheat suitability may lead

¹⁶ We find no evidence of steam-powered threshing machines in any of the primary sources produced before 1830. They never appear in the *General View of Agriculture*, nor on newspaper articles. We interpret this evidence as an indication that steam-powered threshing machines were uncommon in the years before the riots.

¹⁷ In the *General Views of Agriculture*, all published before 1816, we can determine the power source for 91 of the 118 threshing machines mentioned: of these, 10 percent were moved by a water-mill.

¹⁸ This may, of course, bias the LATE upwards.

¹⁹ To validate this argument, we use data on water mill locations from millsarchive.org. The website lists more than 6,600 water mills, mostly in England. These mills were not necessarily used to power threshing machines, although some were. The log of accumulation flow is a significant predictor of water mill use in a parish. Regressing water mill presence on log accumulation flow yields *t*-statistics between 15 and 19, depending on the estimation method. Results are available upon request.

²⁰ Hobsbawm and Rudé (2014) argue that “oats and barley were definitely cheaper to thresh by hand.”

to specialization in wheat production, changing labor force composition. That is why neither accumulation flow nor wheat suitability are plausibly excludable.

Using the interaction of wheat suitability and accumulation flow means that we identify effects from places where both happened to be high. For interacted variables, the exclusion restriction in general is more plausible (Munshi and Rosenzweig 2016). In the case of threshing machine adoption, because we control for accumulation flow and wheat suitability separately, the product of the two is unlikely to affect unrest except through the adoption of water-powered threshing machines. For example, by including wheat suitability in the regressions, we effectively compare parishes that have the same potential to grow wheat, and then examine the effect of abundant water power. Because wheat production before the arrival of threshing machines did not rely on water power, it plausibly had no effect on agriculture before the machines arrived.²¹

Table 3 supports our argument. The interaction term does not correlate with most pre-determined characteristics. For example, the share of agricultural land cultivated with wheat in 1801 is not systematically higher or lower in areas with high wheat suitability and accumulation flow.²² However, our instrument is significantly correlated with the population living in the parish in 1821 (column 2). To alleviate the concern that this correlation with parish size is driving results, we control for 1821 population in all specifications. Also, column 3 shows that when controlling for population, the interaction of accumulation flow and wheat suitability still does not predict the share of land cultivated with wheat in 1801. Also, our instrument is not significantly correlated with the area of the parish (column 4), population density (column 5), distance to the closest of 15 large manufacturing centers (column 6), the share of enclosed commons in 1820 (column 7), the log of the Poor Rates per capita in 1801 (column 8), or the sex ratio in 1821 (column 9). Column 10 shows that the share of workers employed in agriculture is positively correlated with the instrument, and the relationship is

²¹ Accumulation flow does not capture the potential for irrigation. The existence of river is not sufficient to install a water-mill, which also requires the water to flow with enough speed and mass rate.

²² The General Views of Agriculture for the counties of Bedfordshire, Norfolk and Hampshire compiled in the 1790s do not mention threshing machines. Threshing machines are mentioned only in the Scottish counties of Aberdeenshire and Banffshire (Anderson 1794, Donaldson 1794).

significant at the 10 percent level. Overall, these results support the validity of our identification strategy.

c. First stage: Threshing machines adoption

Figure 3 illustrates the relationship between threshing machine adoption, accumulation flow, and wheat suitability. The upper half of panel A plots a local polynomial of threshing machine adoption in each parish (on the y-axis) against the log accumulation flow (on the x-axis);²³ Panel B does the same for wheat suitability. Threshing machines are more common in places where wheat harvests are more abundant, and accumulation flow is high. These relationships are tightly estimated for values with a greater number of parishes (bottom half of panels A and B). We now predict threshing machine adoption with the following model:

$$\begin{aligned} Machines_p = & \alpha_0 + \alpha_1 \log acc_p \times \log Yield^{wheat}_p + \\ & \alpha_2 \log acc_p + \alpha_3 \log Yield^{wheat}_p + \alpha_{pop} \log Pop1821_p + \alpha_X X_p + \psi_r + u_p \end{aligned} \quad (2)$$

We regress the number of threshing machines in parish p ($Machines_p$), on the logarithm of the accumulation flow ($\log acc$), the log potential yield of wheat ($\log Yield^{wheat}$), and the interaction between these two variables. In the simplest specification, we control for 1821 population. We then add a vector of controls and 5 region fixed effects.

The first 3 columns of Table 4 reports first stage estimates. When we control for population only, the F -stat of the instrument is 9.5 (column 1); with additional controls, it is 9 (column 2). With region fixed effects, the coefficient of the instrument becomes larger and significance improves, with an F -stat of 17.4, well above the critical value of 10. The interaction of wheat and water mill suitability strongly predicts diffusion of threshing machines. Because in some of these specifications the F -stat is slightly below 10, we also report the Rubin-Anderson test (Stock, Wright and Yogo 2002; Anderson and Rubin 1949).

²³ To produce this figure, we use the Epanechnikov kernel function and a bandwidth of 0.198 (a value calculated with the ‘rule of the thumb’ formula).

d. Reduced form and IV results

Before presenting our econometric results, we illustrate our findings visually. Figure 4 combines information on wheat suitability and the location of Swing riots. Black dots identify parishes with riots, and their size indicates the number of unrest episodes. Riots were concentrated in Wiltshire, Berkshire and Hampshire, in the South-Eastern counties of Kent and Sussex, and in Norfolk. These regions are also the ones that are more suitable to wheat cultivation. Figure 4 shows significant variation within areas with relatively homogeneous wheat suitability. Our identification strategy exploits this heterogeneity by allowing the effect of wheat suitability to differ in places with and without the possibility to install water mills. For three areas (enlarged panels), we show riot locations and log accumulation flow. Riots were much more common in areas with more water flow.

Table 4 shows the strength of this pattern statistically. When we only include the 1821 parish population in column 4, we find a positive and significant coefficient on the interaction term. When we add other parish-level characteristics (column 5), the precision of the estimates improves. The point estimate of the interaction term is stable, demonstrating that our instrument is uncorrelated with other observable characteristics. Adding region fixed effects further improves the precision of our estimates.

The reduced form results point to a strong and robust relationship between our instrument and the diffusion of riots – the interaction between water mill and grain suitability always predicts more riots. The IV results are similar. Whether we control for population only (column 7), the full set of controls (column 8), or fixed effects and controls (column 9), we find that there is a large and significant effect from the confluence of accumulation flow and wheat suitability on riot frequency.

The IV estimates in Table 4 suggest that one extra machine, installed because of land characteristics, translated into 4.8 more riots during 1830-32. This is larger than the effect under OLS. There are two reasons why downward bias under OLS is plausible. First, reverse causality is likely to attenuate estimates because farmers scared of unruly workers might have been reluctant to install labor-saving machinery. Second, our

measure of machine adoption is noisy: we only count machines publicized in local newspapers or mentioned in the *General Views of Agriculture*.²⁴

To illustrate the robustness of our results to limited violations of the exclusion restriction, we also perform the test proposed by Conley, Hansen and Rossi (2012). We report these results in Appendix B.2. The direct effect of the instrument on riots would have to account for more than half of the overall effect before the estimated coefficient becomes insignificant. Such large direct effects are not likely, especially because we are already controlling for the direct effect of wheat suitability and accumulation flow separately.

4 Mechanisms and repercussions

In this section, we examine the channels that led from technology adoption to unrest. We document that in areas where machines appeared together with other factors that impoverished rural workers, the relationship between technology adoption and riots was stronger. In contrast, access to alternative labor markets and generous welfare support dampened the effect of mechanization on riots. Finally, we show that the effect of the riots lingered, reducing both innovation and technology adoption in affected areas.

a. Manufacturing employment

Where workers could easily find alternative employment, labor-saving technologies did not lead to social unrest. In 1830s England, many towns were thriving. We expect rural workers living in areas nearby to be more likely to migrate in response to the introduction of new labor-saving machines. In these areas, the introduction of threshing machines should engender less opposition, resulting in fewer Swing riots.

²⁴ Let us call $TrueMachines_p$ the true measure of machines in parish p . We only observe $Machines_p = \pi TrueMachines_p$, for some $\pi < 1$. Thus, if β^*_I is the true effect of $TrueMachine$ on $Riot$, equation (1) will estimate a smaller coefficient $\beta_I = \beta^*_I \times \pi$. To guess how many machines our adoption measure is missing, we can use the data on machine-breaking: We observe attacks on machines in 320 separate parishes; in only 11 percent (36) of these parishes were advertisements published mentioning threshers. Thus, OLS estimates may underestimate the true effect of machines on riots by almost 90 percent. This would explain between 70 and 40 percent of the difference between OLS and two-stage least squares estimates.

For each parish in England, we compute the distance to the closest of 15 manufacturing centers. We then split the sample into above-median and below-median distance from one of these centers.²⁵ We plot OLS estimates of equation (1) for these two sub-samples on the left side of Figure 5 (full results are in Table C3). Estimates in red show that adoption of threshing machines led to significantly more riots in the 5,049 parishes that lie far away from manufacturing centers. In contrast, the relationship is not significantly different from 0 for the other half of the sample, as indicated by the estimates in green. The coefficients are significantly different from each other in all specifications. The right side of Figure 5 turns to the reduced form. Again, having the possibility to install a water-mill in a wheat-producing area leads to significantly more unrest in parishes that are far away from a manufacturing center (estimates in red), but not in those that lie closer to them (estimates in green). The coefficients are different from each other with a confidence of $p = 0.12$ or better. Overall, these results suggest that urban labor markets reduced instability by offering an ‘escape valve’ for surplus labor after the introduction of labor-saving technology.

b. Enclosures

We now ask whether enclosure prior to 1820 amplified the effect of machine adoption on riots. This is plausible because enclosure on average worsened conditions for agricultural laborers (Neeson 1996; Mingay 2014): where most land is enclosed, labor-saving technologies is especially harmful to workers since they have no other source of income.

In Figure 6, we split our sample into two groups, depending on whether an above-median share of land was enclosed (full results are in Table C4).²⁶ The left side of the figure shows OLS regressions: we plot in red estimates obtained on the sample

²⁵ The 15 manufacturing centers are in Gloucestershire, Lancashire, Middlesex (London), Norfolk, Warwickshire and Yorkshire, West Riding. See Appendix A for details. The median parish is Winchfield in Hampshire which lies 62 km from London.

²⁶ We only observe enclosures for registration districts, and parishes in the same district share the same value of enclosure. The median parish is in the districts of Biggleswade (Bedford), Billericay, Colchester, Ongar, Romford (Essex) and Market Harborough (Leicester). There are 107 parishes in these districts, and we assign them to the ‘low’ enclosure group: this is the reason why splitting parishes at the median does not produce two samples of exactly the same size.

with high enclosures and in green those on the sample with low enclosures. In all cases, the relationship between machines and riots is strong and precisely estimated in parishes with above-median enclosures. In contrast, we find no significant association between machines and riots where few enclosures occurred. The coefficients of the threshing machine variable in the two samples are significantly different from each other ($p = 0.07$ or better). The right side of Figure 6 shows the reduced form estimates in the same two samples. Again, we find a significant correlation between riots and our instrument in the high-enclosure parishes. While the difference between the coefficients in the two samples is not significant, the relationship between riots and the determinants of machine adoption is noisy and unstable in the sample of parishes with few enclosures. Overall, there is some evidence that enclosures exacerbated the effect of machines on riots.

c. Generosity of poor relief

New technology typically creates a net gain for society. One important policy question is whether workers can be ‘bought off,’ accepting the adoption of new technology because redistribution guarantees a minimum living standard. We use new data on the local generosity of poor relief to examine this question, using information on poor relief for a total of 1,333 parishes across England. We split this sample into parishes with above vs below-median poor relief per capita.²⁷

Figure 7 shows the results (full results are in Table C5). The left side reports OLS estimates. For the small sample of parishes for which we have data on poor relief generosity we have low power, and we find a significant relationship between machines and riot only in the specification without region fixed effects. Within this sample however, the strongest effect comes from the parishes that have low poor relief. For this group the coefficient on machines is positive and larger than the one for the group of generous parishes. Despite lack of power we also find relatively low p -values for these estimates, which are significantly different from 0 at the 8.5, 11.4 and 12.9 percent

²⁷ The median parish is Doddington in Cambridgeshire, which collects and redistributes £0.6 per capita.

levels. On the right-hand side of Figure 7, we show reduced form estimates. In parishes with above-average poor relief, the effect of our instrument on unrest is muted. While places with more watermill suitability and better cultivation conditions for wheat are more likely to see unrest in 1830, the relationship is stable and precisely estimated only in the subsample of parishes where the poor received little support. In contrast, where poor laws offered generous support, wheat and water mill suitability do not predict riots. Overall, these results provide tentative support for the idea that machines led to more riots in parishes that treated their poor poorly.

d. Aftermath: Innovation and technology adoption 1832-1850

Based on anecdotal evidence, Hobsbawn (1952) argues that the Swing riots effectively caused threshing machines to disappear in the decades after the revolt: “The wrecking of the helpless farm-laborers in 1830 seems to have been the most effective of all. ... the thrashing machines did not return on anything like the old scale.” If this was the case, the Swing riots would be one of the few cases where organized resistance to new technology slowed down adoption (Mokyr 2002). While eloquently argued, there is currently no direct evidence for Hobsbawn’s claim.

To investigate the aftereffect of the riots, we look at the invention of new technologies and their adoption. For invention, we collect data on the place of residence of every inventor who registered a patent in Britain in the years 1813-1843 (Woodcroft 1854). For adoption, we focus on the diffusion of agricultural machines in 1832-1853 as indicated by farm advertisements mentioning ‘threshing machines,’ or ‘mowing machines.’²⁸ We complement the information on threshing machines with diffusion of mowing machines because the latter were labor saving and became available in the years after the riots (Walton 1973).²⁹ To study the effect of riots on innovation and adoption, we regress these variables on the distance to the closest machine broken during the Swing riots.

²⁸ Because of time and financial constraints, we collect advertisements from 8 randomly selected years: 1832, 1835, 1838, 1841, 1844, 1847, 1850 and 1853.

²⁹ Results with only threshing machine adoption are qualitatively similar. In all specifications we exclude urban areas and focus on rural parishes where riots were more likely to have had an impact.

The first 4 columns of Table 5 report the results with invention.³⁰ The dependent variable is the number of inventors who registered a patent. Places farther from a machine-breaking riot were home to significantly more inventors in the 10 years after the riots. In column 2 we control for inventive activity in the 10 years before the riots and find that distance to a machine attack is still positively and significantly associated with innovative activity after the riots. When we add other parish-level controls on column 3 we still find a positive and significant effect. Finally, adding 5 region fixed effects reduces the point estimate, but the coefficient remains significantly different from 0 at the 10 percent level. The average parish in these regressions lies 13.2 km from a Swing attack on a threshing machine. The estimate in column 4 implies that this parish would be home to 0.005 more inventors relative to a parish where workers destroyed a machines. This is equivalent to 31 percent of the average number of inventors in our sample of parishes.

We now turn to the association between riots and machine adoption. Here, the empirical challenge is that wheat-producing areas that adopted threshing machines in the first three decades of 1800 were also more likely to reintroduce these machines after 1830. We deal with this issue in two ways. First, we restrict attention to parishes within 35 km from one of the threshing machines attacked during Swing. This effectively discards the North of England and Wales, and centers attention on the most important areas for cereal cultivation. Second, we control for the diffusion of machines prior to 1830.

Columns 5 to 8 of Table 5 report the results of this analysis. In all specification the dependent variable is the number of threshing machines and mowing machines observed in the years 1832-1853. In column 5 we find a strong positive effect. When we add controls for past adoption (column 6), parish characteristics (column 7) and region fixed effects (column 8) the coefficient remains unaffected and significance improves. The average parish in these regressions lies 13.6 km from a Swing attack on a threshing

³⁰ This excludes 437 parishes within 10 km from one of the 15 manufacturing centers used in section 4.a. Inventors living in these parishes registered 71 percent of patents in the years 1813-1829 and 75 percent of patents in the years 1832-1843.

machine: the estimates from Table 5 imply that this parish would adopt an additional 0.01 labor saving machines in the 20 years after the riots than the parish that experienced the attack. This is equivalent of about 22 percent of the average number of machines adopted between 1832 and 1853 (0.06). Overall, these results provide suggestive evidence that riots discouraged innovative activity in the years following unrest.

5 Robustness

In this section we show the robustness of our results.

a. Robustness: Definition of suitability to wheat production

In our baseline results, we use potential yield attainable by rain-fed agriculture with ‘intermediate-level inputs’ and ‘improved management.’ While justified by the highly commercialized nature of English agriculture, the assumption of fertilizers use may be problematic – FAO researchers used data on chemical products not available in 1800.³¹

Here, we measure wheat suitability with yields under the FAO ‘low input’ scenario which is calculated assuming “no use of chemicals for pest and disease control.” We report results for first stage, reduced form, and IV in Table C6. All coefficients remain highly significant and magnitudes are similar to our baseline estimates.

b. Robustness: Spatial autocorrelation

In section 3, we base inference on conventional robust standard errors that do not account for spatial correlation in the explanatory variable. However, the geographic distribution of machines and riots, as well as water-mill and wheat suitability, suggest that these variables vary smoothly over space. Hence, spatial correlation of errors may be a concern. Here, we show that accounting for spatial correlation has no effect on the significance of our results.

³¹ While English farmers would routinely use several types of manure such as chalk, marl, clay and excrements as fertilizers (Rahm 1844), they did not have access to more recent chemical products.

We control for spatial correlation in two ways. First, we compute standard errors with the formula proposed by Conley (1999). We experiment with three different cutoffs: 20, 50 and 100 km. Second, we estimate standard errors in a non-parametric way, and cluster them at the level of the closest city that publishes a newspaper. This creates 60 separate clusters.

Table C7 reports the results. OLS results remain strong and significant when we introduce Conley standard errors or cluster at the newspaper city level. Similarly, all reduced form results survive when we account for spatial correlation: spatially robust standard errors tend again to be larger than conventional robust standard errors, but all estimates remain significant at the 2.8 percent level or better. All in all, these results suggest that spatial autocorrelation is not responsible for the significance of our findings.

c. Robustness: Sample restrictions

Part of the information we use to track machine adoption comes from historical newspapers. These newspapers come from 60 towns and cities, and they were more likely to advertise farm sales near the place of publication. Similarly, part of the riot data come from newspapers, and may be more likely to report unrest in the same surrounding villages. To control for this possible confounding mechanism, we include the distance to the closest newspaper in all our regressions. Additionally, here we show that all our results survive if we restrict the sample to parishes within 50 kilometers from the closest newspaper. We report our estimates on Table C8. This table shows estimates for OLS (columns 1-2), first stage (columns 3-4), reduced form (columns 5-6) and IV (columns 7-8). These estimates confirm that none of our results is driven by the potentially uneven coverage of English parishes offered by 1800 newspapers.

A second concern with our results is that they may reflect the contrast between English and Welsh parishes. English parishes specialized in cereal production and bore the brunt of the Swing riots. In contrast, pastoral agriculture was more common in Wales, and the riots left this region almost untouched. We already show that all results

are robust to including five region fixed effects. Table C9 shows that excluding the 949 Welsh parishes from our regressions further strengthens our results.

A third concern has to do with the timing of the riots. While Holland (2005) records episodes that happened until the end of 1832, most of the protests took place during the winter of 1830-31, and the most violent part of the revolt was over by the spring of 1831. Including later unrest episodes may introduce noise. To address this concern, we replicate the whole analysis after excluding all episodes that happened after April 1831.³² Results in Table C10 confirm that the specific definition of riots is not driving our results.

A final concern has to do with the urban nature of some of the parishes in our sample. Around 3.4 percent of the English parishes have a share of families employed in agriculture below 10 percent: these places were mostly urban, and in 1821 they were home to about 35 percent of the English population. Because threshing machines affected agricultural workers and Swing was mostly a rural uprising, it is useful to evaluate whether our results hold when we remove urban parishes from the sample. Table C11 reports results for parishes with agricultural share greater than 10 percent: coefficients are similar to our baseline estimates.

6 Conclusions

In this paper, we examine a canonical case of technology-induced social unrest: the ‘Captain Swing’ riots in England in 1830-32, the largest wave of unrest in recorded English history. Using newly-compiled data on the diffusion of threshing machines, we first demonstrate that labor-saving technology was a key determinant of the probability of unrest – and that machine-breaking typically spilled over into general rioting. Based on data about soil fertility and suitability for water power, we also show that the link was causal: Areas with more water power and better conditions for wheat cultivation witnessed both greater adoption of threshing machines and markedly more riots. While

³² This excludes 619 episodes, and leaving 2421 riots.

many factors probably contributed to the outbreak of unrest in England and Wales in 1830-32, we demonstrate a clear causal contribution of technological change to political conflict.

New technology did not lead to more unrest in all parts of England. In the vicinity of major manufacturing towns, favorable conditions for threshing machine adoption did not spell arson, attacks on the local authorities, machine breaking or tumultuous assemblies of the poor. In other words, where ease of access to alternative employment made workers' exit a realistic option, technological unemployment did not translate into social unrest. We also find that generous transfers to the poorest mitigated the impact of new technology. Where England's nascent welfare state in the form of the Poor Law put an effective floor under the earnings of the poor, technological unemployment did not translate into political instability and unrest to the same extent. This matters all the more because the riots of 1830-32 had major repercussions – their effect lingered after 1832 in the form of lower technology adoption and reduced rates of innovation.

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FIGURES

Figure 1. Share of parishes affected by Swing riots, conditional on threshing machine use. Swing riots from Holland (2005). Left bar: parishes with no threshing machines between 1800 and 1830; right bar: parishes with at least one threshing machine.

Figure 2. Geographical distribution of 'Swing' riots. Source: Holland (2005).

Figure 3. Panel A. Visualization of the first stage: Number of threshing machines and potential yield of wheat. **Panel B.** Visualization of the first stage: number of threshing machines and accumulation flow.

Figure 4. Illustration of reduced form: The map on the left reproduces the potential yield of wheat and the location of the Swing riots (as solid black dots) across England and Wales. The panels on the right magnify three areas of the map, showing riot locations (as hollow white dots) and log accumulation flow.

Figure 5. Mechanism: Distance to closest manufacturing center. Left side: coefficient and standard errors for OLS estimates of threshing machines on riots. Right side: coefficient and standard errors for reduced form estimates of log potential yield of wheat times log accumulation flow on riots. Red estimates: sample of parishes distant from manufacturing centers; green estimates: sample of parishes close to manufacturing centers. See Table C3 for full set of results.

Figure 6. Mechanism: Enclosures and unrest. Left side: coefficient and standard errors for OLS estimates of threshing machines on riots. Right side: coefficient and standard errors for reduced form estimates of log potential yield of wheat times log accumulation flow on riots. Red estimates: sample of parishes with high enclosure; green estimates: sample of parishes low enclosures. See Table C4 for full set of results.

Figure 7. Mechanism: Poor Law generosity and unrest. Left side: coefficient and standard errors for OLS estimates of threshing machines on riots. Right side: coefficient and standard errors for reduced form estimates of log potential yield of wheat times log accumulation flow on riots. Red estimates: sample of parishes with non-generous poor rates; green estimates: sample of parishes with generous poor rates. See Table C5 for full set of results.

TABLES

		Mean	St. dev.	Obs.
Main variables	Threshing machines (1800-30)	0.061	0.286	10099
	Swing riots (1830-32)	0.301	1.083	10099
	Attacks on machines (1830-32)	0.052	0.363	10099
	Threshing and mowing machines (1832-53)	0.054	0.381	10099
	Number of patents before riots (1813-1828)	0.103	2.659	10099
	Number of patents after riots (1832-1843)	0.153	4.259	10099
	Share of commons enclosed (until 1820)	0.027	0.040	7019
Agricultural unemployment	Unemployment share: winter	0.137	0.158	673
	Unemployment share: summer	0.071	0.116	695
	Unemployment share: winter - summer	0.060	0.108	649
Parish characteristics	Population (1821)	1165.6	4580.8	10099
	Share of families in agriculture in (1821)	0.679	0.245	10099
	Sex ratio (1821)	1.023	0.204	10099
Geographical characteristics	Potential yield: wheat (intermediate ins) - t/ha	3.805	0.421	10099
	log accumulation flow - number of cells	3.488	1.726	10099
	log Parish area (square meters)	16.041	0.933	10099
Relevant Distances	Distance to closest city with newspaper - km	24.337	17.978	10099
	Distance to Elham (first riot location) - km	236.30	107.58	10099
	Distance to closest industrial city - km	66.483	38.081	10099
Weather variables	Abnormal precipitation (spring 1830) - mm	18.679	15.706	10099
	Abnormal precipitation (summer 1830) - mm	104.11	22.746	10099
	Abnormal temperature (fall 1830) - degrees	0.277	0.068	10099

Table 1. Summary statistics.

Dep. var.:	Number of Swing riots				
	(1)	(2)	(3)	(4)	(5)
Threshing machines	0.288 (0.067)	0.269 (0.067)	0.217 (0.067)	0.270 (0.080)	0.227 (0.081)
log(1821 population)	0.190 (0.013)	0.159 (0.017)	0.152 (0.017)	0.184 (0.018)	0.184 (0.018)
log(Parish area)		0.067 (0.019)	0.078 (0.019)	0.136 (0.027)	0.134 (0.027)
% families in agriculture		-0.046 (0.050)	-0.092 (0.048)	-0.143 (0.070)	-0.157 (0.069)
log(sex ratio)		-0.129 (0.046)	-0.098 (0.046)	-0.042 (0.060)	-0.005 (0.061)
log(distance to Elham)		-0.344 (0.033)	-0.204 (0.045)	0.266 (0.070)	0.372 (0.072)
log(dist. to city with newspaper)		-0.018 (0.016)	-0.018 (0.018)	-0.014 (0.021)	-0.009 (0.023)
Abnormal precipitation, spring 1830				-0.009 (0.003)	-0.011 (0.003)
Abnormal precipitation, summer 1830				0.001 (0.002)	0.001 (0.002)
Abnormal temperature, fall 1830				-2.748 (0.777)	-1.957 (0.873)
Percentage of land enclosed in 1820				0.001 (0.004)	0.000 (0.004)
Constant	-0.875 (0.072)	0.149 (0.251)		-3.415 (0.430)	
Region fixed effects (5)			✓		✓
Observations	10,099	10,099	10,099	7,019	7,019
R-squared	0.054	0.092	0.100	0.097	0.103

Table 2. Threshing machines and riots. Column 1 reports estimates of equation (1) when controlling for 1821 population only; column 2 adds other parish characteristics and column 3 five region fixed effects. Columns 4 and 5 include weather variables and enclosures as controls. Dependent variable is the number of ‘Swing’ riots. Robust standard errors in parentheses.

Dep. var.:	log(pot. yield wheat) × log(accumulation flow)		log pot. yield wheat	log acc. flow	log 1821 population	Obs.	R ²
Share of wheat area in 1801	0.035	(0.022)	✓	✓		3,326	0.07
log 1821 population	-0.422	(0.117)	✓	✓		10,099	0.06
Share of wheat area in 1801	0.035	(0.022)	✓	✓	✓	3,326	0.07
log parish area	-0.150	(0.130)	✓	✓	✓	10,099	0.40
log population per m2	0.150	(0.130)	✓	✓	✓	10,099	0.48
log distance to manufacturing city	-0.121	(0.080)	✓	✓	✓	10,086	0.06
Share enclosed commons in 1820	-1.786	(1.196)	✓	✓	✓	7,019	0.02
log 1801 poor rates per capita	-0.058	(0.078)	✓	✓	✓	1,333	0.07
Share families in agriculture in 1821	0.022	(0.012)	✓	✓	✓	10,099	0.36
log 1821 sex ratio	-0.002	(0.006)	✓	✓	✓	10,099	0.05

Table 3. Balancedness table. Each row reports a separate regression: dependent variable is reported on the left column. Columns 2 and 3: coefficients and robust standard errors for the excluded instrument. Each regressions controls for log potential yield of wheat and log accumulation flow. All regressions except the first two control for 1821 population.

Dep. var.:	Threshing machine ads			Number of Swing riots					
Equation:	First stage			Reduced form			Two-stages least squares		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Threshing machine							5.647 (1.591)	4.830 (1.193)	4.757 (1.123)
log(pot. yield wheat) × log(accumulation flow)	0.039 (0.013)	0.041 (0.014)	0.044 (0.011)	0.218 (0.082)	0.196 (0.052)	0.212 (0.045)			
log(potential yield wheat)	-0.045 (0.044)	-0.036 (0.049)	-0.070 (0.034)	-0.105 (0.318)	-0.242 (0.197)	-0.321 (0.163)	0.148 (0.141)	-0.068 (0.117)	0.014 (0.094)
log(accumulation flow)	-0.051 (0.017)	-0.053 (0.018)	-0.057 (0.014)	-0.294 (0.109)	-0.257 (0.069)	-0.277 (0.059)	-0.009 (0.010)	-0.001 (0.009)	-0.007 (0.009)
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Parish-level characteristics		✓	✓		✓	✓		✓	✓
Region fixed effects (5)			✓			✓			✓
R-squared	0.019	0.021	0.049	0.061	0.092	0.102			
F-stat excluded instrument	9.5	9.0	17.4						
Rubin-Anderson test (<i>p</i> -value)							0.007	0.000	0.000
Observations	10,099	10,099	10,099	10,099	10,099	10,099	10,099	10,099	10,099

Table 4. Identification. Columns 1-3: first stage regression. Columns 4-6: reduced form regression. Columns 7-9: IV regressions. Dependent variable is: columns 1-3: number of threshing machines in the parish; columns 4-9: number of Swing riots in the parish. Robust standard errors in parentheses.

Dep. var.:	Patents 1832-1843				Threshing machines + mowing machines 1832-1853			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Distance to machine attack (meters)	0.396 (0.208)	0.304 (0.138)	0.457 (0.194)	0.385 (0.226)	1.047 (0.533)	1.235 (0.531)	1.441 (0.584)	1.674 (0.562)
Patents 1813-1829		0.742 (0.138)	0.710 (0.139)	0.709 (0.139)				
Threshing machines 1800-1830						0.101 (0.033)	0.084 (0.032)	0.072 (0.032)
log(1821 population)			0.041 (0.009)	0.042 (0.009)			0.029 (0.007)	0.028 (0.008)
log(Parish area)			-0.025 (0.010)	-0.026 (0.011)			0.008 (0.009)	0.013 (0.009)
% families in agriculture			-0.027 (0.017)	-0.026 (0.017)			0.010 (0.027)	-0.004 (0.027)
log(sex ratio)			0.021 (0.014)	0.016 (0.013)			-0.023 (0.026)	-0.019 (0.026)
log(distance to Elham)			-0.001 (0.005)	-0.003 (0.006)			-0.011 (0.007)	0.009 (0.007)
log(dist. to newspaper)			-0.028 (0.012)	-0.029 (0.012)			-0.038 (0.016)	-0.040 (0.015)
Constant	0.027 (0.006)	0.007 (0.006)	0.256 (0.130)		0.046 (0.008)	0.036 (0.008)	-0.113 (0.117)	
Region fixed effects (5)				✓				✓
Observations	9,665	9,665	9,665	9,665	6,703	6,703	6,703	6,703
R-squared	0.001	0.377	0.388	0.388	0.001	0.006	0.017	0.027

Table 5. Aftermath: Effect of riots on innovative activity. In columns 1-4 the dependent variable is the number of patents registered by inventors in the years 1833-43. In columns 5-8 the dependent variable is the number of threshing machines and mowing machines found on newspaper advertisements in the years 1832-1853. Robust standard errors are in parentheses.

APPENDIXES (for online publication)

A Data appendix

A.1 *Ancient parishes of England and Wales*

To construct our database, we start from the map of ancient parishes of England and Wales prepared by Burton *et al.* (2004). This map derives from earlier electronic maps by Kain and Oliver (2001), and contains a GIS database of all parishes of England and Wales in 1851. The map consists of 22,729 separate polygons, each identifying a separate place in England and Wales. These places are localities smaller than a parish, so that a given parish is often made of several distinct places. Because we observe all our variables at the parish level, we start by aggregating the 22,729 polygons into 11,285 parishes.³³

Next, we aggregate a subset of these parishes into larger units of observation. We do this in two cases. First, large urban areas such as London, Liverpool or Manchester consists of several distinct parishes. Treating these areas as separate observations is incorrect, because we always observe riots and threshing machines for a whole city, and we are never able to assign them to any specific area within the city. Thus, we assign all parishes belonging to a city to a single observation. We also aggregate different parishes into larger units when the information from at least one of our sources does not allow us to compute one of our variables more precisely. This happens when one of our sources records a riot, a threshing machine or Census population for a large area comprising several parishes. In these cases, we also aggregate all variables at the level of the larger unit of observation. Table A1 reports the full list of cities constructed with several parishes.³⁴

At the end of this process, we are left with 10,700 separate observations. Of these, we are able to match 10,123 to the 1821 Population Census based on the county and parish name. We drop 21 of these observations because they have 0 population in 1821: this leaves us with the sample of 10,102 observations. Finally, 3 of these parishes have 0 potential yield of wheat according to the FAO database: when we take the logarithm of this variable we drop them and we are left with our final database of 10,099 observations.

³³ We do this based on the fields *GAZ_CNTY* and *PAR*, which identify the county and the parish in the map.

³⁴ There is a second reason for aggregating parishes within cities. Because most of riots and almost all machines appear in rural areas, keeping separate observations for each urban parish effectively duplicates observations with no riots and no machines. This would introduce the “Moulton problem” (Moulton, 1990) and, by biasing standard errors downwards, it would artificially increase the precision of our estimates.

County	City or village	Parishes aggregated	County	City or village	Parishes aggregated
London	London	80	Huntingdonshire	Sawtry	3
Yorkshire, west riding	York	55	Nottinghamshire	Nottingham	3
Norfolk	Norwich	36	Kent	Dover	3
Devon	Exeter	25	Worcestershire	Droitwich	3
Kent	Canterbury	24	Dorset	Wareham	3
Lincolnshire	Lincoln	21	Lincolnshire	Saltfleetby	3
Gloucestershire	Bristol	20	Suffolk	Fornham	3
Oxfordshire	Oxford	13	Kent	Rochester	3
Cheshire	Chester	13	Dorset	Shaftesbury	3
Suffolk	Ipswich	13	Essex	Maldon	3
Hampshire	Winchester	12	Somerset	Bath	3
Gloucestershire	Gloucester	12	Glamorganshire	Cardiff	3
Essex	Colchester	12	Hertfordshire	Hertford	3
Cambridgeshire	Cambridge	12	Lincolnshire	Wainfleet	3
Leicestershire	Leicester	11	Suffolk	Bury st edmunds	2
Worcestershire	Worcester	11	Pembrokeshire	Pembroke	2
Sussex	Chichester	11	Yorkshire, west riding	Ferry fryston	2
Sussex	Hastings	7	Wiltshire	Marlborough	2
Shropshire	Shrewsbury	7	Suffolk	Bungay	2
Hampshire	Southampton	7	Herefordshire	Sutton	2
Sussex	Lewes	6	Devon	Dartmouth	2
Herefordshire	Hereford	6	Norfolk	Walpole	2
Lincolnshire	Stamford	5	Northamptonshire	Peterborough	2
Surrey	Guildford	5	Norfolk	Thetford	2
Bedfordshire	Bedford	5	Warwickshire	Warwick	2
Northamptonshire	Northampton	5	Glamorganshire	Swansea	2
Berkshire	Wallingford	5	Dorset	Dorchester	2
Huntingdonshire	Huntingdon	4	Devon	Plympton	2
Kent	Sandwich	4	Wiltshire	Orcheston	2
Suffolk	Sudbury	4	Nottinghamshire	Sutton bonington	2
Cambridgeshire	Ely	4	Buckinghamshire	Stony stratford	2
Wiltshire	Salisbury	4	Devon	Plymouth	2
Yorkshire, north riding	Thornton dale and ellerburn	4	Norfolk	Warham	2
Brecknockshire	Brecon	4	Cornwall	Launceston	2
Derbyshire	Derby	4	Warwickshire	Coventry	2

Table A1. List of cities created by aggregating more than one parish from the original shapefile created by Burton *et al.* (2004).

County	City or village	Parishes aggregated	County	City or village	Parishes aggregated	County	City or village	Parishes aggregated
Norfolk	Wiggenhall St German	4	Somerset	Pilton And North Wootton	2	Norfolk	Witchingham	2
Yorkshire, East Riding	Beverley	4	Norfolk	Oxwick And Pattesley	2	Norfolk	Alpington & Yelverton	2
Norfolk	Lynn	4	Herefordshire	Tedstone	2	Wiltshire	Collingbourne	2
Middlesex	Westminster	4	Lincolnshire	Ludford	2	Norfolk	Beckham	2
Berkshire	Windsor	3	Norfolk	Beechamwell	2	Northamptonshire	Boddington	2
Buckinghamshire	Brickhill	3	Wiltshire	Savernake	2	Norfolk	Poringland	2
Norfolk	Bircham	3	Yorkshire, East Riding	Hull	2	Suffolk	Whelnetham	2
Dorset	Blandford	3	Suffolk	Hargrave And Southwell Park	2	Cornwall	St Columb	2
Berkshire	Reading	3	Yorkshire, West Riding	Sawley And Tosside	2	Somerset	Taunton	2
Norfolk	Wretham	2	Worcestershire	Evesham	2	Worcestershire	Pershore	2
Norfolk	Bawburgh And Bowthorpe	2	Nottinghamshire	Retford	2	Kent	Snodland And Paddlesworth	2
Worcestershire	Great Witley & Martley	2	Norfolk	Fornceett	2	Lincolnshire	Mumby	2
Middlesex	S.Andrew Holborn & S.George Martyr	2	Norfolk	Glandford And Bayfield	2	Devon	Axminster & Uplyme	2
Norfolk	Ranworth With Panxworth	2	Dorset	Lytchett	2	Wiltshire	Cricklade	2
Norfolk	Terrington	2	Norfolk	Lamas And Little Hautbois	2	Wiltshire	Codford	2
Wiltshire	Tisbury	2	Cumberland	Carlisle	2	Suffolk	Newmarket Upton And Fishley	2
Suffolk	Icklingham	2	Norfolk	Rudham	2	Norfolk		2
Norfolk	South Walsham	2	Norfolk	Somerton	2	Cambridgeshire	Wisbech	2
Wiltshire	Manningford	2	Norfolk	Sporle And Palgrave	2	Lincolnshire	Somercotes	2
Wiltshire	Lavington	2	Lincolnshire	Great Limber And Brocklesby	2	Kent	Deptford	2
Lincolnshire	Stoke	2	Norfolk	Weasenham	2	Hampshire	Alresford	2
Wiltshire	Cheverell	2	Norfolk	Walton	2	Somerset	Brewham	2
Carmarthenshire	Carmarthen	2	Cambridgeshire	Abington	2	Wiltshire	Chitterne	2
Sussex	Bersted And Pagham	2	Northamptonshire	Cranford	2	Berkshire	Bucklebury	2
Cornwall	Perranuthnoe And St Hilary	2	Oxfordshire	Barton	2	Kent	Stanford	2
Wiltshire	Sherston	2	Leicestershire	Leicester Forest	2	Kent	Romney	2
Lincolnshire	Sleaford	2	Norfolk	Long Stratton	2	Landrake & St Erney		2
Dorset	Whitchurch And Catherson	2	Gloucestershire	Forest Of Dean	2	Cornwall	Lulworth	2
Norfolk	Beeston And Bittering	2	Middlesex	S.Giles in the Fields & S.George Bloomsbury	2	Dorset	Abingdon	2
						Berkshire	Barming	2

Table A1 (*cont.*). List of other geographical units created by aggregating more than one parish from the original shapefile created by Burton *et al.* (2004).

A.2 Variable construction

In this section, we describe data sources and variable construction.

Threshing machines 1800-1830. We assemble a list of threshing machines in use before the riots from two data sources. The first is built from threshing machines advertisements found on English and Welsh newspapers. The second are the reports of threshing machines on the *General Views of Agriculture*. We collect newspaper advertisements from the website *British Newspaper Archive*:³⁵ within the universe of the 60 regional newspaper published between 1800 and 1830, we search for the exact string ‘threshing machine.’ We restrict our search to articles classified as either “advertisement” or “classifieds.” Next, we read in full each article retrieved, and determine whether it is relevant for our research. We consider relevant information any article that advertises the sale or the lease of a threshing machine or of a farm that lists a threshing machine among its assets. In one case, we also consider the information provided by a threshing machine manufacturer who lists name and location of their clients: these clients are farmers located in parishes all over the country (see Figure C3). We drop all advertisements of threshing machines producers that only provide information about the location of the factory, usually an industrial town. We also only consider a single threshing machine whenever we find the same advertisement printed more than once. In the last step, we manually geo-locate each advertisement, and find the parish in which the threshing machine or the farm is located on the map prepared by Burton, *et al.* (2004).

We complement this source with a list of threshing machines we found on the *General Views of Agriculture* for all English counties. In the second editions of each of these publications, the surveyors devoted an entire chapter to threshing machines, relating information on every machine they found in the countryside, including the name of the owner and the place of operation. We locate each of these machines on the map of Burton *et al.* (2004) and make sure that we do not double count any machine from the newspapers by comparing the names of the owners in the two sources. Whenever we link a parish to either an advertisement or a machine from the *General Views*, we add 1 to the number of threshing machines we find in that parish.

Swing riots. Data on Swing riot comes from a database compiled by the Family and Community Historical Research Society (Holland 2005). The data contains a comprehensive list of Captain Swing incidents between January 1830 and December 1832. The information

³⁵ See: <http://www.britishnewspaperarchive.co.uk/>. We collected these articles during the spring of 2016.

comes from official records and historical newspapers and contains date, parish, and type of crime perpetrated by rioters. We consider only episodes that happened between August 1830 and December 1832. For each of these episodes, we manually match the parish of the riot to the historical map of English and Welsh parishes (Burton *et al.* 2004). On this map, we identify the location of these riots with the county (variable *GAZ_CNTY*) and either the name of the parish (variable *PAR*) or the name of the place (variable *PLA*). In our baseline results, we use a variable that contains every episode listed in the database, irrespective of the nature of the protest.

1821 Population. Total number of people in a parish comes from the 1821 Census of England (Southall *et al.* 2004). The original variable in the database is *TOT_POP*: ‘Total number of inhabitants’ in 1821. Data come at the parish level: we merge it manually to the historical map of English and Welsh parishes using the county (variable *ANC_CNTY*) and parish (variable *ANC_PAR*) reported in the Census. We use the natural logarithm of this variable in all regressions.

Share of families in agriculture in 1821. We construct this variable with data from the 1821 Census of England (Southall *et al.* 2004) as the number of families chiefly employed in agriculture (variable *FAMAGRI*) divided by the total number of families in the parish. The total number of families is the sum of three variables: *FAMAGRI*, *FAMTRADE* (families chiefly employed in trade) and *FAMOTHER* (families chiefly employed in other activities). Census data come at the parish level and we merge it to the historical map of English and Welsh parishes as we did with the 1821 population.

Sex ratio in 1821. We compute the sex ratio with data from the 1821 Census as the total number of men (variable *TOT_MALE*) divided by the total number of women (variable *TOT_FEM*). Census data come at the parish level and we merge it to the historical map of English and Welsh parishes as we did with the 1821 population. We use the natural logarithm of this variable in all regressions.

Parish area. The total area of the parish (in square kilometers) is calculated with ArcGIS based on the map of historical parishes of England and Wales we produced after aggregating using the map of Burton *et al.* (2004). We use the natural logarithm of this variable in all regressions.

Distance to Elham, location of the first Swing riot. We construct this variable as the distance of the centroid of every parish in our map to Elham, the parish that saw the first

episode of the Swing riots according to Griffin (2012). We use the natural logarithm of this variable in all regressions.

Distance to closest city with a newspaper. To construct this variable, we first determine which of the newspapers stored on the *British Newspaper Archive* was in print between 1800 and 1830. Next, we manually geo-code the cities in which these newspapers were printed. We then calculate the distance of the centroid of every parish in our map to each of these cities. Finally, we keep only the distance to the closest city. We use the natural logarithm of this variable in all regressions.

Abnormal precipitation in the spring (summer) of 1830. We source historical precipitation from Pauling *et al.* (2006). They used documentary evidence and natural proxies to prepare a database with seasonal precipitation for the period 1500-1900 over a 0.5×0.5 degrees grid covering Europe (approximately 55.5×55.5 km). To construct abnormal precipitation in the spring (summer) of 1830 across England and Wales, we take average spring (summer) precipitation in 1830 and subtract the average spring (summer) precipitation in the years 1800-1828. We do this for every cell that covers the British Isle, obtaining a new raster with the abnormal precipitation in the spring (summer) of 1830. Next, we resample this raster on a finer grid of 88.8×88.8 meters with the "nearest" method, and we superimpose it to our historical map of English and Welsh parishes described above. For every cell of the raster we take its centroid and assign it to the parish where the centroid falls. Finally, for every parish we calculate the average abnormal precipitation in the spring (summer) of 1830 of every cell that falls inside the parish.

Abnormal temperature in the fall 1830. We source historical temperature from Luterbacher *et al.* (2004). They used documentary evidence and natural proxies to prepare a database with seasonal temperature for the period 1500-1900 over a 0.5×0.5 degrees grid covering Europe (approximately 55.5×55.5 kilometers). To construct abnormal temperature in the fall of 1830 across England and Wales, we follow the same procedure described for abnormal precipitation. We take average fall temperature in 1830 and subtract the average fall temperature in the years 1800-1828. We do this for every cell that covers the British Isle, obtaining a new raster with the abnormal fall temperature of 1830. Next, we resample this raster on a finer grid of 88.8×88.8 meters with the "nearest" method, and we superimpose it to our historical map of English and Welsh parishes described above. For every cell of the raster we take its centroid and assign it to the parish where the centroid falls. Finally, for

every parish we calculate the average abnormal temperature in the fall of 1830 of every cell that falls inside the parish.

Share of land enclosed. We source data on enclosures from Gonner (1912). In the tables on pages 270-278, Gonner reports information on the percentage of land in commons that was enclosed before 1870. He collected information across 340 'registration districts' covering 7,019 parishes and 68 percent of England's area. In order to estimate the percentage of land enclosed *before* the Swing riots, we combine the information on this table with information from the table on page 279-281 of the same book. In this second table, Gonner reports the share of land in commons enclosed in each decade between 1760 and 1870 for every county in England and Wales. We estimate the share of land enclosed in 1820 by multiplying district-level enclosures in 1870 with the proportion of enclosures that happened before 1820 in the county of every district. We use the registration district reported in the 1821 Census to match each parish to its registration district. The parishes in the registration districts of Biggleswade (Bedford), Billericay, Colchester, Ongar, Romford (Essex) and Market Harborough (Leicester) have the median level of enclosure: we define parishes with 'high' enclosures those parishes with more than this level of enclosures.

Potential yield of wheat with intermediate (low) inputs. We construct potential yield of wheat for each parish by combining data from the Food and Agriculture Organization Global Agro-Ecological Zones database (FAO-GAEZ) and the map of English and Welsh parishes. We use the potential yield for summer wheat computed under the assumption of intermediate (low) inputs and rain-fed irrigation. The original data is a raster that covers the entire land mass of the Earth on a grid of about 9.25×9.25 kilometers. We first resample the raster on a finer grid of 88.8×88.8 meters with the "nearest" method. Next, we superimpose the raster to our historical map of English and Welsh parishes described above, and for every cell of the raster we take its centroid and assign it to the parish where the centroid falls. Finally, for every parish we take the average potential yield of all the cells that fall inside the parish. We use the natural logarithm of these variables in all regressions.

Accumulation flow. We source the *accumulation flow* from the HydroSHEDS database, prepared by Lehner, Verdin and Jarvis (2008). They use elevation data from the Shuttle Radar Topography Mission at the 3 arc-second resolution to derive accumulation flow on a global, 15 arc-seconds grid (approximately 462.5×462.5 meters). The accumulation flow captures the amount of upstream area that drains into each cell of this grid, and it is calculated by counting the number of upstream cells that drain water into a target cell. To assign the

average accumulation flow to each parish in England, we first resample the raster on a finer grid of 88.8×88.8 meters with the "nearest" method. Next, we superimpose the raster to our historical map of English and Welsh parishes described above, and for every cell of the raster we take its centroid and assign it to the parish where the centroid falls. For every parish we take the average accumulation flow of all the cells that fall inside the parish. We resample the raster on a finer grid of 88.8×88.8 meters with the "nearest" method. Next, we superimpose the raster to our historical map of English and Welsh parishes described above, and for every cell of the raster we take its centroid and assign it to the parish where the centroid falls. Finally, for every parish we take the average accumulation flow of all the cells that fall inside the parish. We use the natural logarithm of this variable in all regressions.

Relative unemployment in 1834. We collect data on winter and summer unemployment from the Appendix B.1 of the "Poor Law Report" of 1834.³⁶ The report is a Parliamentary inquiry that collects information on a selected sample of parishes across England and Wales. Figure C8 shows the questionnaire and the answers provided by two parishes. Officials surveyed a total of 1,391 parishes, and recorded the answers provided by local informants. Not all of these places provided valid answers to every question and we have valid unemployment data for 618 parishes. To reconstruct parish-level unemployment, we digitize the answers of question 5 and 6.³⁷ Question 5 reads: 'number of agricultural labourers in your parish?'; question 6 reads: 'number of labourers generally out of employment, and how maintained in summer and in winter?' We construct unemployment as number of labourers out of employment divided by the total number of labourers: we do this separately for winter and for summer and we set to missing 6 parishes where unemployment is above 100 percent. We construct relative unemployment as the difference between winter and summer unemployment.

Poor law generosity. We define generosity of a parish based on data from the "Poor Law Report" of 1834. From the report, we digitized the population in 1801 (first entry of question A on the questionnaire) and *Poor Rates* collected in 1803 (first entry of question B on the questionnaire). We define the generosity of a parish as total value of poor rates in 1803 divided by the 1801 population in the parish. The median parish in terms of generosity is

³⁶ Full title: *Report from his Majesty's commissioners for inquiring into the administration and practical operation of the Poor Laws.*

³⁷ Officials were sent to survey parishes in 3 different waves between 1833 and 1834, and the questionnaire they asked varied slightly between these waves. Question 5 and 6 in the first two issues became question 6 and 7 in the 3rd issue. The content of the answers did not change.

Doddington in Cambridgeshire, which collects 0.6 pounds per capita; we define as ‘generous’ every parish that provides support above this level.

Distance to closest manufacturing city. We consider 15 manufacturing centers in 1821: Bristol in Gloucestershire, Blackburn, Bolton-le-Moors, Liverpool, Manchester, Prestwich, Rochdale, Whalley in Lancashire, London, Norwich in Norfolk, Birmingham in Warwickshire and four cities in Yorkshire, West Riding: Bradford, Halifax, Sheffield and York. We identify these cities by selecting every parish which in 1821 counted more than 45’000 inhabitants. This yielded a list of 25 parishes, from which we excluded 10 parishes that are today part of Greater London.³⁸ In the 1821 census, these centers had on average 82 percent of the families employed in trade and less than 5 percent employed in agriculture. In the rest of English parishes, 21 percent of families were chiefly employed in trade and 68 percent in agriculture. We use the coordinates of the centroid of these cities and of every parish in England to construct the distance of every parish to the closest of manufacturing center. We then divide the sample into two groups: above and below the median distance to these cities. The median parish in terms of distance to manufacturing cities is Winchfield in Hampshire which lies 62 km from London.

Agricultural machines: 1832-1853. We collect information on agricultural machine in use in the 20 years following the riots from the *British Newspaper Archive*. We first select 8 years after the riots: 1832, 1835, 1838, 1841, 1844, 1847, 1850 and 1853. Next, we search newspapers published in these years farm advertisements that mention either ‘threshing machines,’ or ‘mowing machines.’ We read each of these advertisements in full, determining whether they are relevant for our research, and then locate them on the map of Burton *et al.* (2004). The measure of agricultural machine diffusion is the sum of the threshing machine and mowing machine we found in each parish.

Patents: 1813-1843. We digitize every patent registered in England between the 20th of November 1813 and the 15th of June 1843 from Woodcroft (1854). This publication reports, for every patent that was registered in England, the title, the date of registration, the name and occupation of the inventor(s) and the place where they lived. We digitize this information and locate the parish in which each of these inventors were living at the time of the registration. Whenever more than one inventor claims one patent, we assign to each of the parishes of

³⁸ These are: Westminster, St Leonard Shoreditch, St George Hanover Square, St Matthew Bethnal, St George in the East, St Dunstan Stepney, St Giles in the Fields and St George Bloomsbury, Lambeth, St Pancras, St Marylebone. Considering these places as “manufacturing centers” changes nothing, as they lie close to London, which is one of the 15 manufacturing centers.

these inventors a value equal to one divided by the numbers of inventors. We divide patents into two groups: those registered before the 31st of December 1829 and those registered between the 1st of January 1833 and the 15th of June 1843. We do not consider the patents registered during the years 1830-32 to avoid confounding the direct effect of riots on patenting activity.

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B Additional results

B.1 Productivity of threshing machines

In this section, we attempt to quantify the productivity gains of threshing machines relative to manual labor. Contemporary observers recognized quickly the productivity gains offered by threshing machines (Donaldson 1794, p. 20; Batchelor 1813, p.210).³⁹ However, there exists no systematic analysis of productivity for the machines in use in 1800, nor are we aware of any attempt to determine the productivity of machines operated with different power sources.

We source information on machine productivity from the county surveys of the *General View of Agriculture*. Sir John Sinclair commissioned the *General Views* as president of the Board of Agriculture in the 1790s, and professional agronomists prepared these documents under the supervision of Arthur Young. Separate volumes cover each county and the commission surveyed most counties twice: once in 1790s and a second time in the 1810s. We collect all editions covering English counties: a total of 38 separate volumes.

All of the *General Views* published in the 1810s, and several of those that appeared in the 1790s contain a chapter on threshing machines. We read these chapters in full, and collect all information that is useful to determine the productivity of these machines. The officials who prepared these chapters toured the English countryside and took detailed notes of every threshing machine they found. A typical entry in this chapter lists owner and location of the machine, as well as material and shape of each different component. It also reports the mode of operation, the number of men, women and children required to move it and the average quantity of wheat that the machine could thresh in a given amount of time.

We find 121 separate machines in the General Views. To calculate productivity we require information on wheat threshed per unit of time, number of people needed to operate the machine and the main source of power for the machine. Under these constraints, we are able to calculate productivity for 24 horse-powered machines, 3 water-powered machines and a single machine operated by hand. We show the productivities on Figure B1, where we contrast them with the average productivity of a worker threshing with a flail, as estimated by Clark (1987). Our data is too sparse to provide precise measures of relative productivity. However, the differences are stark, and they suggest that horse-powered threshing machines may have been 5 times more productive than manual threshing, and water-powered threshing

³⁹ In the 1794 General View of Banffshire, Donaldson notes: “Threshing-mills have also been introduced of late, and the advantages of them seem to be so well known and established, that there is no doubt of their soon coming into general use” (Donaldson 1794, p. 20).

machines more than 10 times more productive. The estimates also suggest that threshing machines operated with human force did not save as much as other types of machines, and did not offer labor savings.⁴⁰ Available information also suggest that water-power threshing machines were significantly more productive than horse-powered, possibly by a factor of two.

Figure B1. Threshing machine productivity relative to manual threshing. Data for threshing machine comes from the county surveys of the *General View of Agriculture*. Sample size is 3 water-powered threshing machines, 24 horse-powered threshing machines and 1 men-powered threshing machine. We only consider wheat threshed and convert every quantity in bushels. We assume an 8-hours day of work when the surveys report average grains threshed per day. When farmers used women or children to operate these machines we assume that both women and children cost half of what a man does. This is likely to bias productivity downwards, as figures from the Poor Law Report suggest that on average a woman (child) was paid 37.5% (25%) of what men were paid. Average productivity of manual threshers comes from Clark (1987) who uses primary sources to estimate average productivity of English threshers in 1800s.

⁴⁰ We only found two hand-powered threshing machines, both in Berkshire (Mavor 1813). On the first, the informant observes that: “This machine in its present form is evidently more curious than useful. Without horses it is impossible to produce a saving.” About the second, he notes: “The only saving Mr. Tull finds in its use is in making reed for thatching.” Available information allows to estimate productivity only for one of these two machines.

B.2 Plausibility of the instrument

The validity of our instrumental variable estimates relies on the assumption that the interaction between wheat suitability and availability of water power affects the riots only because it made it more convenient to adopt a threshing machines. In section 3.b, we argue that controlling for wheat suitability and accumulation flow separately makes this assumption plausible, and Table 3 confirms that once we control for these two variables, the interaction is uncorrelated with most pre-existing characteristics. In this section we show that even relatively large deviations from the exclusion restriction would not invalidate our conclusions.

To make this point, we apply the union of confidence interval method proposed by Conley, Hansen and Rossi (2012), and estimate lower and upper bounds for the two-stages least squares coefficient of *Machines* on *Riots* when the instrument $\log acc_p \times Yield^{wheat}_p$ is allowed to have a direct effect on riots in equation (1). We allow the direct effect to take values in the interval $\delta \in [-0.1, 0.2]$: we plot these values on the horizontal axis of Figure B2 in this appendix, and for each value we show on the vertical axis the lower and upper bounds of the IV coefficient of *Machines* on *Riots*. The graph shows that for any direct effect of the instrument on the riots that is smaller than 0.1 the effect of machines on riots remains positive and significant.

To gauge the magnitude of this effect, we turn to the reduced form results: in columns 4 through 6 of Table 5, we find that the coefficient of the instrument on the riots is around 0.2 in all specifications. Thus, only if more than half of this effect can be attributed to the direct effect of the instrument on the riots will the significance of the machines on riots disappear. We find this level of direct effect to be unlikely, also because in each of these regressions we are controlling for the level of wheat suitability and accumulation flow separately.

Figure B2. Union of confidence intervals for different values of the violation of the exclusion restrictions (δ). The test is run on the most demanding specification of the IV regression, the one that includes all controls and the 5 regions fixed effects. See Conley, Hanson and Rossi (2012) for details of the methodology.

B.3 Historical weather in England and Wales

FAO researchers compute potential yield for wheat based on soil characteristics, weather records and an agronomic model that assumes the use of a specific input mix. One possible concern with this measure has to do with the weather data used for these calculations. FAO researchers use average weather conditions for the period 1961-1990, which may be different from weather conditions that affected potential yield of wheat at the beginning of 1800.

To determine how much weather changed over the last 200 years we perform two separate tests. In the first one, we use historical records of temperature and precipitation on a $0.5^\circ \times 0.5^\circ$ grid that covers Europe⁴¹ to compare average temperature and precipitation in the period 1801-1830 and 1961-1990. The four panels of figure B3 plot average temperature in the years 1801-1830 (on the x-axes) against the average temperature in the period 1961-1990 (on the y-axes) for the four seasons of the year across the 135 cells that cover England and Wales. The four panels of figure B4 repeat the exercise for precipitation, and table B1 reports correlations for the two variables. The data suggest that weather did not change much across England in the last 200 years. In any given season, cells that were on average colder (wetter) in 1800-1830, are still so in 1960-1990. Moreover, the correlation between the two periods of average temperature (precipitation) is always above 99% (98%).

Correlation between weather in 1801-1830 and weather in 1961-1990.		
	Temperature	Precipitation
Winter	99.78%	99.48%
Spring	99.45%	98.68%
Summer	99.50%	99.13%
Fall	99.95%	98.69%
Observations	135	135

Table B1. Correlation between average weather in the period 1801-1830 and average weather in 1961-1990. The first column reports the correlation for temperature and the second column for precipitation. All correlations are significant at <0.001 level.

⁴¹ Luterbacher *et al.* (2004) and Xoplaki *et al.* (2005) describe the construction of temperature records, and Pauling *et al.* (2006) describe the construction of precipitation data.

Temperature

Note: temperature is measured in °C.

Figure B3. The figure plots average temperature across England and Wales in the period 1801-1830 (on the x-axes) against the average temperature in the period 1961-1990 (on the y-axes) for the four season of the year. Source: Luterbacher *et al.* (2004) and Xoplaki *et al.* (2005).

Precipitation

Note: precipitation is measured in mm.

Figure B4. The figure plots average precipitation across England and Wales in the period 1801-1830 (on the x-axes) against the average temperature in the period 1961-1990 (on the y-axes) for the four season of the year. Source: Pauling *et al.* (2006).

One possible concern with this analysis is that historical weather data are estimated rather than observed. Moreover, data are available only for separate seasons, not for separate months. To address this concern we perform a second test, using the historical series maintained by the Hadley Centre at the UK Meteorological Office. The office collects monthly precipitation records across England and Wales since 1700. Thus, it allows to compare monthly records obtained from actual observations. We use these data to compare the average monthly precipitation during 1801-1830 with the average monthly precipitation in the years 1961-1990. Figure B5 plots these averages for the two periods along with their 95 percent intervals.

The graph confirms that precipitation did not change much in England over the last 200 years: average yearly precipitation is not significantly different in the 30 years used by FAO relative to the 30 years leading to the Swing riots. Unfortunately, precipitation is the only weather variable for which the Hadley Centre preserves historical records. Moreover, these records are admittedly noisy, as they are available only for the whole England. Nevertheless, the analysis of these records, together with the previous analysis, suggest that weather in 1961-1990 is a valid proxy for weather at the beginning of 1800.

Figure B5. The figure plots the average monthly precipitation across England and Wales over the period 1801-1830 (in orange) and over the period 1961-1990 (in green). The bar identify 95 percent intervals. The average yearly precipitation in 1801-1830 was 891mm: this is not significantly different from the average yearly precipitation in 1961-1990, which was 915m (difference: 23,96 mm, s.e.: 24.72).

Source: the Hadley Centre at the Meteorological Office: <http://www.metoffice.gov.uk/hadobs/hadukp/>.

C Additional figures and tables

C.1 Figures

Figure C1. Number of episodes associated to the ‘Swing’ riots. In green we plot the number of attacks on threshing machines. In orange, we plot all other riots that were associated to Swing: including threatening letters and fires. Source: Holland (2005).

SOUTH OF DEVON.

On WEDNESDAY, the 5th day of AUGUST next, by
two o'clock in the afternoon,
AN AUCTION WILL BE HELD,
At the *Castle Inn*, in *Dartmouth*, for SELLING (in
one Lot),
THE undermentioned PREMISES,
namely,
The Fee-Simple and Inheritance of and in the
BARTON of WASHBURN,
Consisting of an excellent Farm House, with a
Cider-Press, Threshing Machine, worked by water,
Barns, Stables, Linbays, and other convenient Out-
houses, and about 212 acres of very superior Mea-
dow, Orchard, Pasture, and Arable Land (be the
same more or less), let to a good and responsible
tenant.
This Property is situate in the parish of *Ashpring-*
ton, about three miles from the excellent market
town of Totnes, six from Dartmouth, eight from
Kingsbridge, and within one mile of lime-kilns.
Also, for Selling the Fee-Simple of all those three
FIELDS, called *HERNAFORD PARKS*, containing about
16 acres, let with and adjoining the aforesaid Barton,
part of the Manor or Lordship of Washburn, and
situate in the parish of *Harberton*.
Also, the Fee-Simple of all that FLOUR or GRIST-
MILL, with 2 acres and 12 perches of Land adjoining,
situate near Washburn Village, and now occupied
by Mr. Coyte, miller.
Also, the Reversionary Estate and Interest in
all those three TENEMENTS, known by the name
of JAY'S, AVERY'S, and WASHBURN MILL TENE-
MENTS, parts of the aforesaid Manor of Washburn.
The Estate is fertile, compact, near manure and
good markets, and easily cultivated, is in a respecta-
ble neighbourhood, and forms altogether a most de-
sirable Property. One half of the purchase-money
may remain on security of the Premises.
Mr. WILLIAM MANNING, the tenant on the Barton,
or Mr. COYTE, at the Mill, will show the Premises ;
and all further particulars may be obtained at the
Office of Mr. HOCKIN, Solicitor, Dartmouth.
Dated 1st July, 1829.

Figure C2. Example of an advertisement for a "threshing machine". On July the 1st, 1829, the *Sherborne Mercury* advertised the sale of a farm in the parish of Ashprington (Devon). We count this advertisement as an indication that threshing machines are used in this parish because the farm includes a 'threshing machine' among the assets that went on sale. Source: *British Newspaper Archive*.

WM. FORGE, Threshing Machine Maker, WITHAM, near the North Bridge, Hull, begs leave to inform the gentlemen farmers and others, that he makes One, Two, Three, and Four-horse Machines on the newest and most improved plan.—W. F. flatters himself, from long experience in the above line, he can make them to the satisfaction of those who may please to favour him with their orders: he will also ensure to make the Machines to thresh, dress, and shake off the Straw in the best manner; if not, they may be returned at his expence.—*.* The lowest price is 35 guineas.

The following are the names of a part of the gentlemen who have already experienced their utility, and of whom enquiry may be made:—

Machines.	Machines.
Mr. Watson, West Ella.....2	Mr. Johnson, Wistow.....1
Mr. Hudson, Newington.....1	Mr. Copland, ditto.....1
Mr. Thompson, Skidby.....2	Mr. Varley, ditto.....1
Mr. Hornby, Riston.....1	<i>Lincolnshire.</i>
Mr. Duggleby, Beswick.....1	Mr. Graham, Wisby.....1
Messrs. Jacksons, Middleton2	Mr. Johnson, Redbourn.....1
Mr. Richardson, Sunk Island2	Rev. Mr. Curtis, Branston....1
George Knowsley, Esq.	Rev. Mr. Dymoke, Scri-
Cottingham.....2	velsby.....1
Mr. Screwtun, Little Weton2	Rev. Messrs. Roe & Smith,
Mr. Dalton, Kirk Ella.....1	Boston West Fen.....1
Mr. Craythorn, Walkington1	Messrs. Oldham & Keal, do. 1
Mr. Pickering, Willoughby 1	Mr. Marston, Swineshead...1
Mr. Carrick, N. Fridingham 1	Messrs. Hall & Co. Stow Park1
Mr. Eastwood, Marton.....1	Mrs. Gibbeson, Lincoln.....1
Mr. Grunshaw, Marfleet.....1	<i>Nottinghamshire.</i>
Mr. Wallis, Bentley.....1	Mr. Raynor, Drinsey Nook...1
Mr. Binnington, Ferriby1	Mr. Smith, East Markham...1
Mr. Tindle, Keyingham.....1	Mr. Becket, Bestwood Park..1
Mr. Brankley, Humbleton...1	Mr. Johnson, Preston.....1
Mr. Smiles, Oustwick.....1	

Orders taken by letters, addressed Wm. Forge, as above.

Figure C3. Example of an advertisement. On February the 2nd, 1808, the *Stamford Mercury* published the notice of William Forge, a threshing machine maker, who advertised his product by suggesting to contact one of his past customers. We code each of the parishes listed above as parishes in which at least one threshing machine is in operation. Source: *British Newspaper Archive*.

Figure C4. Number of advertisements for ‘threshing machines’ that appeared on British newspapers: 1800-1830. Source: *British Newspaper Archive*.

Figure C5. Geographical distribution of ‘threshing machines’ published by British newspapers, and mentioned in the *General Views of Agriculture* during the years 1800-1830. Red dots identify parishes with threshing machines, and dots are drawn so that they are proportional to the number of threshing machine we find in a given parish. Blue dots identify cities that printed at least one of the newspaper from which we collect our advertisements. Source: *British Newspaper Archive*.

Figure C6. Accumulation flow in England. Source: Lehner, Verdin and Jarvis (2008).

Figure C7. Potential yield attainable for wheat with intermediate level of agricultural inputs and no artificial irrigation (in tons per hectare). Source: FAO-GAEZ (2015).

QUESTIONS, &c.
PART FIRST, Comprising Extracts (A.) (B.) (C.) from
Parliamentary Documents, and QUESTIONS 1 to 13.

NAME and COUNTY of Parish or Township to which
the Answers refer?

SIGNATURE of RESPONDENT?

(A.)—POPULATION 1801—1811—1821—1831.

(B.)—POOR'S RATES, 1803—1813—1821—1831.

(C.)—EXPENSE per head on the whole Population in
1803—1813—1821—1831, estimated by the
nearest Census.

5.—NUMBER of Agricultural Labourers in your Parish?—

6.—NUMBER of Labourers generally out of Employment, and how maintained in Summer and Winter?—

County of CAMBRIDGE—continued.

ANSWERS.

HOLY TRINITY (ISLE OF ELY.) (3)

Charles Mosely, } Overseers.
Edward Stevens,

(A.)—2,721—2,285—3,438—4,325.

(B.)—£1,719—£2,820—£2,596—2,850.

(C.)—12s. 7d.—£1. 4s. 9.—15s. 1d.—13s. 2d.

5.—170, besides a considerable number of watermen and porters.

6.—Summer, average 6; Winter, average 50, maintained by the parish.

TRUMPINGTON. (2)

George Cuming,
late Assistant Overseer.

(A.)—494—508—540—722.

(B.)—£388—£366—£383—£372.

(C.)—15s. 8d.—14s. 4d.—14s. 2d.—10s. 8d.

5.—Number above 20, 82; under 20 and above 10, 50 and upwards; total, 132.

6.—Summer, 6 on the parish funds; Winter, 12 ditto.

Figure C8. Sample page from the Poor Law Commission Report for two parishes, Holy Trinity and Trumpington, in Cambridgeshire. We construct winter and summer unemployment by dividing the answers to question 6 by the answer of question 5. We approximate generosity of poor relief with the value of poor's rates in 1803 (first entry of question B) divided by the 1801 population (first entry of question A).

C.2 Tables

Dep. var.:	Winter unemployment – summer unemployment		
Threshing machines	0.021 (0.008)	0.016 (0.008)	0.017 (0.008)
log(1821 population)		0.013 (0.003)	0.017 (0.006)
log(Parish area)			-0.008 (0.006)
% families in agriculture			-0.021 (0.023)
log(sex ratio)			0.001 (0.038)
log(distance to Elham)			-0.036 (0.009)
log(dist. To city with newspaper)			0.014 (0.005)
Constant	0.054 (0.004)	-0.032 (0.021)	0.226 (0.061)
Observations	618	618	618
R-squared	0.006	0.026	0.093

Table C1. Threshing machines and the labor market. The dependent variable in columns 1-3 is winter unemployment rate minus summer unemployment rate. Robust standard errors in parentheses.

Dep. var.:	=1 if at least one Swing riot happened in parish						Number of Swing riots		
Estimation method:	Linear probability model			Probit			Poisson		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Threshing machines	0.084 (0.015)	0.057 (0.015)	0.048 (0.015)	0.084 (0.015)	0.057 (0.015)	0.048 (0.015)	0.371 (0.061)	0.194 (0.066)	0.136 (0.068)
log(1821 population)	0.065 (0.003)	0.054 (0.005)	0.052 (0.005)	0.065 (0.003)	0.054 (0.005)	0.052 (0.005)	0.520 (0.022)	0.474 (0.053)	0.441 (0.053)
log(Parish area)		0.031 (0.005)	0.031 (0.005)		0.031 (0.005)	0.031 (0.005)		0.470 (0.065)	0.461 (0.065)
% families in agriculture		-0.037 (0.017)	-0.042 (0.017)		-0.037 (0.017)	-0.042 (0.017)		0.068 (0.206)	-0.026 (0.210)
log(sex ratio)		-0.042 (0.019)	-0.038 (0.019)		-0.042 (0.019)	-0.038 (0.019)		-0.473 (0.265)	-0.553 (0.268)
log(distance to Elham)		-0.021 (0.013)	0.004 (0.012)		-0.021 (0.013)	0.004 (0.012)		0.057 (0.074)	0.020 (0.075)
log(dist. to newspaper)		-0.011 (0.005)	-0.013 (0.006)		-0.011 (0.005)	-0.013 (0.006)		-0.020 (0.053)	-0.008 (0.057)
Constant	-0.261 (0.018)	-0.165 (0.071)		-0.261 (0.018)	-0.165 (0.071)		-4.633 (0.144)	-8.070 (0.838)	
Region fixed effects (5)			✓			✓			✓
Observations	10,099	10,099	10,099	10,099	10,099	10,099	10,099	10,099	10,099
R-squared	0.059	0.120	0.129						
Pseudo R-squared				0.059	0.120	0.129	0.102	0.215	0.228

Table C2. Robustness to different estimation methods. Columns 1-3: linear probability model; Columns 4-6: probit model; Columns 7-9: Poisson regression. Dependent variable is: Columns 1-6: a dummy indicator for whether Swing riots happened in the parish; Columns 7-9: number of Swing riots in a parish. Robust standard errors are in parentheses.

Dep. var.:		Number of Swing riots							
Sample of parishes:	All	Distance to manuf. city		All	Distance to manuf. city		All	Distance to manuf. city	
		Above median	Below median		Above median	Below median		Above median	Below median
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. OLS									
Threshing machines	0.288 (0.067)	0.406 (0.104)	0.120 (0.060)	0.269 (0.067)	0.390 (0.102)	0.091 (0.060)	0.217 (0.067)	0.312 (0.103)	0.063 (0.059)
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Parish characteristics				✓	✓	✓	✓	✓	✓
Region F.E.s (5)							✓	✓	✓
Observations	10,099	5,049	5,050	10,099	5,049	5,050	10,099	5,049	5,050
R-squared	0.054	0.066	0.046	0.092	0.118	0.074	0.100	0.135	0.077
p close = distant		0.017			0.012			0.037	
Panel B. Reduced form									
log(pot. yield wheat) × log(accumulation flow)	0.218 (0.082)	0.295 (0.095)	0.096 (0.075)	0.196 (0.052)	0.255 (0.056)	0.112 (0.072)	0.212 (0.045)	0.268 (0.047)	0.128 (0.073)
log(potential yield wheat)	-0.105 (0.318)	-0.340 (0.343)	0.617 (0.310)	-0.242 (0.197)	-0.490 (0.187)	0.365 (0.291)	-0.321 (0.163)	-0.586 (0.144)	0.299 (0.296)
log(accumulation flow)	-0.294 (0.109)	-0.370 (0.123)	-0.142 (0.100)	-0.257 (0.069)	-0.314 (0.071)	-0.157 (0.098)	-0.277 (0.059)	-0.330 (0.058)	-0.179 (0.098)
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Parish characteristics				✓	✓	✓	✓	✓	✓
Region F.E.s (5)							✓	✓	✓
Observations	10,099	5,049	5,050	10,099	5,049	5,050	10,099	5,049	5,050
R-squared	0.061	0.076	0.055	0.092	0.115	0.078	0.102	0.135	0.081
p close = distant		0.099			0.118			0.107	

Table C3. Mechanism: Distance to closest manufacturing center. Panel A: OLS estimates; Panel B: reduced form estimates. The table reports results after splitting the sample according to the distance to the closest manufacturing center. Columns 1, 4 and 7: baseline results (full sample); columns 2, 5 and 8: results for 5049 parishes below the median parish in terms of distance to manufacturing center; columns 3, 6 and 9: results for 5050 parishes above median parish. The median parish is Winchfield in Hampshire which lies 62 km from London. Robust standard errors are in parentheses.

Dep. var.:	Number of Swing riots								
Sample of parishes:	All	High enclosures	Low enclosures	All	High enclosures	Low enclosures	All	High enclosures	Low enclosures
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. OLS									
Threshing machines	0.328 (0.081)	0.446 (0.110)	0.116 (0.099)	0.312 (0.081)	0.409 (0.111)	0.105 (0.099)	0.233 (0.082)	0.326 (0.112)	0.053 (0.101)
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Parish characteristics				✓	✓	✓	✓	✓	✓
Region fixed effects (5)							✓	✓	✓
Observations	7,019	3,468	3,551	7,019	3,468	3,551	7,019	3,468	3,551
R-squared	0.077	0.082	0.075	0.085	0.096	0.083	0.099	0.114	0.091
p-value high = low		0.027			0.041			0.070	
Panel B. Reduced Form									
log(pot. yield wheat) × log(accumulation flow)	0.669 (0.186)	0.668 (0.194)	0.683 (0.453)	0.701 (0.186)	0.714 (0.193)	0.710 (0.449)	0.672 (0.180)	0.663 (0.187)	0.809 (0.453)
log(potential yield wheat)	0.649 (0.565)	0.373 (0.578)	1.651 (1.414)	0.463 (0.560)	-0.244 (0.588)	1.876 (1.444)	0.133 (0.554)	-0.727 (0.586)	1.392 (1.488)
log(accumulation flow)	-0.925 (0.254)	-0.929 (0.266)	-0.937 (0.620)	-0.964 (0.254)	-0.990 (0.265)	-0.967 (0.615)	-0.921 (0.245)	-0.914 (0.257)	-1.102 (0.620)
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Parish characteristics				✓	✓	✓	✓	✓	✓
Region fixed effects (5)							✓	✓	✓
Observations	7,019	3,468	3,551	7,019	3,468	3,551	7,019	3,468	3,551
R-squared	0.080	0.077	0.084	0.088	0.090	0.094	0.102	0.110	0.102
p-value high = low		0.975			0.994			0.765	

Table C4. Mechanism: Enclosures and unrest. Panel A: OLS estimates; Panel B: reduced form estimates. The table reports results after splitting the sample according to 1820 level of enclosures. Columns 1, 4 and 7: baseline results (all parishes with enclosure information); columns 2, 5 and 8: results for 3505 parishes above the median parish in terms of enclosures; columns 3, 6 and 9: results for 3514 parishes below the median parish. Robust standard errors are in parentheses.

Dep. var.:	Number of Swing riots								
Sample of parishes:	All	Non-generous	Generous	All	Non-generous	Generous	All	Non-generous	Generous
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
<i>Panel A. OLS</i>									
Threshing machines	0.371 (0.195)	0.455 (0.259)	0.172 (0.289)	0.358 (0.191)	0.407 (0.257)	0.261 (0.287)	0.308 (0.195)	0.389 (0.256)	0.207 (0.298)
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Parish characteristics				✓	✓	✓	✓	✓	✓
Region fixed effects (5)							✓	✓	✓
Observations	1,333	667	666	1,333	667	666	1,333	667	666
R-squared	0.061	0.097	0.106	0.153	0.171	0.160	0.156	0.176	0.163
<i>p</i> -value generous = non-generous		0.466			0.706			0.642	
<i>Panel B. Reduced Form</i>									
log(pot. yield wheat) × log(accumulation flow)	0.253 (0.118)	0.209 (0.073)	-0.513 (0.848)	0.221 (0.086)	0.190 (0.060)	-0.284 (0.792)	0.278 (0.090)	0.254 (0.073)	-0.217 (0.828)
log(potential yield wheat)	-0.067 (0.380)	-0.342 (0.219)	7.430 (3.985)	-0.441 (0.293)	-0.589 (0.223)	5.194 (3.738)	-0.653 (0.305)	-0.778 (0.245)	5.305 (3.939)
log(accumulation flow)	-0.352 (0.151)	-0.246 (0.086)	0.692 (1.148)	-0.278 (0.101)	-0.221 (0.067)	0.410 (1.070)	-0.348 (0.106)	-0.294 (0.084)	0.314 (1.118)
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Parish characteristics				✓	✓	✓	✓	✓	✓
Region fixed effects (5)							✓	✓	✓
Observations	1,333	667	666	1,333	667	666	1,333	667	666
R-squared	0.074	0.099	0.122	0.151	0.154	0.167	0.156	0.168	0.169
<i>p</i> -value generous = non-generous		0.396			0.550			0.572	

Table C5. Mechanism: Poor Law generosity and unrest. Panel A: OLS estimates; Panel B: reduced form estimates. The table reports results after splitting the sample according to poor law generosity. Columns 1, 4 and 7: baseline results (all parishes with poor law information); columns 2, 5 and 8: results for 667 parishes below median parish in terms of generosity; columns 3, 6 and 9: results for 666 parishes above the median parish. Median parish collects on average £0.6 per person. Robust standard errors are in parentheses.

Dep. var.:	Threshing machine ads			Number of Swing riots					
Equation:	First stage			Reduced form		Two-stages least squares			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Threshing machines							5.727 (1.371)	4.324 (1.100)	4.858 (1.238)
log(pot. yield wheat-low ins) × log(accumulation flow)	0.047 (0.013)	0.050 (0.015)	0.045 (0.011)	0.267 (0.071)	0.218 (0.044)	0.219 (0.038)			
log(pot. yield wheat- low ins)	-0.059 (0.045)	-0.048 (0.052)	-0.073 (0.034)	-0.278 (0.263)	-0.380 (0.146)	-0.441 (0.118)	0.059 (0.125)	-0.172 (0.135)	-0.084 (0.095)
log(accumulation flow)	-0.018 (0.005)	-0.020 (0.006)	-0.016 (0.004)	-0.111 (0.030)	-0.085 (0.018)	-0.085 (0.015)	-0.008 (0.010)	-0.000 (0.008)	-0.008 (0.009)
log(1821 population)	0.031 (0.003)	0.017 (0.004)	0.015 (0.004)	0.211 (0.014)	0.153 (0.017)	0.146 (0.017)	0.031 (0.042)	0.078 (0.029)	0.074 (0.030)
log(Parish area)		0.022 (0.005)	0.026 (0.005)		0.098 (0.021)	0.103 (0.021)		0.002 (0.036)	-0.024 (0.042)
% families in agriculture		-0.026 (0.016)	-0.044 (0.016)		-0.100 (0.051)	-0.137 (0.050)		0.011 (0.084)	0.078 (0.099)
log(sex ratio)		-0.040 (0.014)	-0.017 (0.014)		-0.122 (0.046)	-0.092 (0.047)		0.048 (0.084)	-0.011 (0.084)
log(distance to Elham)		-0.000 (0.004)	0.064 (0.008)		-0.315 (0.035)	-0.176 (0.045)		-0.315 (0.037)	-0.485 (0.097)
log(dist. to newspaper)		-0.007 (0.006)	-0.008 (0.006)		-0.013 (0.016)	-0.018 (0.018)		0.018 (0.029)	0.021 (0.035)
Region fixed effects (5)			✓			✓			✓
Observations	10,099	10,099	10,099	10,099	10,099	10,099	10,099	10,099	10,099
R-squared	0.021	0.023	0.048	0.062	0.092	0.101			
F-stat excluded instrument	12.5	11.8	18.0						
Rubin-Anderson test (<i>p</i>)							0.000	0.000	0.000

Table C6. Robustness to the definition of wheat suitability. Columns 1-3: first stage regressions; Columns 4-6 reduced form regressions; Columns 7-9: IV regressions. In all regression we use potential yield of wheat calculated under the assumption of ‘low’ level of inputs. Robust standard errors are in parentheses.

Equation:	OLS			Reduced form		
	(1)	(2)	(3)	(4)	(5)	(6)
Threshing machines	0.288	0.269	0.217			
Huber-White robust s.e.	(0.067)	(0.067)	(0.067)			
Conley s.e.: cutoff 20 km	(0.071)	(0.070)	(0.069)			
Conley s.e.: cutoff 50 km	(0.091)	(0.089)	(0.081)			
Conley s.e.: cutoff 100 km	(0.106)	(0.102)	(0.085)			
Clustered s.e.: closest newspaper city	(0.081)	(0.079)	(0.076)			
log(pot. yield wheat) × log(accumulation flow)				0.218	0.193	0.209
Huber-White robust s.e.				(0.082)	(0.052)	(0.045)
Conley s.e.: cutoff 20 km				(0.084)	(0.057)	(0.051)
Conley s.e.: cutoff 50 km				(0.095)	(0.070)	(0.064)
Conley s.e.: cutoff 100 km				(0.099)	(0.080)	(0.074)
Clustered s.e.: closest newspaper city				(0.097)	(0.072)	(0.067)
log(1821 population)	✓	✓	✓	✓	✓	✓
Parish-level characteristics		✓	✓		✓	✓
log(pot. yield) & log(acc. flow)				✓	✓	✓
Region fixed effects (5)			✓			✓
Observations	10,099	10,099	10,099	10,099	10,099	10,099

Table C7. Robustness to spatial correlation. Columns 1-3: OLS estimates; Columns 4-6: reduced form regressions. We report the point estimates and the Huber-Eicker-White robust standard errors on the first two rows (identical to those shown in Tables 2 and 4); standard errors calculated with the Conley (1999) formula on rows 3 through 5 and then those clustered at the level of the closest city with a newspaper.

Dep. var.: Equation:	Number of Swing riots OLS		Number of machine ads First stage		Number of Swing riots Reduced form Two-stages least squares			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Threshing machines	0.216 (0.069)	0.193 (0.069)					4.883 (1.268)	4.818 (1.223)
log(pot. yield wheat) × log(accumulation flow)			0.040 (0.014)	0.043 (0.011)	0.198 (0.056)	0.209 (0.050)		
log(potential yield wheat)			-0.038 (0.051)	-0.067 (0.036)	-0.244 (0.213)	-0.306 (0.181)	-0.058 (0.120)	0.018 (0.101)
log(accumulation flow)			-0.054 (0.019)	-0.056 (0.015)	-0.261 (0.075)	-0.274 (0.066)	0.002 (0.010)	-0.005 (0.009)
Parish-level characteristics	✓	✓	✓	✓	✓	✓	✓	✓
Region fixed effects (5)		✓		✓		✓		✓
Observations	9,355	9,355	9,353	9,353	9,353	9,353	9,353	9,353
R-squared	0.096	0.101	0.021	0.048	0.091	0.100		
F-stat excluded instrument			8.2	15.1				
Rubin-Anderson test (<i>p</i>)							0.000	0.000

Table C8. Robustness to restricting the sample to the parishes within 50 km from the closest newspaper. Columns 1-2: OLS regressions; Columns 3-4: first stage regressions; Columns 5-6: reduced form regression; Columns 7-8: IV regressions. The dependent variable is: Columns 1-2 and 5-8: the number of Swing riots; Columns 3-4: the number of threshing machines. Robust standard errors are in parentheses.

Dep. var.:	Number of Swing riots		Number of machine ads		Number of Swing riots			
Equation:	OLS		First stage		Reduced form		Two-stages least squares	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Threshing machines	0.262	0.211					4.248	4.262
	(0.068)	(0.068)					(1.070)	(1.113)
log(pot. yield wheat) × log(accumulation flow)			0.050	0.054	0.211	0.231		
			(0.014)	(0.012)	(0.063)	(0.056)		
log(potential yield wheat)			-0.071	-0.105	-0.280	-0.360	0.022	0.088
			(0.049)	(0.036)	(0.240)	(0.204)	(0.107)	(0.108)
log(accumulation flow)			-0.066	-0.070	-0.278	-0.304	0.002	-0.004
			(0.019)	(0.016)	(0.085)	(0.075)	(0.009)	(0.009)
Parish-level characteristics	✓	✓	✓	✓	✓	✓	✓	✓
Region fixed effects (5)		✓		✓		✓		✓
Observations	9,153	9,153	9,150	9,150	9,150	9,150	9,150	9,150
R-squared	0.091	0.099	0.021	0.048	0.092	0.101		
F-stat excluded instrument			11.7	20.4				
Rubin-Anderson test (<i>p</i>)							0.001	0.000

Table C9. Robustness to excluding all parishes in Wales. Columns 1-2: OLS regressions; Columns 3-4: first stage regressions; Columns 5-6: reduced form regression; Columns 7-8: IV regressions. The dependent variable is: Columns 1-2 and 5-8: the number of Swing riots; Columns 3-4: the number of threshing machines. Robust standard errors are in parentheses.

Dep. var.: Equation:	Number of Swing riots (August 1830-April 1831)								
		OLS			Reduced form		Two-stages least squares		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Threshing machines	0.224 (0.061)	0.240 (0.061)	0.174 (0.061)				4.391 (1.317)	3.681 (0.960)	3.609 (0.899)
log(pot. yield wheat) × log(accumulation flow)				0.170 (0.068)	0.149 (0.042)	0.161 (0.036)			
log(potential yield wheat)				-0.061 (0.264)	-0.180 (0.158)	-0.244 (0.130)	0.136 (0.119)	-0.047 (0.094)	0.010 (0.075)
log(accumulation flow)				-0.231 (0.090)	-0.198 (0.055)	-0.211 (0.047)	-0.010 (0.008)	-0.003 (0.007)	-0.007 (0.007)
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Parish-level characteristics		✓	✓		✓	✓		✓	✓
Region fixed effects (5)			✓			✓			✓
Observations	10,099	10,099	10,099	10,099	10,099	10,099	10,099	10,099	10,099
R-squared	0.077	0.041	0.084	0.046	0.076	0.085			
Rubin-Anderson test (<i>p</i>)							0.012	0.000	0.000

Table C10. Robustness to timing of the riots: only episodes between August 1830 and April 1831. Columns 1-3: OLS regressions; Columns 4-6: reduced form regression; Columns 7-9: IV regressions. The dependent variable is the number of Swing riots that happened between August 1830 and April 1831. Robust standard errors are in parentheses.

Dep. var.: Equation:	Number of Swing riots OLS		Number of machine ads First stage		Number of Swing riots Reduced form Two-stages least squares			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Threshing machines	0.222 (0.068)	0.163 (0.068)					4.602 (1.301)	4.662 (1.279)
log(pot. yield wheat) × log(accumulation flow)			0.036 (0.015)	0.038 (0.011)	0.165 (0.058)	0.179 (0.049)		
log(potential yield wheat)			-0.017 (0.055)	-0.049 (0.036)	-0.135 (0.229)	-0.216 (0.187)	-0.056 (0.125)	0.014 (0.104)
log(accumulation flow)			-0.047 (0.019)	-0.048 (0.014)	-0.219 (0.077)	-0.235 (0.065)	-0.003 (0.009)	-0.010 (0.009)
Parish-level characteristics	✓	✓	✓	✓	✓	✓	✓	✓
Region fixed effects (5)		✓		✓		✓		✓
Observations	9,758	9,758	9,756	9,756	9,756	9,756	9,756	9,756
R-squared	0.085	0.095	0.020	0.046	0.086	0.097		
F-stat excluded instrument			6.1	12.7				
Rubin-Anderson test (<i>p</i>)							0.004	0.000

Table C11. Robustness to excluding all urban parishes. Urban parishes are defined as parishes with less than 10% of families employed in agriculture in 1821: these are 343 in all, or 3.4% of all parishes. Columns 1-2: OLS regressions; Columns 3-4: first stage regressions; Columns 5-6: reduced form regression; Columns 7-8: IV regressions. The dependent variable is: Columns 1-2 and 5-8: the number of Swing riots; Columns 3-4: the number of threshing machines. Robust standard errors are in parentheses.