

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

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**Abstract:** Can the adoption of labor-saving technology lead to social instability and unrest? We examine a canonical historical case, the so-called ‘Captain Swing’ riots in 1830s Britain. Variouslly attributed to the adverse consequences of weather shocks, the shortcomings of the Poor Law, or the after-effects of enclosure, we emphasize the importance of a new technology – the threshing machine. Invented in the 1780s, it spread during and after the Napoleonic Wars. Using farm advertisements from newspapers published in 66 English and Welsh towns, we compile a new measure of the technology’s diffusion. Parishes with ads for threshing machines had much higher riot probabilities in 1830 – and the relationship was even stronger for machine-breaking attacks. Threshing machines were mainly useful in wheat-growing areas. To establish a causal role for labor-saving technology, we instrument technology adoption with the FAO measure of soil suitability for wheat, and show that this in turn predicts unrest.

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

*JEL Classification:* P16, J21, J43, N33

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# 1 Introduction

Machines increasingly do the work of humans. In the 18<sup>th</sup> and early 19<sup>th</sup> century, spinners and weavers lost their jobs to the Spinning Jenny and the Arkwright frame; more recently, phone operators, clerks, and bookkeepers have been replaced by computers (Autor, Levy, and Murnane, 2003). David Ricardo, writing in 1821, argued that “the substitution of machinery for human labor, is often very injurious to the interests of the class of laborers.”<sup>1</sup> The concern that technological mass unemployment may lead to unrest and political instability has an equally long lineage. Marx famously prophesized that the adoption of new technologies, spread by capitalism, would so immiserize the working class that workers would rise up in revolt.<sup>2</sup> More recently, John M. Keynes (1930) argued “[w]e are being afflicted with a new disease of which some readers may not have heard the name, but of which they will hear a great deal in the years to come — namely, technological unemployment.” Similarly, Wassily Leontief argued that the “specter of technological unemployment ... receded after the demand for skilled workers needed to operate complex (but dumb) machines replaced the demand for unskilled physical labor, is here again. But there are good reasons to believe that this time it will not retreat” (Leontief 1983).

While the possibility of technology-induced unemployment was on the minds of classical political economists,<sup>3</sup> it largely fell out of intellectual favor amongst economists, and modern textbooks routinely dismiss it (Summers 2013). However, 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).<sup>4</sup> There is also good evidence that new agricultural technologies can drive workers out of agriculture (Bustos, Caprettini and Ponticelli, 2016). What is unclear is whether such labor-saving technological change can create political instability and social unrest. Even canonical examples of technology-induced unrest,

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<sup>1</sup> In writing this passage, Ricardo had famously changed his mind, inserting the section in question only in the third (1821) edition. In earlier editions, he had unambiguously argued that technological change benefitted all.

<sup>2</sup> Keynes (1931) in his ‘Economic Possibilities for our Grandchildren’ argued that labor-replacing technological change was a key contributor to unemployment during the Great Depression and predicted the arrival of the 15-hour week.

<sup>3</sup> Mokyr, Vickers and Ziebarth (2015).

<sup>4</sup> 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 and 2007). This would be 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).

such as the famous Luddite revolt and the Captain Swing riots in industrializing England, have been called into question: in the “...Luddite (1811–16) and Captain Swing (1830–32) riots, the role actually played by the concerns of laborers about being replaced by machinery has been greatly exaggerated.” (Mokyr, Vickers and Ziebarth, 2015).<sup>5</sup>

In this paper, we examine the social and political consequences of technological change, looking at a famous case – the ‘Captain Swing’ riots in England, 1830-32. They constitute the largest case of labor unrest in English history, with more than 2,000 riots affecting a total of 21 counties. Farm houses were torched and machines destroyed in large number. Overseers of the poor were attacked and driven out of the parish; employers agreed to wage hikes under the threat of violence. All over the country, troops had to be deployed to quell the chaos. Many causes have been cited for the outbreak of the ‘Captain Swing’ riots (Hobsbawn and Rudé, 2014; Griffin, 2012). Most prominently among them are the Poor Laws (an early form of welfare payments), failed harvests, and the release of a large number of soldiers and mariners from military service after the end of the Napoleonic Wars. While all of these may have contributed to the outbreak of unrest, we demonstrate that – contrary to recent revisionist scholarship – the spread of labor-saving technology in the form of threshing machines was a key factor responsible for the riots.

We proceed in two steps: First, we hand-collect new data on the spread of threshing machines, exploiting information from 66 local newspapers containing advertisements on farms for sale.<sup>6</sup> This allows us to gauge the quantitative contribution of technology adoption to unrest. Figure 1 shows our main result. We compare parishes with and without advertisements for threshing equipment in the pre-1830 period. Where the new technology was adopted, the probability of riots was approximately 50% higher, with the share of parishes affected rising from 0.13 to 0.2. The relative upward shift is even greater when we focus on agricultural riots only, defined as cases of unrest where farm equipment was targeted and destroyed. Here, the relative frequency was more than twice as high in areas with threshing machines as in those without them.

Second, we combine our diffusion data with FAO data on soil suitability. Where English and Welsh soil was particularly suited to wheat – the principal crop for which threshing machines were used – adoption rates for threshing machines were markedly higher. Moreover, the component of threshing machine adoption driven by soil

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<sup>5</sup> See also Stevenson (2013).

<sup>6</sup> Of these, 37 contained at least one advertisement.

suitability predicts unrest in 1830-32 to a large extent. This in turn suggests that the effects of labor-saving technology on unrest are causal.

In addition to the literature on the effects of technological change on labor markets, our results relate to two other areas of research – the economic determinants of political instability and unrest, and the historiography of ‘Captain Swing’. Most of the theoretical contributions on the determinants of political instability and social unrest moves from the observation that low-income countries are more prone to civil conflict than richer countries (Fearon and Laitin, 2003; Collier and Hoeffler, 2004). While it is tempting to explain this correlation with the argument that people living in low-income countries face a lower opportunity cost of organizing a rebellion, Fearon (2007) notes that the effect of income on unrest is ambiguous, because in low-income countries also the loot for which the rebels fight is small; this should also reduce the incentives to rebel. Chassang and Padró i Miquel (2009) qualify this conclusion, and show that *temporary* negative income shocks can increase the chances of revolt, while permanent income shocks have always an ambiguous effect.

The empirical literature on social unrest has sought to identify the causal effect of income shocks on revolt by looking for exogenous shocks to income. Miguel Satyanath and Sergenti (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), looking at cross-country evidence for period 1919 to 2008 argue that episodes of 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 historiography of the ‘Captain Swing’ riots. Systematic analysis began with the Parliamentary Inquiry that followed the unrest (Checkland, 1974). It largely blamed them on failings of the Poor Law. The Hammonds (1987) famously attributed the riots to growing immiserization of laborers in the countryside. Hobsbawn and Rudé compiled the first systematic database on the riots, and 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 their analysis updated by Griffin (2012). Aidt and Franck (2015) have recently shown how the riots contributed to the 1832 Reform Act. Finally, Aidt, Leon and Satchell (2016) analyse how riots spread across England over the two years of unrest, and argue that "contagion" played a significant role in the diffusion of the riots.

Relative to these papers, we make the following contributions. First, we focus on a massive, relatively 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; steam threshing completely eliminated winter earnings for agricultural laborers, who constituted the relative majority of the labor force in the plurality of English counties (Shaw-Taylor et al. 2010). This is in contrast with the more recent analysis of skill-biased technological change, which focuses on relatively gradual changes affecting a smaller part of the labor force, such as telephone operators or secretaries. Second, we provide evidence for an additional channel in the economic literature on conflict – the distributional effect of the new technology. The literature on income shocks and conflict typically assumes that shocks have to be negative (either temporarily or permanently) to lead to confrontation. New technologies represent a positive shock to output but create distributional effects that may adversely affect some groups. Threshing machines were labor-saving and reduced the share of output going to labor; this lowered rural workers' opportunity cost of revolt. The asymmetric effect of an income shock that alters the relative price of factors is reminiscent of the model in Dal Bó and Dal Bó (2011), who show that in a two sectors economy a shock to the capital-intensive sector increases the likelihood of civil conflict.<sup>7</sup>

We proceed as follows. Section 2 summarizes the historical background. Section 3 presents our data, and section 4, our main empirical results. Section 5 examines the robustness of our findings, and Section 6 concludes.

## **2 Historical Background**

Threshing was a key part of the agricultural production process since the invention of sedentary agriculture. Before grain can be processed or stored, the corn has to be loosened from the husks (threshing), and then the straw and husks have to be

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<sup>7</sup> Dube and Vargas (2013) show evidence consistent with this theory. Another related paper is Manacorda and Tesei (2016), who examine the role of communication technology in facilitating protests in Africa.

separated from the corn (winnowing). Performed by hand, threshing is a laborious process. Typically, flails – two sticks connected by a short chain – were used in hand-threshing. The larger stick was swung overhead, into a pile of grain. Threshing provided employment during the winter months when other forms of work were in short supply. The Scottish engineer Andrew Meikle invented the first threshing machine in 1786 (Macdonald, 1975). Initially driven by hand, horses or water-power, threshing machines were soon paired with steam engines.

### *2.1 Agriculture in early 1800 England*

In contrast to most European countries, English agriculture by 1800 was highly efficient and almost completely commercialized. The largest landowners, often members of the nobility or the landed gentry, rarely took any active role in the operation of estates (Hobsbawm and Rudé, 2014, p.23-24). Below the landowners was a larger class of farmer-tenants: they rented the land from the nobility and landed gentry and ran the farms for a profit. These farmers often used advanced techniques for their time: they regularly rotated crops, allowing either one year of fallow every three, or planting turnip and clover after two consecutive years of cereal cultivation (Rahm, 1844; pp. 195-197 and pp. 433-441). They also fertilized abundantly their fields and sold most of their output on the market. Large estates often employed agricultural servants year-round (as did some of the tenant farmers). Agricultural servants typically began work in their teens, and were required to stay celibate (Voigtländer and Voth, 2013). Once married, they had to move out of the household of their employer.

Agricultural laborers were at the bottom of the social pyramid. They were often illiterate and owned few assets. During the early modern period, they had progressively lost access to common lands – first via the “yeoman’s enclosure” (Allen 1992), then through the wave of parliamentary enclosures during the 18<sup>th</sup> century (Neeson, 2008; Mingay, 2014). Also, population growth made their employment less certain (Hobsbawm and Rudé, 2014, p. 42). By the beginning of the nineteenth century, most agricultural laborers worked mainly as hired hands: in the spring, they prepared the fields, and in the summer they harvested, usually under piece-work contracts that were signed by the day, by the week or at most by the season (Thompson, 2013, p. 235, and Hobsbawm and Rudé, 2014, pp. 39-40). During the winter, when agricultural work was scarce, many of these laborers found employment

as “threshers”. Until 1800 almost every farmer in England hired workers to thresh the grains manually, or outsourced the process to local barns.<sup>8</sup>

Another aspect that contributed to the hardship of rural laborers was low labor mobility. This was the result of a system of social insurance known as the “Poor Laws” which granted income support to the “impotent poors” during periods of distress.<sup>9</sup> Under the rules that were in place in the first decades of 1800, the poor could only apply for support in their parish of residence (Marshall, 1977; Boyer 1990). This discouraged migration even over short distances. Limited labor mobility in turn exacerbated the condition of the laboring poor in the countryside because it reduced out-migration (Redford, 1976).<sup>10</sup> The system also created peculiar externalities, with farmers sometimes hiring laborers who were maintained by the neighboring parish (Hammond and Hammond 1987).

Against this background, farmers adopted threshing machines at an accelerating rate from the turn of the century onwards. The new machines could thresh an entire harvest in a few weeks, reducing costs by up to one-third compared to manual threshing (Hobsbawm and Rudé, 2014, p. 362). Machine-threshed grain also yielded about 10% more corn (Hammond and Hammond 1987). Immediately after its invention, threshing machines spread relatively slowly as the machines were too expensive relative to manual labor (Hobsbawm and Rudé, 2014: p. 361; Macdonald, 1975, p.74), but this changed with the Napoleonic Wars. As Great Britain and France went to war, the British army expanded to 250’000 men, and the navy to 140’000 (Colley, 2009; p. 293). Because rural laborers made up a significant share of the British armed forces, labor suddenly became scarce in the countryside (Hobsbawm and Rudé, 2014; p. 359 who quote Stevenson, 1815; p. 144). Farmers responded by adopting a number of labor-saving technologies, including threshing machines.

After Napoleon’s defeat at Waterloo in 1815, Britain discharged most of its soldiers and labor in the countryside became relatively abundant again. Nonetheless,

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<sup>8</sup> 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, p. 221).

<sup>9</sup> The Old Poor Law went back to 1601, when the “Acte for the Reliefe of the Poore” or “Act of Elisabeth” was introduced (Marshall, 1977: p. 10). The basic framework remained in place until the 1834 reform (Marshall, 1977; Boyer, 1990).

<sup>10</sup> Boyer (1990) contends that the Poor Law did not slow down rural-urban migration at the aggregate level. His conclusion does not exclude the possibility that the Poor Laws prevented rural-rural migration, and Landau (1995) present evidence that the “Laws of Settlement” were used in the 18<sup>th</sup> century to systematically limit migration across parishes.

once adopted and suitably refined through long years of use, threshing machines continued to spread.<sup>11</sup> In addition to the low cost, the machine's speed created a vital advantage because the price of wheat typically dropped quickly after the harvest. Farmers who had threshed grain to sell immediately could obtain higher prices, and they also saved the cost of storage. Both large and small producers kept using the new machines even after the most acute labor shortages had ended.

## 2.2 *Captain Swing riots*

The 'Swing' riots broke out in the last days of August 1830, in East Kent.<sup>12</sup> They spread first in the South-East of England, and then across the whole island. By the winter of 1832, more than 2,000 riots had broken out in 21 different counties. Almost all of these episodes took place in rural areas; rioters were mostly rural workers, sometimes led by craftsmen and artisans (Hobsbawn and Rudé, 2014: p.207; Stevenson, 2013: p. 266). The first protests saw rioters breaking agricultural machines (most of the time the hated threshing machines): between September and the end of November 1830 Holland (2005) lists 492 machines broken, of which 452 were threshing machines.

Unrest took several forms. Arson attacks were common (Tilly, 1995: p. 218). In many parishes, the overseers of the poor were forced out by rioters, often being transported in carts previously used by the overseers themselves. Similarly, wage negotiations occurred frequently, with farmers agreeing to a minimum wage under the proviso that tithes and rents would be commensurately reduced (Griffin 2012; Hammond and Hammond 1987). Threatening letters – signed by the mythical 'Captain Swing' – were sent to farmers. These letters captured the public imagination, and by October 1830, *The Times* of London began to apply the term 'Swing' to the whole wave of riots (Griffin, 2012: p.3). Unrest simmered for more than two years, until the winter of 1832, when Holland (2005) records the last episodes (two fires set in Nottingham and Norfolk and one riot that broke out in Surrey).

After an initially timid response, the central government adopted a harsh line. It ordered the army and local militias – typically composed of local yeomen – to attack rioters. The British government also set up a special commission to deal with the

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<sup>11</sup> The following theory was proposed by Hobsbawn and Rudé (2014; Appendix IV).

<sup>12</sup> Until recently, most historians followed Hobsbawn and Rudé (2014) who placed the start of the riots on the 28<sup>th</sup> of August 1830, when a gang of people smashed a threshing machine in the parish of Lower Hardres, in Kent (Hobsbawn and Rudé, 2014: p. 97; Stevenson, 2013: p. 264). Recently, Griffin argued that riots began on the 24<sup>th</sup> of August 1830, when in the Kentish parish of Elham some 20 men destroyed another threshing machine (Griffin, 2012: p.87).



unrest (Hobsbawn and Rudé, 2014: p. 253-263). It passed 252 death sentences, but commuted many to transportation to Australia or New Zealand (Hobsbawn and Rudé, 2014: pp. 265-279).

### *2.3 Causes of unrest*

Several factors contributed to the wave of riots in 1830-32. Hobsbawn and Rudé emphasize how the already difficult situation of rural workers was made unsustainable by bad weather, a poor harvest and the prospect of a harsh winter (Hobsbawn and Rudé, 2014: p. 91). Once the revolt had started, riots spread to the rest of the country, often as a result of bands of workers travelling from parish to parish to exact justice on the landlords (Tilly, 1995: p. 319) or following the accounts of incidents in nearby parishes reported by “linkmen” travelling along the major roads (Archer, 2000: p. 20). The year 1830 also saw an increase in political agitation as well as discussions of electoral reform. Against the background of the July revolution in France, agitators like William Cobbett toured the countryside, arguing for the need for change, a living wage, and a rebalancing of power (Wells 1997; Dyck, 2005). News of the French (and Belgian) revolutions may have provided the spark that ignited the revolt in the South East of England (Archer, 2000: p. 20; Charlesworth, 1979: p. 37-9). In addition, discussions of electoral reform had come to naught under the Duke of Wellington’s Tory government. They would eventually lead to the Great Reform Act of 1832 under his liberal successor – but only after Wellington’s government fell during the worst period of the riots (Aidt and Franck 2015).

Whatever the immediate motives of the riots, historians agree that the underlying cause of unrest was a progressive deterioration of the economic and social situation of rural workers. Three factors contributed to the decline. First, since the end of 1600 the enclosure movement had progressively deprived rural workers of the access to common lands, effectively transforming them into a “landless proletariat, relying almost exclusively on wage-labor” (Hobsbawn and Rudé, 2014: p. 35, see also Hammond and Hammond, 1987). Second, bringing in the harvest in areas with arable farming required a large workforce – but employment opportunities were scarce during the rest of the year. The Poor Laws, a system of income support funded and administered at the parish level, in general maintained a sufficient number of agricultural laborers (Boyer, 1990). Since the beginning of the 1800s, the system had come under considerable strain because of population pressure and the decline of cottage industry (Stevenson, 2013: p. 262). It also – perversely – encouraged bastardy, and penalized savings amongst the poor (Hammond and Hammond 1987). As an increasing number of people received income support, allowances were generally

reduced, the conditions for receiving them were tightened, and workers became increasingly dissatisfied with the system (Thompson, 2013: p. 244-245). Third, the progressive mechanization of agriculture made redundant much of the agricultural labor force and undermined its standard of living. The adoption of threshing machines was especially harmful for rural workers because it deprived them of the major source of income during the winter season.

While these three factors appear in almost any account of the Swing riots, historians disagree on their relative importance. On the one end of the spectrum we find Thompson and Royle, who place great emphasis on the role of enclosures and on the loss to the access to land (Thompson, 2013; Royle, 2000). The Parliamentary enquiry, set up after the 1830-32 riots, largely laid the blame at the feet of the “Old Poor Law” – soon to be reformed thoroughly. Finally, Hobsbawm and Rudé (2014) emphasize the importance of new machines.

### 3 Data

We use three main sources: information on riots, FAO land suitability data, and agricultural advertisements from nineteenth century British newspapers. We complement this information with the number of days in which grass can grow as well as the data from British historical censuses. In this section we describe each of these sources; details about individual variables can be found in appendix A.

Data on Swing riots comes from a database compiled by the Family and Community Historical Research Society (Holland 2005).<sup>13</sup> It contains a comprehensive list of Captain Swing incidents between January 1830 and December 1832. The information comes from official records and historical newspapers and contains the date, the parish, and the type of crime perpetrated by rioters. The database builds on Hobsbawm and Rudé (2014), adding a further 785 riots to their original list of 1475 incidents.

Some of the riots during the years 1830-32 are particularly relevant for our paper – what we call “agricultural riots”. These are protests targeting agricultural machines, especially threshing machines, and other types of farm equipment. Figure 2 reports the total number of Swing riots over time, broken down by “agricultural riots” and other events. Figure 3 shows the geographical distribution of these incidents.

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<sup>13</sup> Aidt and Franck (2015) recently used these data in their study of the political consequences of the Swing riots.

To track the spread of threshing machines over time, we use information from 66 regional newspapers (63 from England and 3 from Wales), of which 37 had at least one advertisement. We examine the universe of 118,758 newspaper issues published between January 1800 and July 1830, searching for advertisements containing the exact string “threshing machine”. These would typically relate to the sale or lease of a farm. Figure 4 and Figure 5 show two typical advertisements contained in our database. Figure 6 reports the number of advertisements of threshing machines that appeared during the thirty years leading up to the Swing riots. In order to assign these articles to different areas of Britain, we manually code the exact parish where a farmer was selling his threshing machine. We have a total of 409 advertisements in 363 parishes. Figure 7 shows the geographical distribution of the advertisements we collected along with the cities where our newspapers were printed.

Data on suitability of different parishes of England and Wales to the cultivation of cereals comes from the Global Agro-Ecological Zones database (FAO-GAEZ). These data report the potential output that can be harvested in a given area by cultivating wheat. FAO researchers compute this potential output by using soil characteristics, historical weather records and an agronomic model that assumes the use of a specific level of inputs.<sup>14</sup> These measures are available for grid cells of about  $9.25 \times 9.25$  kilometers. We construct a measure of potential output at the parish level by superimposing a map with the boundaries of historical British parishes on the grid of soil suitability, and then computing the average yield attainable in every parish. Figure 8 shows the potential output for wheat in Britain.

Finally, we complement these data with three additional sources. The first one is the number of days in which grass can grow across British counties (Down *et al.* (1981)). The second source is British population census for the year 1821 prepared by Southall *et al.* (2004). Finally, we also use data on occupational structure as compiled by Shaw-Taylor *et al.* (2010). Table 1 reports summary statistics for our variables, and Appendix A describes every variable used in the analysis and explains how we match data from different sources.

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<sup>14</sup> 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. See section 5.1 for a more complete discussion of this assumption.

## 4 Empirical analysis

### 4.1 Threshing machines and riots

We start by documenting the correlation between the adoption of threshing machines in the first three decades of the 1800s and the riots of 1830-32. The aim of this section is to establish that places where threshing machines spread faster, as measured by the number of threshing machines on sale in the years 1800-1830, were also more likely to stage a protest in 1830-32.

Figure 1 illustrates our main finding, by dividing English parishes into two groups according to whether we observe at least one threshing machine advertisement. We first look at all cases of unrest during the Swing riots. Parishes with at least one advertisement for a threshing machine pre-1830 had a 7.6 percentage point higher likelihood of having a Swing riot compared to parishes with no ads, an increase of almost 60 percent. When we focus on agricultural unrest alone – attacks on farms, destruction of the harvest or fences, or the breaking of farm equipment including threshing machines – the overall level of unrest is lower. The increase in the probability of unrest in parishes with threshing machines however is greater, more than doubling from 3.6 to 7.4%. Overall, both graphs show a strong unconditional association between the diffusion of new technology and the 1830-32 riots.

Next, we show that this basic relationship holds in a setting with a richer set of controls. We estimate variations of the following regression specification:

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

Where  $Riot_p$  is the number of riots in parish  $p$  during 1830-32,  $Ads_p$  is the number of advertisements for threshing machines,  $Pop1821$  is the total population living in the parish in 1821,<sup>15</sup> and  $X_p$  is the vector of additional parish-level characteristics. These include: the (logarithm of) the area of the parish; the share of families that are chiefly employed in agriculture in 1821; the (logarithm of) the number of days in which grass can grow in the parish; the (logarithm of) the male-female ratio in 1821; and the (logarithm of) the distance to the closest city that prints one newspaper. The area of

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<sup>15</sup> Both riots and number of advertisement are positively and significantly correlated with population. Riots were more likely to happen in more populated areas ( $\rho=0.18$ , significant at <0.1 percent). Adverts for threshing machines were more common in parishes with large populations ( $\rho=0.1$ , also significant at <0.1 percent). Accordingly we control for the (logarithm) of the total population living in the parish 9 years before the start of the riots, in 1821.

the parish allows us to control for another dimension of size apart from the population. The share of agricultural families proxies for the degree of agricultural specialization in the parish, while the number of days in which grass can grow controls for the profitability of pasture. Both of these variables have the potential to affect riots, because Swing was almost exclusively a rural phenomenon. The relative presence of men over women could also affect the emergence of riots, which in most cases were a men's affair (Stevenson, 2013: p. 268).<sup>16</sup> Controlling for distance to the closest city that printed a newspaper is important because the collection of data on threshing machines and riots relies on information reported in newspapers. Thus, parishes that are closer to the place of publication of a newspaper may have better news coverage of farm advertisements, and they may end up having more riots recorded in our database (which also relies on newspaper reports).

Finally, in the most demanding specification we include fixed effects for the 41 counties in England and Wales. Regressions with county fixed effects identify the relationship between threshing machines and riots within relatively small geographical units. With county fixed effects our regression becomes:

$$Riot_p = \beta_0 + \beta_1 Ads_p + \beta_{pop} Pop1821_p + \beta_X X_p + \theta_c + e_p \quad (2)$$

Here and in the following we will look at agricultural riots and Swing riots separately. We first show that that the frequency of all riots and the presence of threshing machines are positively correlated. Next, we focus on a more narrowly defined dependent variable in the form of agricultural riots.

Table 2 presents our results. In all cases we report beta coefficients, to ease the interpretation of results and the comparison of coefficients across tables. The first three columns show regressions when the dependent variable is number of Swing riots. Column 1 reports the estimates of equation (1) when we control only for the 1821 population in the parish: here the coefficient on  $Ads_{pc}$  is positive and significant ( $p = 0.002$ ). Adding other parish-level controls in column 2 does not affect neither the point estimates nor significance ( $p = 0.001$ ). Column 3 adds county fixed effects. Here the point estimate drops by 39 percent in magnitude but remains significant at the 5 percent level ( $p = 0.044$ ). This last result underscores that the correlation between machine adoption and agricultural riots is strong even within narrowly defined geographical units.

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<sup>16</sup> In the data collected by Holland (2005), out of the 1566 Swing offenders who were processed and whose first name reveals clearly the gender, only 21 were women (1.34 percent).

On columns 4 through 6 of Table 2 we turn to agricultural riots. The results for these episodes are consistent with those for the full population of Swing riots: on column 4 we estimate equation (1) controlling only for population, and we find a coefficient on  $Ads_{pc}$  that is positive and significant ( $p = 0.005$ ). Controlling for other parish characteristics on column 5 does not affect estimates and improves significance ( $p = 0.004$ ). Adding county fixed effect reduces the point estimate by 22 percent but preserves significance at the 5 percent.

To sum up, the results presented in this section point to a strong and positive correlation between riots and adoption of the new machines. The strength of these results is noteworthy because our variable capturing technology adoption must be noisy. It is highly likely that we mis-classify numerous parishes where threshing machines were in operation but that did not appear in any newspaper advertisement. This will bias our estimates downwards (Deaton, 2000: p.99). We therefore think of the coefficients in Table 2 as lower bounds of the true effect.

#### 4.2 Identification

The correlations shown in the previous section show a close association between the adoption of threshing machines and the incidence of Swing riots – especially those directed against farm equipment. There are three reasons why we should be cautious before interpreting this relationship as causal.

First, a regression of the number of riots on the diffusion of threshing machines may yield biased estimates if the general inclination of the rural population to riot affected the decisions of landlords and tenants to adopt new, labor saving technologies. If the presence of unruly rural workers made farmers more likely to try production technologies that required less labor, then the estimates will be upward biased. If the opposite was true however, the OLS estimates will be biased downward instead. Accounts from the period do not suggest that landlords adopted the new technology in response to higher risk of unrest and, if anything, it is possible that they delayed adoption where labor was abundant, wages low, and the risk of protest higher. If this is true, then estimates in Table 2 will be biased downward.

Second, unobserved characteristics of British agriculture may affect both the willingness of farmers to adopt the new technologies and the inclination of rural workers to revolt. In Table 2 the point estimates are not affected much by the inclusion of parish-level characteristics, suggesting that the correlation between machines and riots is not the product of spurious correlation between these two variables and the controls in the vector  $X_p$  that appears in regression (1). Although this

vector contains several important characteristics that may be correlated with the riots, it is possible that other omitted variables are biasing our estimates.

Third, it is possible that parishes with advertisements for threshing machines are also over-represented in the Swing riot data of Holland (2005) – as the latter is also partly based on newspaper accounts. This could cause positive correlation in the error with which dependent and independent variables are measured, introducing upward bias in the OLS estimates.

We address these problems by using an instrument for the adoption of labor-saving technologies. Threshing machines were almost exclusively used for the processing of a single crop: wheat.<sup>17</sup> As a result, rural workers were more likely to see machines substitute one of their tasks in areas that were more suited to the cultivation of wheat. We measure soil suitability for wheat with FAO's potential yield data for this crop.

Soil suitability for wheat is a valid instrument for the adoption of the new threshing machine if it predicts their adoption and at the same time does not influence the probability of unrest via any other channel. Wheat suitability is likely to be a significant predictor of the adoption because, by affecting how much wheat can be produced, it changes the profitability of using the new machines. This assumption can be tested formally, and in the next section we show soil suitability to wheat production strongly predicts the number of threshing machines found in 1800 British newspapers. The exclusion restriction is also likely to hold. Wheat-growing areas were not necessarily better or worse off than others. Suitability for wheat cultivation *per se* is unlikely to affect the likelihood of rural workers to riot, except through its effect on the adoption of the new labor-saving technologies. This should be true especially once we control for all the parish-level characteristics included in the vector  $X_p$ .

Using soil suitability should alleviate concerns that the correlation between riots and machines is driven by the two variables being constructed from overlapping data sources. This is because the potential yield of wheat is defined for the whole territory of England and Wales, and it is measured with the same level of accuracy regardless of the distance to the closest city that publishes a newspaper. For this reason, the measurement error of the potential yield is unlikely to be correlated with the measurement error of the dependent variable and create the same problem that arises with the threshing machine measure.

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<sup>17</sup> Hobsbawm and Rudé argue that “oats and barley were definitely cheaper to thresh by hand” (Hobsbawm and Rudé, 2014, p. 361).

### 4.3 First Stage: Threshing Machines and Potential Yield of Wheat

We start by documenting the relationship between suitability for wheat – our proxy for the profitability of using threshing machines – and our measure of technology adoption. In Figure 9, we plot the unconditional relationship between the potential yield of wheat in tons per hectare (on the x-axis of the upper panel) and the share of parishes for which we observe at least one threshing machine advertisement between 1800 and 1830 (on the y-axis of the upper panel). The figure shows the local polynomial and 95 percent confidence interval.<sup>18</sup> Parishes more suitable to wheat cultivation were systematically more likely to have a threshing machine on sale advertised in British newspapers. The line has a clear positive slope, and it becomes more tightly estimated above 3.5 tonnes per hectare of potential yield, where we observe a greater number of parishes (see the frequency distribution in the bottom panel).<sup>19</sup>

In the first 3 columns of panel (A) of Table 3 we confirm that the relationship between soil suitability and threshing machine adoption is strong. We fit the following model:

$$Ads_p = \alpha_0 + \alpha_1 Yield^{wheat}_p + \alpha_{pop} Pop1821_p + \alpha_X X_p + \psi_c + u_p \quad (3)$$

In the simplest specification we are going to regress the total number of threshing machines advertisement we observe in parish  $p$  in county  $c$  ( $Ads_p$ ), on the potential yield of wheat ( $Yield^{wheat}_p$ ) while controlling for the total number of people recorded in parish  $p$  in the 1821 Census ( $Pop1821_p$ ). Next, we add the same vector of parish level controls included in regression (1):  $X_p$ . In the most demanding specification we add 41 county fixed effects ( $\psi_c$ ), effectively estimating the impact of soil suitability on the adoption of threshing machines within small geographical units. Because counties are relatively homogeneous in terms of soil suitability, this is a very demanding specification.

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<sup>18</sup> 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).

<sup>19</sup> Interestingly, as far as our data allows us to tell, there is no important relationship between grain suitability and the timing of threshing machine adoption – parishes with highest suitability for wheat were broadly as likely to adopt early as those with somewhat lower suitability. This suggests that the technology’s diffusion was partly affected by non-economic factors such as local availability, knowledge of its existence, etc.



The first column in panel (A) of Table 3 reports the estimates of equation (3) when we only control for the 1821 population. The beta coefficient is positive and highly significant, with an  $F$ -stat of 41.8. In the second column, we add the other parish-level controls: in this regression the point estimate becomes larger and statistical significance improves ( $F = 62.3$ ), suggesting that these controls capture variation in the dependent variable that was biasing downward the estimates in the first column. In the third column, we add the fixed effects for the 41 counties in which our parishes are located. In this regression the coefficient of  $Yield^{wheat}_{pc}$  becomes smaller but remains significant at the 5 percent level ( $p = 0.021$ ). Since threshing machines could process grains cultivated in different parishes, it is not surprising that the point estimate becomes smaller once we control for fixed effects of relatively small geographical units. On the contrary, it is interesting that a substantial share of the correlation between wheat suitability and the adoption of threshing machines in the first 30 years of 1800 comes from within relatively small geographical units. However, because in this last regression the  $F$ -test becomes smaller than 10 ( $F = 5.1$ ), we will report the results of the Rubin-Anderson test whenever we present our instrumental variable estimates.

#### 4.4 *Reduced Form: Riots and Potential Yield of Wheat*

We now move to the study of the determinants of riots. We start by discussing the results of our reduced form: the relationship between land suitability for wheat cultivation and the outbreak of Swing riots. These results are important for two reasons. First, since FAO measures yield potential with greater precision than 1800s advertisements capture threshing machine adoption, even in the absence of other sources of bias the point estimates are likely to be more precisely estimated in the reduced form regressions than in the OLS regressions. Second, because FAO calculates potential yields using inputs that are beyond the control of 1800s farmers (soil and weather characteristics), the results of our reduced form regressions identify the causal effect that being located in an area suitable for wheat cultivation had on the spread of the Swing riots.

Before presenting our econometric results, we start with a visual illustration of our findings. Figure 10 reproduces our measure of wheat suitability shown in Figure 8, and adds the location of all the Swing riots episodes: the centroid of each parish in which at least one Swing riot happened is flagged with a black dot, and we draw larger dots in parishes where more episodes are recorded. The map reveal that across England and Wales, riots concentrated disproportionately in the South and South-East: in the area where the county of Wiltshire, Berkshire and Hampshire meet, in the

South-Eastern counties of Kent and Sussex, and in the Eastern county of Norfolk. These regions are also the ones that are more suitable to wheat cultivation, according to the FAO-GAEZ data.

The two graphs in Figure 11 complement the visual illustration of the map on Figure 10, by displaying the unconditional relationship between riots and potential yield for wheat. To produce these graphs, we split all English and Welsh parishes into two equal-sized groups according to whether they have potential yield for wheat above or below the potential yield of the median parish.<sup>20</sup> In the top panel of Figure 11, we show the share of parishes in the two groups that experienced at least one episode associated to the Swing riots. The graph shows that parishes above the median potential yield were 1.7 times more likely to experience at least one episode of Swing riots than parishes below the median ( $p < 0.001$ ). In the bottom panel of Figure 11 we reproduce the share of parishes in these two groups in which at least one agricultural riot took place, along with the standard errors of our estimates. Overall, parishes above the median potential yield for wheat were 2.6 times more likely to experience at least one agricultural riot than parishes below the median ( $p < 0.001$ ).

Next, we proceed to present our results in a regression framework. We fit the following model to the data:

$$Riot_p = \gamma_0 + \gamma_1 Yield^{wheat}_p + \gamma_{pop} Pop1821_p + \gamma_X X_p + \eta_c + v_p \quad (4)$$

where  $Yield^{wheat}_{pc}$  is our measure of profitability of wheat cultivation: the potential yield of this crop in tonnes per acre.

As we did in section 4.1, we study the effect of soil suitability for wheat cultivation separately for all the episodes associated with the Swing riots and for riots that targeted specifically machines and other farm capital (our variable *agricultural riots*). Columns 4 through 6 of panel (A) of Table 3 show our results when the dependent variable is number of Swing riots. When we only include the 1821 parish population in column 4 the beta coefficient on potential yield is positive and highly significant ( $p < 0.001$ ). The beta coefficient remains stable and significant at less than 0.1% level when we add other parish-level controls on column 5. Finally, on column 6 we add a full set of 41 county fixed effects: relative to the estimates on column 5 the beta coefficient of this regression drops by three-fourths but remains significant at 0.1 percent level. This result suggests that a great part of the correlation between riots and

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<sup>20</sup> The median parish is the parish of Dymock in the North of Gloucestershire, whose land can produce 3.98 tonnes of wheat per hectare, on average.

wheat suitability is generated by differences across counties. However, the result in column 6 also indicates that even within narrow geographical units, variation in the profitability of the new technology led to significant differences in the number of agricultural riots.

We now turn to the analysis of agricultural riots. In column 4 of panel (B) of Table 3 we report our beta coefficient when we only include 1821 population. The effect of potential yield of wheat is positive and highly significant ( $p < 0.001$ ). In column 5 we add the other parish-level controls. The beta coefficient of our explanatory variable remains positive and significant, and the point estimate is unaffected. In column 6 we also add county fixed effects. The beta coefficient stays positive and significant at the 5 percent level ( $p = 0.049$ ), but the point estimates drops by four-fifths. The comparison between the beta coefficients on columns 5 and 6 confirms that also for the agricultural riots a great part of the correlation with wheat suitability is generated by differences across counties. However the correlation remains positive and highly significant even within counties.

#### *4.5 Two-Stages Least Squares*

We now turn to the two-stage-least-squares estimates. The noise in our measure of threshing machine adoption is likely to bias the estimates presented in section 4.1 downward. At the same time, correlated errors in the measurement of riots and machinery diffusion could bias our coefficient upwards. Given the amount of noise that we suspect is present in our main explanatory variable, it is reasonable to expect that, on net, the two-stages least squares estimates to be significantly larger than the coefficients discussed in section 4.1.

Columns 7 through 9 of Table 3 confirm that this is the case. The table reports regressions with the total number of Swing riots as the dependent variable on panel (A) and with number of agricultural riots in panel (B). For both outcomes, the estimates are positive and significant at the 1 percent level or less when all parish-level controls are included. When we look at variation within counties, estimates drop but remain significant at the 5.1 percent level (in the case of total number of Swing riots) and at the 12.5 percent level (in the case of agricultural riots).

As we expected, point estimates are also significantly larger than point estimates reported on Table 2. If we assume that the entire difference between OLS and two-stages least squares comes from the noise in our explanatory variable, the number of advertisements of threshing machine, we must conclude that the noise-to-

signal ratio in our OLS regressions is between 9 and 5.<sup>21</sup> Given the nature of the data collected for the adoption of threshing machines, we think that such level of measurement is not unreasonable.

## 5 Robustness

### 5.1 Definition of suitability to wheat production

So far, we used as an exogenous instrument for threshing machines adoption the potential yield for wheat. FAO researchers compute this measure using soil and weather characteristics, along with specific assumptions about the source of irrigation, input use and farm management (Fischer *et al.* 2011).<sup>22</sup> In all our regressions we have used the potential yield attainable by rain-fed agriculture with “intermediate-level inputs” and “improved management”. Under these assumptions, agricultural production is partly market oriented, in the sense that “commercial sale is a management objective”. Farmers practice “adequate fallow” and rely on “manual labor with hand tools and/or animal traction and some mechanization” (Fisher *et al.*, 2011, p. 56). In addition, farmers plant the “improved varieties” of seeds that were in use before the Green Revolution of the 1940s (see also Gollin *et al.*, 2016), and apply “some fertilizer” as well as “pest, disease and weed control.” Most of these characteristics are a good match with English agricultural conditions in the early

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<sup>21</sup> We calculate the noise-to-signal ratio as follows. First, we assume that the two-stages least squares estimate of the effect of machines on riots in the specification with riots fixed effects is a consistent estimate of the true underlying parameter that links the new technology to protest. Next, we use the formula for the bias of the OLS estimator in the presence of measurement error for the explanatory variable (Deaton, 2000: p. 99). The formula states that in a regression of  $y$  on  $x$  and  $z$ , where  $x$  is an explanatory variable measured with error, and  $z$  is a vector of other explanatory variable precisely estimated, the probability limit of the estimated coefficient of  $x$  is:

$$\text{plim } \hat{\beta}_x = \beta_x \lambda$$

where  $\beta_x$  is the true underlying parameter,  $\hat{\beta}_x$  is the OLS estimate and the bias  $\lambda$  is equal to:  $\{[\sigma_x^2 / (\sigma_x^2 + \sigma_e^2)] - R_{xz}^2\} / (1 - R_{xz}^2)$ . The bias of  $\beta_x$  depends thus on the variance of the correctly measured variable  $x$  ( $\sigma_x^2$ ), the variance of the measurement error ( $\sigma_e^2$ ) and on the  $R^2$  of a regression of  $x$  on the vector of correctly measured variables  $z$  ( $R_{xz}^2$ ). From here, simple manipulation yields the formula for the noise-to-signal ratio, defined as  $\sigma_e^2 \setminus \sigma_x^2$ .

<sup>22</sup> One possible concern has to do with the weather variables used to compute potential yield in the FAO measure. FAO researchers use average weather conditions for the period 1961-1990, and these may differ from weather condition at the beginning of the 1800. For the period 1801-1830 we obtained average monthly precipitation across England: in Appendix C we show that average precipitation was not significantly different in 1801-1830 compared to 1961-1990.

1800s, especially the kind of farms that would consider the adoption of the new threshing machines.<sup>23</sup> Nevertheless, the assumption of fertilizers may be problematic, because it is possible that some of the factors considered by FAO researchers for their “intermediate input” measure were in fact not available to English farmers of the nineteenth century.<sup>24</sup>

It could be argued that a early 19<sup>th</sup> century conditions in England are more accurately described as lying between the FAO’s “low” and “intermediate” levels of inputs. The one advantage of the potential yield calculated under the assumption of low inputs is that it is calculated assuming “no use of chemicals for pest and disease control”: this was obviously a technology unavailable to English farmers in 1800. However, farm management, crop rotation and labor-capital mix are best represented by the assumptions embedded in the intermediate inputs measure rather than the low inputs one. In sum, the ideal measure should be closer to the potential yield computed under “intermediate level” of inputs, but arguably somewhat below that.

To alleviate concerns that overestimation of potential yields is driving results, we also present estimates for low input use (Table 4). The first three columns of panel (A) show the first stage when the potential yield is calculated assuming low inputs. The first two columns report estimates of equations (3) with only 1821 population and with all parish-level controls respectively. Potential yield is a strong predictor of threshing machine adoption even under the low input assumption. Moreover, the beta coefficients are slightly larger than in the regressions in which potential yield was calculated assuming an intermediate level of inputs. In column 3 we add the 41 county fixed effects. In these regressions the low inputs instrument has a smaller beta coefficient and a lower significance than in our baseline regressions. This suggests that the potential yield attainable with low level of inputs can capture broad differences in soil and weather potential across different regions of England and Wales, but does not reflect adequately finer variations that may have driven differential adoption within small British counties.

In columns 4 through 6, we report estimates of the reduced form equation (4): panel A uses the number of Swing riots as the dependent variable, and panel B uses the number of agricultural riots. Beta coefficients of our instrument estimated without county fixed effects are reported in columns 4 and 5 are indistinguishable from the

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<sup>23</sup> See also the discussion in section 2.1.

<sup>24</sup> While English farmers would routinely use several types of manure such as chalk, marl, clay and excrements to fertilize their fields (Rahm, 1844: pp. 314-324), they were less likely to have access to chemical products that FAO researchers may consider in their definition of “intermediate inputs”.

same coefficients estimated with our preferred measure of potential yield in Table 3. When we add county fixed effects on column 6 we find a smaller beta coefficient and reduced significance when the potential yield is computed under the low input assumption. When the dependent variable is total number of Swing riots the significance remains below 0.05, but grows relative to our baseline results ( $p = 0.023$  with low inputs against  $p = 0.001$  with intermediate inputs). In the case of the regression of agricultural riots the  $p$  value exceeds 0.10.

The results with two-stages least squares in columns 7 through 9 of Table 4 tell a similar story. Point estimates are always smaller when we estimate them with the low inputs measure of potential yield. Significance is always less than 0.1 percent when no county fixed effects are included. The results in this section confirm that our baseline results are not driven by the particular assumptions about the input use embedded in the FAO-GAEZ measure of potential yield.

## 5.2 *Spatial autocorrelation*

Results in section 4 are based on conventional robust standard errors that do not account for the spatial correlation of both the dependent and explanatory variables. Visual inspection of maps in Figure 3, Figure 7 and Figure 8 suggest that all our variables of interest display significant spatial correlation. This is hardly surprising, as riots may have spread more easily along regional social networks, local manufacturers of threshing machines may have promoted their diffusion in specific areas, and the potential yield measures are calculated with soil and weather characteristics, which in turn vary smoothly over space. While this spatial correlation does not invalidate our strategy, it does imply that our standard errors may be downward biased. In this section we show that accounting for spatial correlation has no effect on our main results.

We control for spatial correlation in two ways. First, we compute standard errors with the formula proposed by Conley (1999). In his model, Conley assumes that spatial correlation across location decays with distance until a given cutoff beyond which spatial correlation is assumed to be 0. Because the cutoff underlying the true data generating process is unknown and because its choice is somewhat arbitrary, we experiment with three different cutoffs. In particular, we present standard errors obtained when spatial correlation is assumed to disappear beyond 20, 50 and 100 km.<sup>25</sup> Second, we estimate standard errors in a non-parametric way, and

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<sup>25</sup> For reference, the post office operated on a network of “post towns” which were located between 20 and 24 Km apart. Such network allowed couriers to stop and change their horses regularly (Heblich and

allow any correlation in the error terms of parishes that are served by the same newspaper. We do so by identifying for each parish the closest city that publishes a newspaper, and then by clustering standard errors at the level of these cities. This procedure should produce standard errors that are consistent even if both riots and threshing machines adoption were correlated across parishes that read news reported by the same journals.

Table 5 reports the results of this robustness check. On the first two rows of both panel (A) and panel (B), we reproduce our baseline estimates for the first stage, the OLS and the reduced form regressions. On the first row we report the point estimate and on the second row the Huber-Eicker-White robust standard errors. Below these estimates we then report standard errors calculated with the Conley (1999) formula and those clustered at the level of the closest city with a newspaper. Panel (A) of the table reports the OLS estimates of equations (1)-(2). In all specifications spatial correlation affects only slightly the estimated standard errors and in all regressions the coefficients on the number of threshing machine advertised remain significant at the 10 percent level or less.

In columns 1 through 3 of panel (B) we show the first stage regressions. Results remain strong even when standard errors account for spatial correlation. In the regression with all controls and without county fixed effects significance remains below 1 percent. When we add county fixed effects instead, the standard errors grow by a factor of 1.1 at most, and the potential yield remains significant at the 3 percent level even when we allow spatial correlation to operate at distances up to 100 km. Columns 4 through 9 report our estimates of the reduced form (4). Here, the coefficient of potential yield of wheat remains significant at 1 percent in the regressions of both total number of Swing riots and agricultural riots when we do not include county fixed effects. With county fixed effects, potential yield remains significant at the 2 percent level or less when the dependent variable is the total number of Swing riots and loses significance slightly when spatial correlation decays slowly when the dependent variable is agricultural riots. All in all, the results in this section suggest spatial correlation is arguably not biasing downwards our standard errors.

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Trew, 2016). In practice, any of the laborers who took part in the riots would very rarely have access to a horse, and would move mostly on foot, covering not more than 30 Km per day.

### 5.3 *Sample restriction: parishes within 40 km from a newspaper*

Both the riot episodes and our measure of threshing machine adoption are constructed using information extracted from contemporary newspapers.<sup>26</sup> These newspapers were published in 66 individual towns and cities, and they would have been more likely to report facts and advertise farm sales when these events took place relatively close to the place of publication. The average number of Swing riots within 40 km from one of these 70 locations is 0.06 higher than in parishes farther away ( $p = 0.012$ ). In contrast, the difference in the number of advertisements between the parishes around these cities and those beyond the 40 kilometers limit is not significant. However, it may still be the case that threshing machines are over-represented in parishes that are closer to places that print one of these newspapers (for instance if the true number of threshing machines is higher farther away from the cities).

The uneven coverage offered by contemporary news implies that part of the correlation between our variables may be the result of the fact that parishes closer to newspaper cities were more likely to appear in our database, rather than the consequence of protest against new machines. Moreover, although in principle the uneven coverage should not matter for our instrument, in practice parishes around cities tend to be more fertile (potential yield within 40 kilometers from one of these cities is 0.21 tons per hectare higher than beyond this limit, and the difference is significant at the 0.1 percent level). Thus, the fact that larger cities (or at least cities that print newspapers) tend to develop on more fertile ground may also bias our instrumental estimates.

In order to control for this possible confounding mechanism, we show that all our results are strengthened when we restrict our sample to those parishes that lie within 40 kilometers from the closest city. Restricting the sample in this fashion also alleviates a different concern: namely, that our results may be driven by the contrast between English parishes and Welsh parishes. English parishes specialized in cereal production and bore the brunt of the Swing riot. In contrast, Welsh parishes typically lie further west. There, pastoral agriculture was more common, and Wales remained almost untouched by the riots. While newspaper cities are fairly widespread across England, we only have data from two Welsh newspapers (the “Monmouthshire Merlin” of Newport in the South and the “North Wales Chronicle” of Bangor in the

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<sup>26</sup> The geography of Swing riots is reconstructed with official probate records analyzed by Hobsbawn and Rudé (2014) and it has been integrated and extended by the research group coordinated by Holland (2005) using the same probate records along with news reported in local newspapers.



North). Thus, restricting the sample to only those parishes within 40 km from a newspaper city effectively leaves out most of the Welsh parishes in our sample.<sup>27</sup>

On columns 1 and 2 of Table 6 we report beta coefficients of our OLS estimates after restricting ourselves to parishes within 40km of a newspaper town. Despite dropping one-fourth of our observations, significance improves and point estimates grow. When the dependent variable is the total number of Swing riots in panel (A), coefficient grows between 29 percent (without county fixed effects) and 58 percent (with fixed effects). Estimates also become more stable across specifications, suggesting that variation within counties is stronger where our variables are likely to be measured more precisely. When the dependent variable is agricultural riots in panel (B), the coefficient on number of threshing machines advertisements grows between 30 percent (without county fixed effects) and 45 percent (with county fixed effects).

Columns 3 and 4 of panel (A) of Table 6 report the first stage and columns 5 and 6 of both panels the reduced form of the restricted sample. The estimates are very similar to our baseline in section 4. In the first stage, point estimates never vary by more than 10 percent relative to the baseline and if anything they are more stable across specifications. Despite the smaller sample, significance is always preserved. In the reduced form, the point estimates differ from the baseline by 7 percent or less. The one exception is in the regression of agricultural riots when we add county fixed effects: in this case the beta coefficient of potential yield grows from 0.016 to 0.025, improving significance and getting closer to the coefficient of the specification without county fixed effects.

The last two columns of Table 6 show the two-stages least squares estimates on the restricted sample. The pattern is similar to that of the other regressions: in the specification with agricultural riots as dependent variable, the coefficient of number of threshing machine advertisements tend to be larger in the restricted sample, especially in the specification with county fixed effects, where the effect also becomes significant at the 10 percent level. In the regressions on the total number of riots, estimates remain very close to our baseline and always preserve significance. Overall, these results confirm that the uneven coverage of English parishes offered by 1800 newspapers is unlikely to be driving our results.

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<sup>27</sup> Removing also the parishes around Newport and Bangor produces results that are virtually identical to those shown here. These are available upon request.

#### 5.4 *Other types of protest: arson and threatening letters*

So far, we have focused on two main outcomes – the total number of Swing riots and agricultural riots (i.e. the subset of riots that targeted farm equipment). But what about other types of riots? The most common form of protest during the years 1830-32 was not the breaking of agricultural machines, but rather acts of arson in which rioters set haystacks or entire farms on fire (Holland, 2005, records 764 of these episodes, affecting 10 percent of the parishes). Another popular form of protest was the mailing of anonymous letters to landlords, farmers and overseers, threatening attacks if the recipient did not satisfy the demands of laborers (Holland lists 147 such episodes, across 2 percent of the parishes). The mythical character invoked by most letter writers – *Captain Swing* – in the end lent his name to the entire historical episode.

In this section, we study how the adoption of new machines affected other types of protest. In columns 1 through 3 of Table 7 we show the results of estimating equations (1) and (2) using as dependent variable either the total number of acts of arson or the total number of threatening letters. In panel (A) the dependent variable is the total number of fires. In the first column the coefficient on the number of threshing machines advertisements is positive and almost significant at the 10 percent level ( $p = 0.102$ ). Adding more controls in column 2 does not affect the point estimate, but it allows for sharper estimation of the coefficient ( $p = 0.087$ ). Finally, when we add county fixed effects, the coefficient drops by one-third and ceases to be significant at standard levels. Correlation is weaker when the dependent variable is the number of threatening letters. Here the point estimate is quite small and never statistically different from 0.

In columns 4-6 of Table 7 we report the estimates of the reduced form and in columns 7-9 the two-stages least squares estimated on these two outcomes. These tables tell a consistent story: the total number of acts of arson is strongly correlated with potential yield of wheat in all specifications of the reduced form. Moreover, the coefficient on the number of threshing machines is positive and significant at the 1 percent level in the two-stages least squares specification without county fixed effects, and at the 10.3 percent level once we add county fixed effects. Also, the number of threatening letters is strongly correlated with our instrument, as shown in columns 4 and 5 of panel (B). However this variation comes entirely across counties: when we add county fixed effects in column 6 of panel (B) the coefficient on potential yield becomes small and indistinguishable from 0. These results are confirmed in the last three columns of panel (B), which report the two-stages least squares estimates. Here too, our instrumented measure of machine adoption is positively and significantly

correlated with the threatening letters when we do not control for county fixed effects, and it becomes insignificant with county fixed effects.

Overall, these results point to a relationship between new machines and these two types of riots that is positive but not as strong as the one between the new machines and agricultural riots. This is especially true when we look at the use of threatening letters across English counties. However, the relationship is weaker within counties, especially when we look at the diffusion of Swing letters. One possible interpretation is that the general intensity of these protests across counties can be explained by the adoption of the new technology. However, within each of the 41 English counties, other sources of discontent may have been a more powerful driver of the diffusion of fires and threatening letters.

### *5.5 The influence of individual counties*

Are results driven by only a handful of counties – or do they hold in pretty much all parts of the country. To examine this question, we drop all observations from an individual county and re-estimate our main results. Appendix # gives an overview of the main findings. There is no evidence of a single county driving results. While coefficients are not identical across specifications, differences are few and far between.

## **6 Conclusions**

A large literature has analyzed the labor market effect of technological change. Following Autor's pioneering work (Autor, Levy, and Murnane 2003), there is now good evidence that routine jobs are increasingly being replaced by computers, with adverse effects on the wage share in the affected sectors (Acemoglu and Autor 2011; Acemoglu and Restrepo 2016). Recent trends in the labor market therefore echo those of the First Industrial Revolution, when labor was substituted by machines.

In this paper, we examine the extent to which labor-saving technical change can lead to social instability and political unrest. We look at one famous historical episode – the “Captain Swing” riots of 1830-32, which ushered in a period of important political and institutional reform (Aidt and Franck 2015). The importance of technological change in driving the riots has been seriously called into question (Mokyr, Vickers and Ziebarth, 2015). Using newly-compiled data on the diffusion of threshing machines, we first show that labor-saving technology was a key determinant of the probability of unrest. Based on data about soil suitability, we also show that the

link was causal, with areas exhibiting greater suitability of wheat cultivation showing both greater adoption of threshing machines and markedly higher incidence of riots. While many factors probably contributed to the outbreak of unrest in England and Wales in 1830-32, this is one of the very first cases for which a causal contribution of technological change can be demonstrated.

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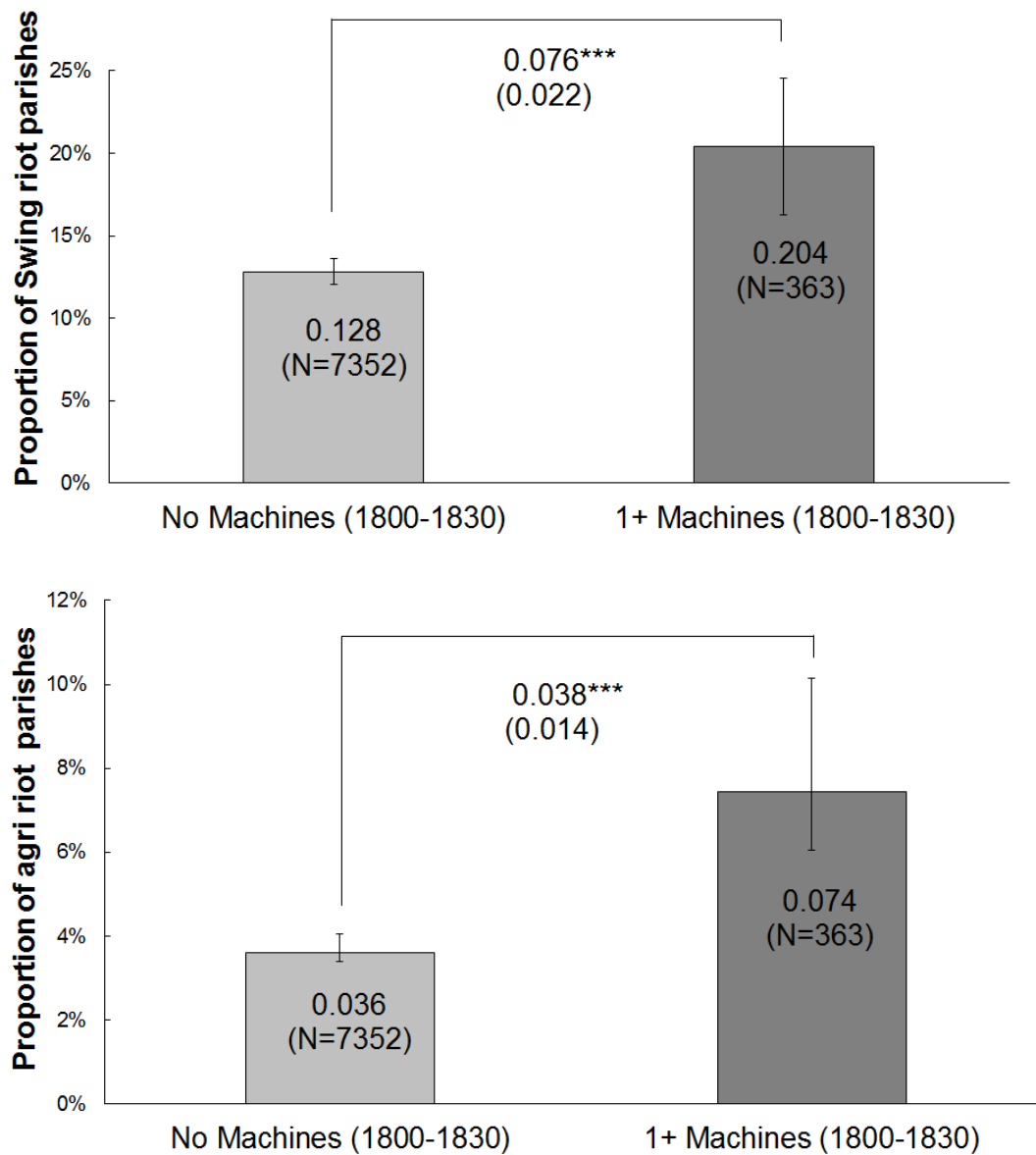
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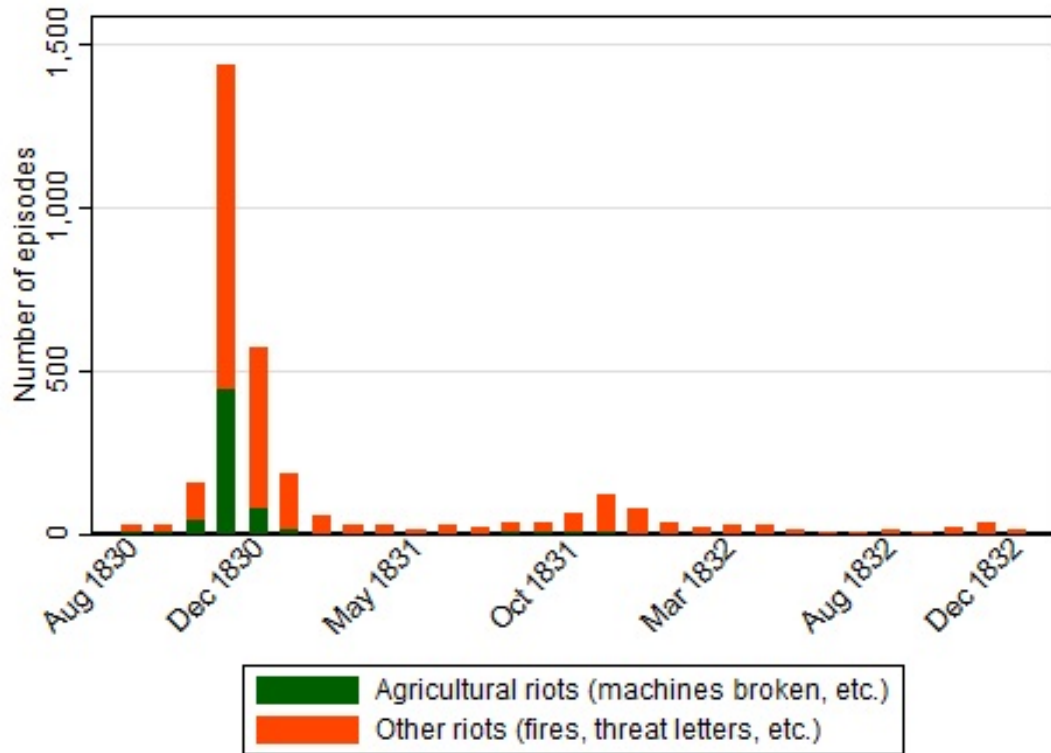
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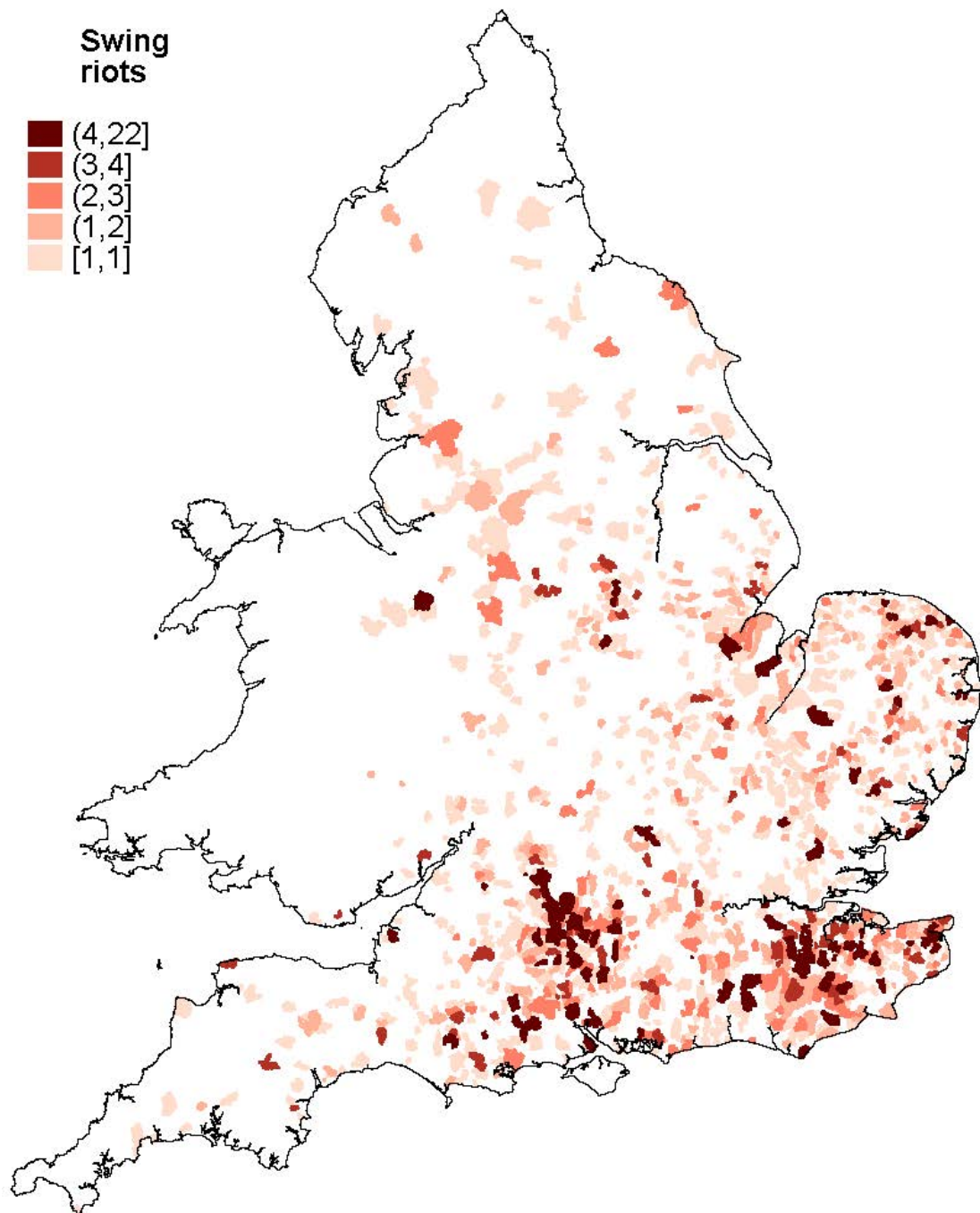
## FIGURES AND GRAPHS



**Figure 1.** Proportion of Swing riots (upper panel) and agricultural riots (lower panel), by whether a threshing machine was in use in the parish. Swing riots are all the riots in the Holland (2005) database of unrest events between 1830 and 1832; agricultural riots are those connected with attacks on threshing machines or other forms of agricultural capital. The left bars are for parishes with no advertisements of a threshing machine between 1800 and 1830, as reflected in the British Newspaper Archive; the right column is for places with at least one advertisement during this period. Cf. Section 3 for details of data construction and Appendix A for variable definitions.



**Figure 2.** Number of episodes associated to the "Swing" riots. In green we plot the number of "agricultural riots": events in which rural workers targeted agricultural machines and other capital of farms. In orange, we plot all other riots that were associated to "Swing": including threatening letters and fires. Source: Holland (2005).



**Figure 3.** Geographical distribution of episodes associated to the "Swing" riots. 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),  
**T**HE 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 4.** 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: The British Newspaper Archive.

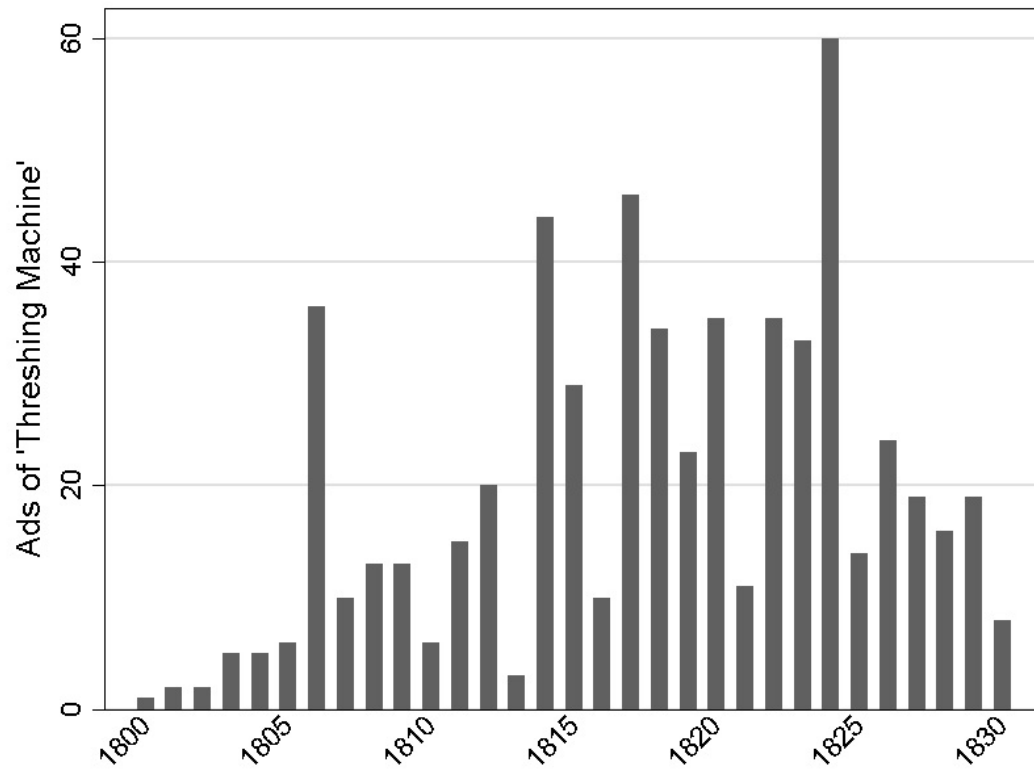
**W**M. FORGE, Threshing Machine Maker, WITHAM, near the North Bridge, Hull, begs leave to inform the gentlemen farmers and others, that he makes One, Two, Three, and Four-horse Machines on the newest and most improved plan.—W. F. flatters himself, from long experience in the above line, he can make 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:—

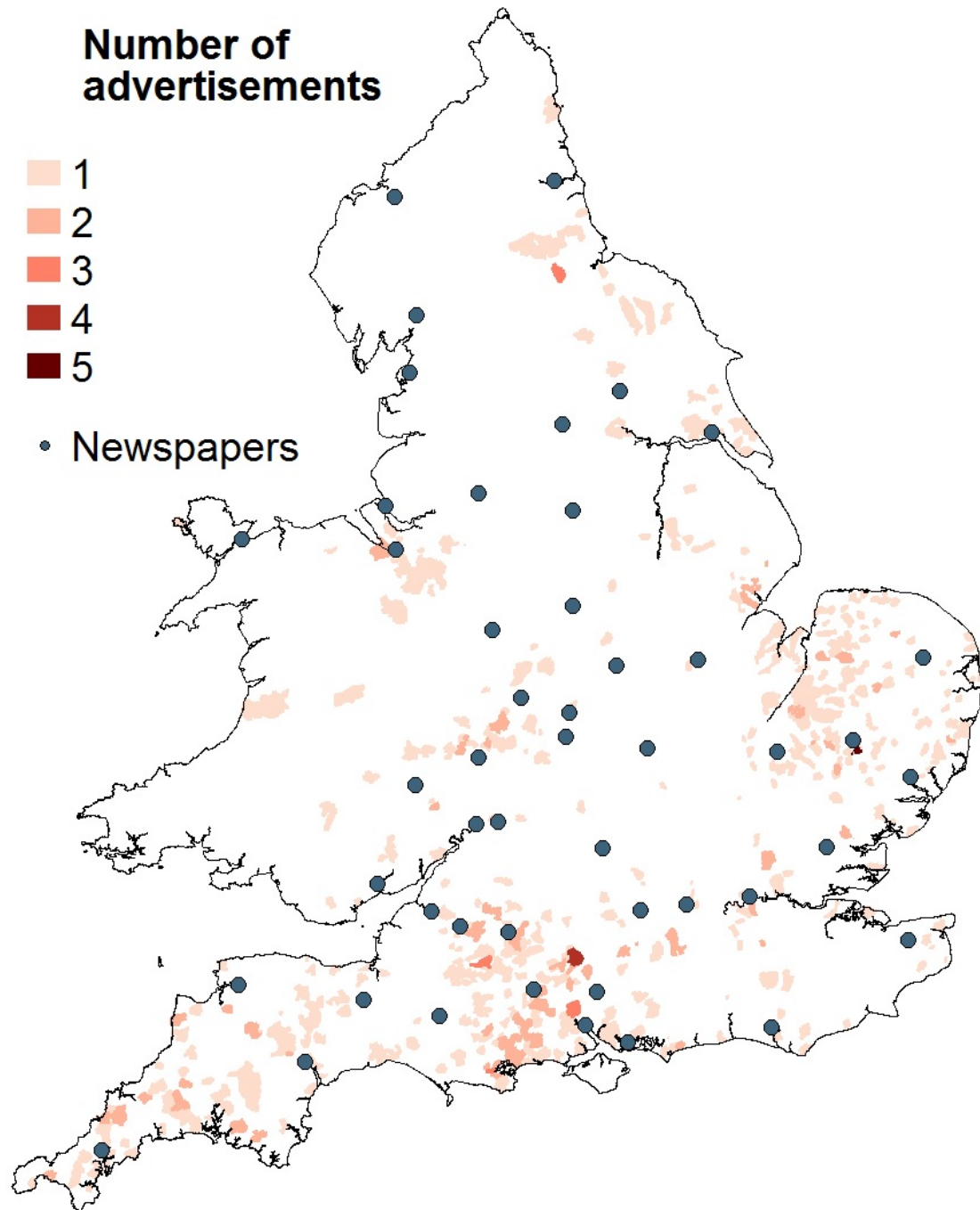
Machines.	Machines.
Mr. Watson, West Ella.....2	Mr. Johnson, Wistow.....1
Mr. Hudson, Newington.....1	Mr. Copland, ditto.....1
Mr. Thompson, Skidby.....2	Mr. Varley, ditto.....1
Mr. Hornby, Riston.....1	<i>Lincolnshire.</i>
Mr. Duggleby, Beswick.....1	Mr. Graham, Wisby.....1
Messrs. Jacksons, Middleton2	Mr. Johnson, Redbourn.....1
Mr. Richardson, Sunk Island 2	Rev. Mr. Curtis, Branston....1
George Knowsley, Esq.	Rev. Mr. Dymoke, Scri-
Cottingham.....2	velsby.....1
Mr. Screwton, Little Weton 2	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 Park 1
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, Ferriby ....1	Mr. Smith, East Markham...1
Mr. Tindle, Keyingham .....1	Mr. Berket, Bestwood Park..1
Mr. Brankley, Humbleton...1	Mr. Johnson, Preston.....1
Mr. Smailes, Oustwick.....1	

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

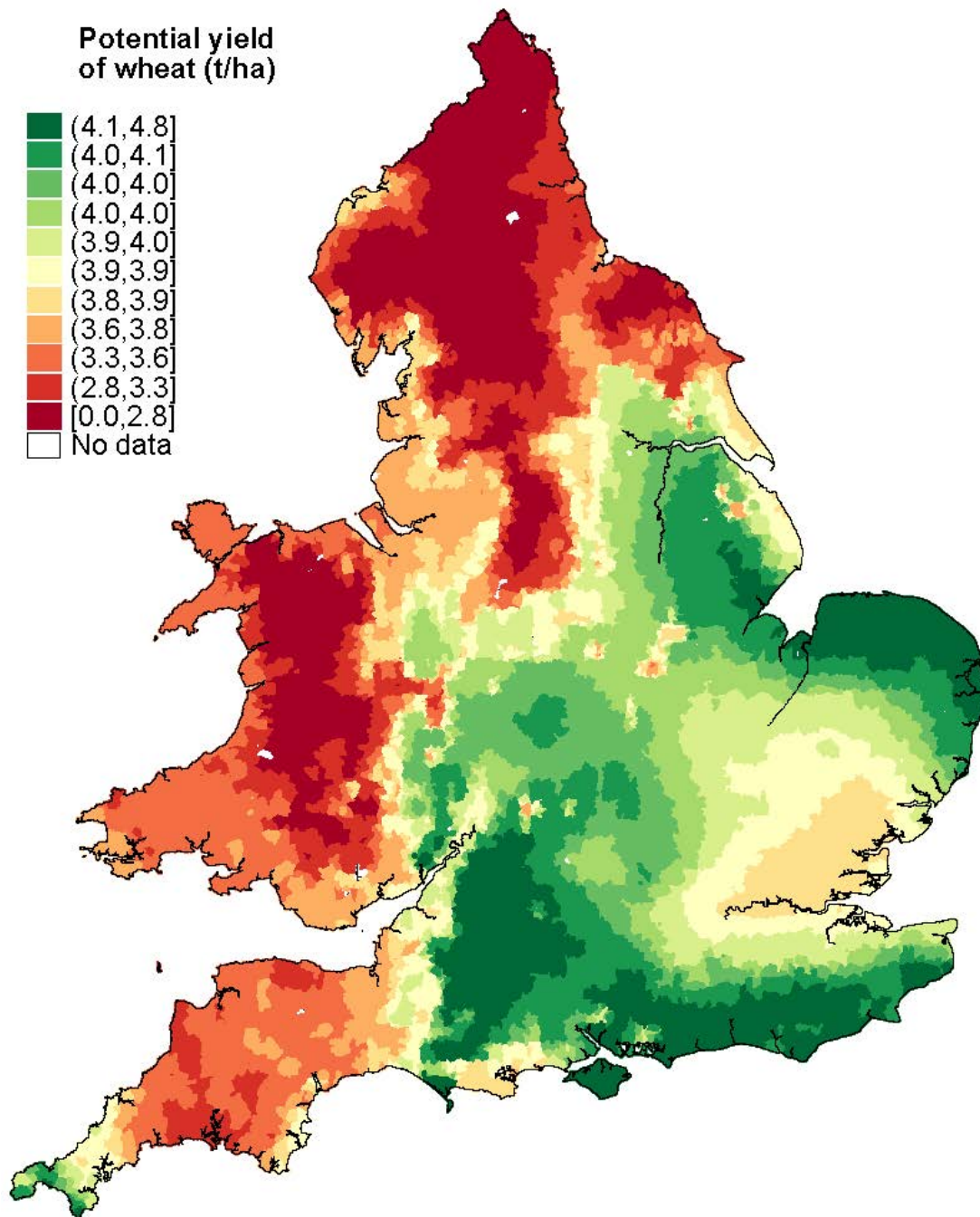
**Figure 5.** Example of an advertisement. On February the 2nd, 1808, the *Stamford Mercury* published the notice of William Forge, a threshing machine maker, that advertised his product by suggesting to contact one of his past customers. We code each of the parishes listed above as parishes in which at least one threshing machine is in operation. Source: The British Newspaper Archive.



**Figure 6.** Number of advertisements for "threshing machines" that appeared on British newspapers: 1800-1830. Source: The British Newspaper Archive.

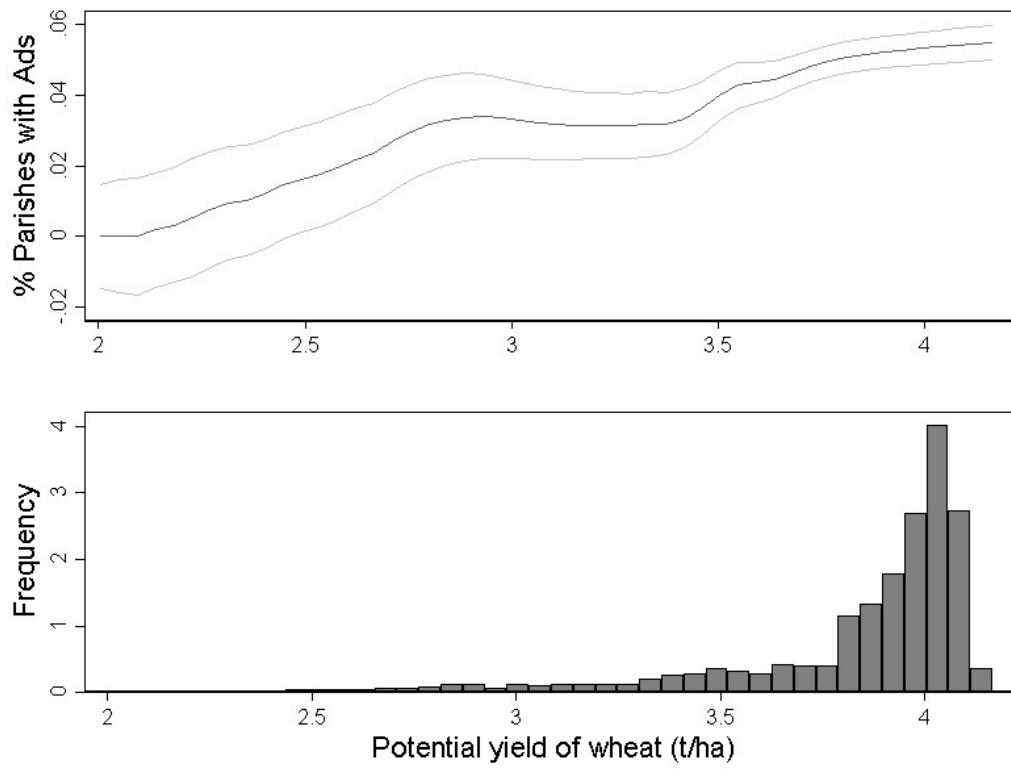


**Figure 7.** Geographical distribution of the advertisements for "threshing machines" that appeared on British newspapers: 1800-1830. Blue dot identify cities that printed at least one of the newspaper from which we collect our advertisements. Source: The British Newspaper Archive.

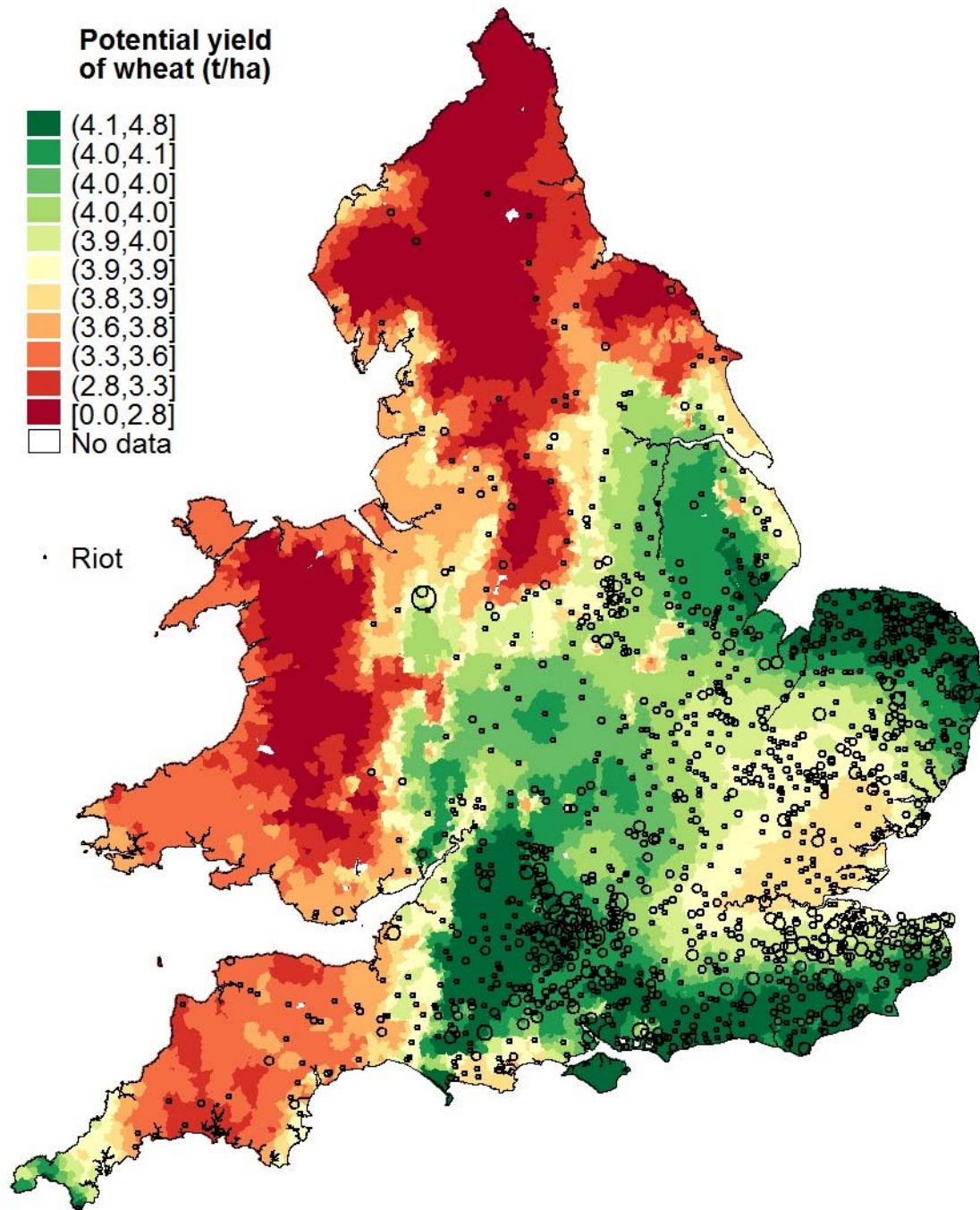


**Figure 8.** Potential yield attainable for wheat with intermediate level of agricultural inputs and no artificial irrigation (in tonnes per hectare). Source: GAEZ FAO (2015).

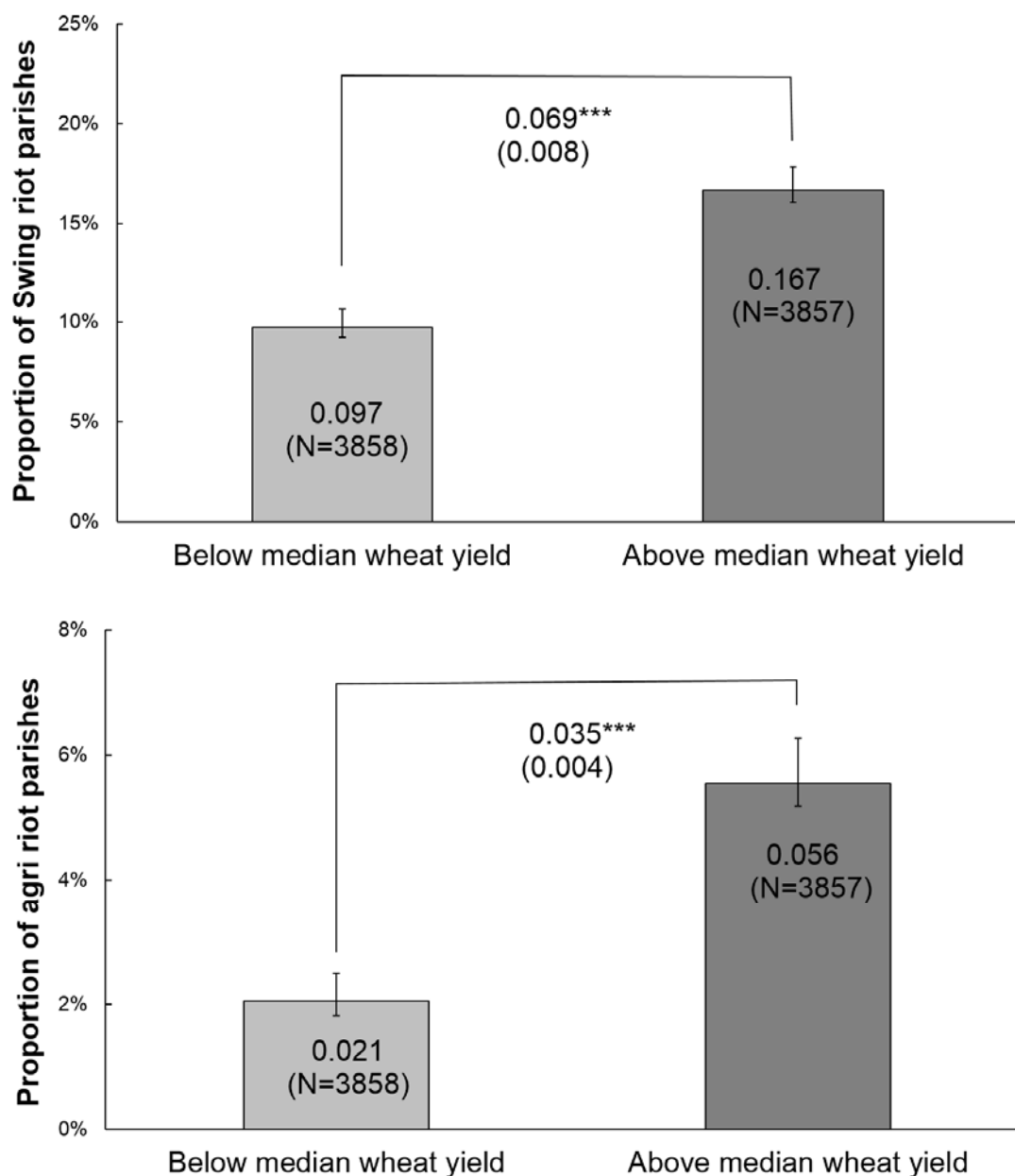




**Figure 9.** Visualization of the First Stage.



**Figure 10.** Potential yield attainable for wheat with intermediate level of agricultural inputs and no artificial irrigation and ‘Swing’ riots. Black dots show the centroid of the parishes in which ‘Swing’ riots happened, and they are proportional to the number of episodes recorded in each of these parishes. Sources: GAEZ FAO (2015) and Holland (2005).



**Figure 11.** Proportion of Swing riots (upper panel) and agricultural riots (lower panel), by suitability of soil to wheat cultivation. Agricultural riots are those connected with attacks on threshing machines or other forms of agricultural capital. The left bars are for parishes with potential yield of wheat below the median for English and Welsh parishes (3.98 tonnes per hectare), the right column are the parishes with potential yield above the median. Cf. Section 3 for details of data construction and Appendix A for variable definitions.

## TABLES

<i>Main variables</i>	Average	St. Dev.	Parishes
"Threshing machine" advertisements	0.053	0.252	7715
Swing riots	0.260	0.951	7715
<i>Agricultural riots</i>	0.060	0.380	7715
<i>Fires</i>	0.099	0.465	7715
<i>Threatening letters</i>	0.019	0.183	7715
<i>Agricultural suitability</i>	Average	St. Dev.	Parishes
Potential yield of wheat	3.836	0.404	7715
Number of days grass can grow	216.1	29.71	7715
<i>Parish characteristics</i>	Average	St. Dev.	Parishes
1821 Population	860.7	2340	7715
Share of families in agriculture in 1821	0.690	0.235	7715
Sex ratio in 1821	1.025	0.161	7715
log(Parish area)	15.99	0.936	7715
Distance to closest city with newspaper (Km)	31.78	23.96	7715

**Table 1.** Summary statistics.

Dep. var.:	Number of "Swing" riots			Number of agricultural riots		
"Threshing machine" Ad	0.064*** (0.020)	0.066*** (0.020)	0.040** (0.020)	0.070*** (0.025)	0.072*** (0.025)	0.056** (0.025)
log(1821 population)	0.172*** (0.015)	0.202*** (0.018)	0.187*** (0.019)	0.068*** (0.011)	0.095*** (0.018)	0.099*** (0.020)
log(Parish area)		-0.001 (0.013)	0.044** (0.017)		-0.013 (0.014)	0.006 (0.019)
log(sex ratio)		0.009 (0.008)	-0.006 (0.008)		0.006 (0.008)	0.007 (0.008)
% families in agriculture		0.033** (0.013)	-0.011 (0.013)		0.031** (0.014)	0.010 (0.014)
log(dist. to journal city)		0.013 (0.010)	0.038*** (0.012)		-0.018* (0.010)	-0.000 (0.012)
log(number of days grass grows)		-0.073*** (0.008)	-0.025 (0.030)		-0.033*** (0.009)	0.058* (0.033)
County fixed effects (41)			✓			✓
Parishes	7,715	7,715	7,715	7,715	7,715	7,715
R-squared	0.036	0.043	0.122	0.011	0.013	0.050

**Table 2.** Threshing machines and riots. Columns (1) and (4) report estimates of regression (1) when controlling for 1821 population only; columns (2) and (5) report estimates of regression (1) and columns (3) and (6) report estimates of regression (2) in the text. Dependent variable is the number of "Swing riots" in columns (1)-(3) and the number of "agricultural riots" in columns (4)-(6). The level of observation is the parish. Robust standard errors are in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel (A)	<u>First Stage</u>			<u>Reduced Form</u>			<u>Second Stage</u>		
Dependent variable:	"Threshing machine" Ad			Number of "Swing" riots					
Potential yield of wheat	0.056***	0.086***	0.033**	0.132***	0.140***	0.036***			
	(0.009)	(0.011)	(0.015)	(0.009)	(0.011)	(0.011)			
"Threshing machine" Ads							2.351***	1.628***	1.068*
							(0.375)	(0.223)	(0.548)
Rubin-Anderson test ( <i>p</i> -value)							[0.000]	[0.000]	[0.001]
R-squared	0.015	0.019	0.063	0.049	0.054	0.121			
First Stage F-statistic	41.8	62.3	5.1						
Panel (B)				<u>Reduced Form</u>			<u>Second Stage</u>		
Dependent variable:				Number of agricultural riots					
Potential yield of wheat				0.084***	0.084***	0.016**			
				(0.007)	(0.009)	(0.008)			
"Threshing machine" Ads							1.496***	0.970***	0.468
							(0.251)	(0.145)	(0.305)
Rubin-Anderson test ( <i>p</i> -value)							[0.000]	[0.000]	[0.049]
R-squared				0.012	0.013	0.047			
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Parish characteristics		✓	✓		✓	✓		✓	✓
County Fixed Effects (41) Parishes			✓			✓			✓
	7,715	7,715	7,715	7,715	7,715	7,715	7,715	7,715	7,715

**Table 3.** Instrumental variable regressions. The table reports in columns (1)-(3) of Panel (A) estimates of equation (3); in columns (4)-(6) estimates of equation (4) and in columns (7)-(9) estimates of equations (1) and (2) where the endogenous variable "Threshing Machine" Ad is instrumented with the potential yield of wheat (medium inputs). Dependent variable is the number of "Threshing Machine" Ad in columns (1)-(3) of Panel (A); the number of "Swing" riots in columns (4)-(9) of Panel (A) and the number of "agricultural riots" in columns (4)-(9) of Panel (B). Parish characteristics are the log of the Parish area, the log of the sex ratio, the share of families chiefly employed in agriculture in 1821, the log of the distance to the closest city that publishes a newspaper and the log of the number of days in which the grass can grow. The Rubin-Anderson test has null hypothesis that the coefficient of the excluded instrument in the reduced form regression is not statistically different from 0. The level of observation is the parish. Robust standard errors are in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel (A)	<u>First Stage</u>			<u>Reduced Form</u>			<u>Second Stage</u>		
Dependent variable:	"Threshing machine" Ad			Number of "Swing" riots					

variable:

Potential yield of wheat (low ins)	0.066***	0.100***	0.031*	0.131***	0.140***	0.023**			
	(0.009)	(0.012)	(0.018)	(0.008)	(0.010)	(0.010)			
“Threshing machine” Ads							1.973***	1.401***	0.739
							(0.280)	(0.187)	(0.517)
Rubin-Anderson test ( <i>p</i> -value)							[0.000]	[0.000]	[0.023]
R-squared	0.016	0.021	0.062	0.049	0.054	0.121			
First Stage F-statistic	56.9	68.3	3.0						

Panel (B) Dependent variable:	<u>Reduced Form</u>			<u>Second Stage</u>					
	Number of agricultural riots								
Potential yield of wheat (low ins)				0.082***	0.083***	0.012			
				(0.008)	(0.009)	(0.009)			
“Threshing machine” Ads							1.241***	0.826***	0.402
							(0.192)	(0.128)	(0.372)
Rubin-Anderson test ( <i>p</i> -value)							[0.000]	[0.000]	[0.185]
R-squared				0.012	0.013	0.047			
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Parish characteristics		✓	✓		✓	✓		✓	✓
County Fixed Effects (41)			✓			✓			✓
Parishes	7,715	7,715	7,715	7,715	7,715	7,715	7,715	7,715	7,715

**Table 4.** Robustness to definition of suitability of wheat production. The table reports in columns (1)-(3) of Panel (A) estimates of equation (3); in columns (4)-(6) estimates of equation (4) and in columns (7)-(9) estimates of equations (1) and (2) where the endogenous variable "Threshing Machine" Ad is instrumented with the potential yield of wheat (low inputs). Dependent variable is the number of "Threshing Machine" Ad in columns (1)-(3) of Panel (A); the number of "Swing" riots in columns (4)-(9) of Panel (A) and the number of "agricultural riots" in columns (4)-(9) of Panel (B). Parish characteristics are the log of the Parish area, the log of the sex ratio, the share of families chiefly employed in agriculture in 1821, the log of the distance to the closest city that publishes a newspaper and the log of the number of days in which the grass can grow. The Rubin-Anderson test has null hypothesis that the coefficient of the excluded instrument in the reduced form regression is not statistically different from 0. The level of observation is the parish. Robust standard errors are in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel (A)									
Dependent variable:				Number of "Swing" riots			Number of agricultural riots		
"Threshing machine" Ads				0.064	0.066	0.040	0.070	0.072	0.056
Huber-White robust s.e.				(0.020)***	(0.020)***	(0.020)**	(0.025)**	(0.025)***	(0.025)**
Conley s.e.: cutoff 20 Km				(0.022)***	(0.022)***	(0.020)**	(0.025)***	(0.025)***	(0.024)**
Conley s.e.: cutoff 50 Km				(0.027)**	(0.028)**	(0.022)*	(0.026)***	(0.026)***	(0.023)**
Conley s.e.: cutoff 100 Km				(0.030)**	(0.031)**	(0.023)*	(0.028)**	(0.029)**	(0.025)**
Clustered s.e.: closest city with newspaper				(0.023)***	(0.023)***	(0.021)*	(0.026)***	(0.026)***	(0.024)**
Panel (B)									
Dependent variable:		First Stage			Reduced Form				
		"Threshing machine" Ad			Number of "Swing" riots			Number of agricultural riots	
Potential yield of wheat	0.056	0.086	0.033	0.132	0.140	0.036	0.084	0.084	0.016
Huber-White robust s.e.	(0.009)***	(0.011)***	(0.015)**	(0.009)***	(0.011)***	(0.011)***	(0.007)***	(0.009)***	(0.008)**
Conley s.e.: cutoff 20 Km	(0.013)***	(0.016)***	(0.016)**	(0.016)***	(0.019)***	(0.013)***	(0.013)***	(0.014)***	(0.011)
Conley s.e.: cutoff 50 Km	(0.020)***	(0.026)***	(0.016)**	(0.027)***	(0.031)***	(0.014)***	(0.019)***	(0.022)***	(0.012)
Conley s.e.: cutoff 100 Km	(0.025)**	(0.033)***	(0.015)**	(0.036)***	(0.043)***	(0.015)**	(0.025)***	(0.029)***	(0.013)
Clustered s.e.: closest city with newspaper	(0.017)***	(0.022)***	(0.015)**	(0.024)***	(0.028)***	(0.015)**	(0.018)***	(0.020)***	(0.012)
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Parish characteristics		✓	✓		✓	✓		✓	✓
County Fixed Effects (41)			✓			✓			✓
Parishes	7,715	7,715	7,715	7,715	7,715	7,715	7,715	7,715	7,715

**Table 5.** Robustness to spatial correlation. The table reports in Panel (A) on columns (4) and (7) estimates of regression (1) when controlling for 1821 population only; in columns (5) and (8) estimates of regression (1); and in columns (6) and (9) estimates of equation (2). In Panel (B) it reports on columns (1)-(3) estimates of equation (3), and on columns (4)-(9) estimates of equation (4). Dependent variable is the number of "Swing" riots in columns (4)-(6) of Panels (A) and (B); the number of " agricultural riots" in columns (7)-(9) of Panels (A) and (B) and the number of "Threshing Machine" Ad in columns (1)-(3) of Panel (B). Parish characteristics are the log of the Parish area, the log of the sex ratio, the share of families chiefly employed in agriculture in 1821, the log of the distance to the closest city that publishes a newspaper and the log of the number of days in which the grass can grow. The level of observation is the parish. Standard errors are in parentheses and are computed with the method described on the leftmost column. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.



	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel (A)	<u>OLS</u>		<u>First Stage</u>		<u>Reduced Form</u>		<u>Second Stage</u>	
Dependent variable:	Number of "Swing" riots		"Threshing machine" Ad		Number of "Swing" riots			
"Threshing machine" Ads	0.083***	0.063**					1.622***	0.943*
	(0.026)	(0.025)					(0.280)	(0.556)
Rubin-Anderson test ( <i>p</i> -value)							[0.000]	[0.010]
Potential yield of wheat			0.080***	0.036**	0.130***	0.034**		
			(0.013)	(0.017)	(0.012)	(0.013)		
R-squared	0.046	0.123	0.023	0.070	0.054	0.120		
First Stage F-statistic			35.7	4.5				
Panel (B)	<u>OLS</u>				<u>Reduced Form</u>		<u>Second Stage</u>	
Dependent variable:	Number of agricultural riots				Number of agricultural riots			
"Threshing machine" Ads	0.093***	0.081***					1.085***	0.703*
	(0.031)	(0.031)					(0.199)	(0.399)
Rubin-Anderson test ( <i>p</i> -value)							[0.000]	[0.004]
Potential yield of wheat					0.087***	0.025***		
					(0.010)	(0.009)		
R-squared	0.015	0.052			0.013	0.046		
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓
Parish characteristics	✓	✓	✓	✓	✓	✓	✓	✓
County Fixed Effects (41)		✓		✓		✓		✓
Parishes	5,806	5,806	5,806	5,806	5,806	5,806	5,806	5,806

**Table 6.** Robustness to restricting the sample to the parishes within 40 kilometers from the closest newspaper. The table reports in Panel (A) on columns (1)-(2) estimates of equation (3); on column (3) and (4) of both Panels estimates of equations (1) and (2); on columns (5) and (6) of both panels estimates of equation (4) and on columns (7) and (8) of both Panels estimates of equations (1) and (2) where the endogenous variable "Threshing Machine" Ad is instrumented with the potential yield of wheat (medium inputs). Dependent variable is the number of "Threshing Machine" Ad in columns (1)-(2) of Panel (A); the number of "Swing" riots in columns (3)-(8) of Panels (A) and the number of "agricultural riots" in columns (3)-(8) of Panels (B). In all regressions the sample is restricted to only those parishes that lie within 40 kilometers from the closest city that publishes at least one newspaper. Parish characteristics are the log of the Parish area, the log of the sex ratio, the share of families chiefly employed in agriculture in 1821, the log of the distance to the closest city that publishes a newspaper and the log of the number of days in which the grass can grow. The level of observation is the parish. Robust standard errors are in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel (A)		<u>OLS</u>			<u>Reduced Form</u>			<u>Second Stage</u>	
Dependent variable:	Number of incendiary attacks								
“Threshing machine” Ads	0.032	0.034*	0.022				1.567***	1.072***	0.888
	(0.020)	(0.020)	(0.020)				(0.270)	(0.179)	(0.552)
Rubin-Anderson test ( <i>p</i> -value)							[0.000]	[0.000]	[0.029]
Potential yield of wheat				0.088***	0.092***	0.030**			
				(0.008)	(0.011)	(0.014)			
R-squared	0.021	0.027	0.061	0.027	0.032	0.061			
Panel (B)		<u>OLS</u>			<u>Reduced Form</u>			<u>Second Stage</u>	
Dependent variable:	Number of threatening letters								
“Threshing machine” Ads	0.014	0.014	0.011				0.659***	0.519***	0.037
	(0.014)	(0.014)	(0.014)				(0.184)	(0.139)	(0.329)
Rubin-Anderson test ( <i>p</i> -value)							[0.000]	[0.000]	[0.911]
Potential yield of wheat				0.037***	0.045***	0.001			
				(0.009)	(0.011)	(0.011)			
R-squared	0.013	0.014	0.030	0.014	0.016	0.030			
log(1821 population)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Parish characteristics		✓	✓		✓	✓		✓	✓
County Fixed Effects (41) Parishes			✓			✓			✓
	7,715	7,715	7,715	7,715	7,715	7,715	7,715	7,715	7,715

**Table 7.** Other forms of protest: incendiary attacks and threatening letters. The table reports on column (1)-(3) of both Panels estimates of equations (**Error! Reference source not found.**), (1) and (2) respectively; on columns (4)-(6) of both panels estimates of equation (4) and on columns (7)-(9) of both Panels estimates of equations (1) and (2) where the endogenous variable "Threshing Machine" Ad is instrumented with the potential yield of wheat (medium inputs). Dependent variable is the number incendiary attacks in Panel (A) and the number of threatening letters in Panels (B). Parish characteristics are the log of the Parish area, the log of the sex ratio, the share of families chiefly employed in agriculture in 1821, the log of the distance to the closest city that publishes a newspaper and the log of the number of days in which the grass can grow. The level of observation is the parish. Robust standard errors are in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

## A Data Appendix

In this appendix we describe data sources and variable construction.

**"Threshing machine" ads.** We collect data on the number of threshing machines advertised in English and Welsh newspapers from the website "British Newspaper Archive."<sup>28</sup> Within the universe of the 66 regional newspaper published between 1800 and 1830, we search for the exact string "threshing machine". We restrict our search to those articles that are 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. We also consider the information provided by some threshing machine manufacturers who list name and location of their clients: these clients are farmers located in parishes all over the country (see Figure 5 for an example). We drop all advertisements of threshing machines producers that only provide information about the location of the factory, usually an industrial town. In the last step, we manually geo-locate each advertisement, and find the parish in which the threshing machine or the farm is located. Our geographical reference is a map of historical parishes in England and Wales prepared by Southall and Burton (2004). Whenever we link a parish to one of our advertisements, we add 1 to the number of threshing machines we find in that parish. However, we only consider a single threshing machine whenever we find the same advertisement printed more than once.

**Swing riots.** Data on Swing riots comes from a database compiled by the Family and Community Historical Research Society (Holland 2005). It contains a comprehensive list of Captain Swing incidents between January 1830 and December 1832. The information comes from official records and historical newspapers and contains the exact date, the parish, and the type of crime perpetrated by rioters. We manually match the parish of each episode to the historical map of English and Welsh parishes (Southall and Burton, 2004). On this map, we identify the location of these riots with the county (variable COUNTY) and either the name of the parish (variable PAR) or the name of the place (variable PLA). For the variable *Swing riot* we consider every episode listed in the database.

**Agricultural riots.** These riots are a subset of the Swing riots: they consist of every episode recorded as "machine breaking" (either threshing machines or other agricultural machines), "damage of crop, fences etc.," "gleaning riot," or "malicious killing of livestock". Breaking of threshing machines represent the overwhelming majority of agricultural riots: 77 percent of these episodes are classified as "Machine breaking (threshing machines)". Destruction of

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<sup>28</sup> Accessible at: <http://www.britishnewspaperarchive.co.uk/>.

other agricultural machines such as winnowing machines represent another 7 percent of these episodes.

**Incendiary attacks.** These events are a subset of the Swing riot variable: they consist of every episode recorded as "incendiarism," "attempted incendiarism," or "incitement to commit incendiarism".

**Threatening letters.** These events are a subset of the Swing riot variable: they consist of every episode recorded as "sending anonymous threatening letters," "seditious notice," or "demanding with menaces."

**Potential yield of wheat (intermediate and 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  $9.25 \times 9.25$  kilometers. We first resample the raster on a finer grid of  $0.0185 \times 0.0185$  kilometers with the "nearest" method. Next, we superimpose the raster to the historical map of English and Welsh parishes prepared by Southall and Burton (2004), and for every cell of the raster we take its centroid and assign it to the parish where this centroid falls. Finally, for every parish we take the average potential yield of all the cells that fall in the parish.

**Number of days grass can grow.** This variable is computed by Down *et al.* (1981), and represent the total number of days in which grass can grow during a calendar year. The original data appears as an image on the book of Down *et al.* (1981): we geo-reference and digitize the map from the book. Next, we convert the map to a raster and superimpose it to the map of historical parishes of England and Wales. Finally, we resample and assign each cell of the raster to the parish where this cell falls, as we did for the potential yield of wheat. In the regressions we use the natural logarithm of this variable.

**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 to the historical map of English and Welsh parishes using the county (variable ANC\_CNTY) and parish (variable ANC\_PAR) reported in the Census. In the regressions we use the natural logarithm of this variable.

**Share of families in agriculture in 1821.** This variable is constructed 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.** The sex ratio is calculated 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. In the regressions we use the natural logarithm of this variable.

**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 prepared by Southall and Burton (2004). In the regressions we use the natural logarithm of this variable.

**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 city in which these newspapers were printed. We then calculate the distance of the centroid of every parish in our map to each of the cities that print at least one newspaper. Finally, we keep only the distance to the closest city. In the regressions we use the natural logarithm of this variable.

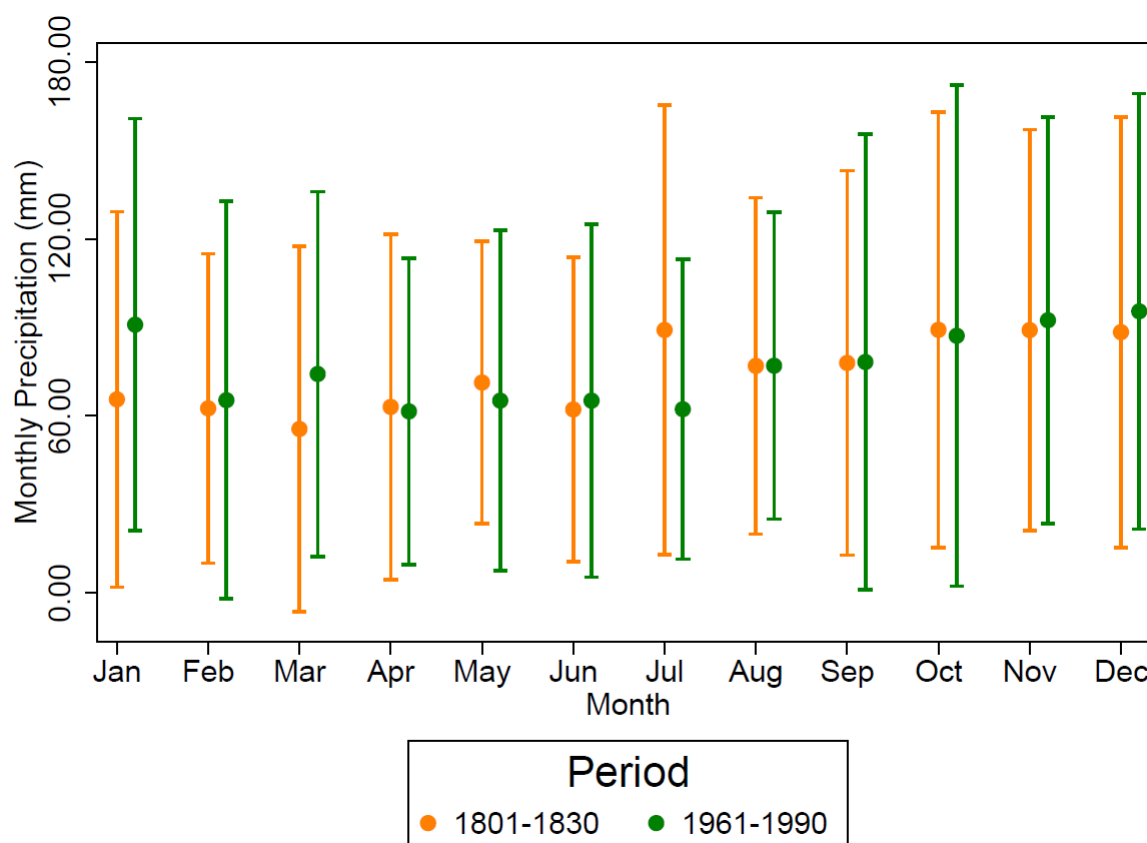
## **B Productivity of Threshing Machine**

## C Additional Results

### C.1 Historical Weather in England

FAO researchers compute potential yield for wheat based on soil characteristics, historical weather records and an agronomic model that assumes the use of a specific level of inputs. One possible concern with this measure has to do with the weather conditions used for these calculations: while FAO researchers use average weather conditions for the period 1961-1990, we are interested in potential yield of wheat for the period 1801-1830, which will depend on weather conditions at the beginning of the 1800.

But just how much did weather change over the last 200 years? To answer this question we turned to the historical series maintained by the Hadley Centre at the UK Meteorological Office, and obtained monthly precipitation records across England and Wales for the years 1801-1830. We then compared the average monthly precipitation during these 30 years with the average monthly precipitation in the years 1961-1990. The following graph plots these averages for the two periods along with their 95 percent intervals.



**Figure C1.** 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: 23,96mm, s.e.: 24.72).

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

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 we have historical records for the period under study. Moreover, these records are admittedly noisy, as they are available only for the whole England. Nevertheless, the analysis of these records suggest that the assumption that weather in 1961-1990 is a good proxy for weather at the beginning of the 1800 is reasonable.