Famine, Finance, and Adjustment to Environmental Shock: Microcredit and the Great Famine in Ireland

Goodspeed, Tyler

Harvard University

July 2013

Famine, Finance, and Adjustment to Environmental Shock: Microcredit and the Great Famine in Ireland

July 2013

Tyler Beck Goodspeed*

Abstract

The Great Famine of Ireland from 1845-51 ranks as one of the most lethal of all time, claiming approximately one eighth of the country's population. Utilizing Famine Relief Commission reports to develop a micro-level dataset of blight severity, I find that in the short run, districts more severely infected by blight experienced larger population declines and accumulations of buffer livestock. In the medium and long runs, however, worse affected districts experienced greater substitutions toward other tillage crops and grazing livestock. Using annual reports of the Irish Loan Funds, I further find that access to microfinance credit was an important factor in short- and long-run adjustment to blight. Districts with at least one microfinance fund during the Famine experienced substantially smaller population declines and larger increases in buffer livestock during and immediately after the Famine, and greater medium- and long-run substitutions toward other crops and grazing livestock, than districts without a fund.

Keywords: microfinance, famine, Ireland, economic history, agriculture, adjustment

* Harvard University (tgoodsp@fas.harvard.edu). I thank Richard Hornbeck, Cormac Ó Gráda, Joel Mokyr, Benjamin Friedman, Sean Barrett, Peter Solar, Liam Kennedy, Emma Rothschild, and seminar participants at LSE, MIT, Harvard, and Queens University Belfast for detailed comments and suggestions. I thank Aidan Hollis and Arthur Sweetman for generously sharing their data on the Irish Loan Funds, and Jenna Pace and Seth Rose for mapping support. I am also grateful to Will Hamilton for invaluable research assistance.

An important feature of agricultural economies with incomplete markets is that short-run adjustments to adverse production shocks are often impeded by binding constraints that may be relaxed only over the long run (Swinton 1988; de Janvry, Fafchamps, and Sadoulet 1991; Besley and Case 1993; Foster and Rosenzweig 1995; Conley and Udry 2010). In particular, uncertainty, as well as capital and land constraints, can result in demographic change constituting the primary short-run margin of adjustment (Rosenzweig and Stark 1989; Rosenzweig and Wolpin 1993; Townsend 1994; Udry 1994; Dercon 1996; Fafchamps, Udry, and Czukas 1998; Munshi 2004). Research has also demonstrated that production shocks in the form of adverse environmental change are especially harmful to developing economies, with the threat likely to intensify (World Bank 2009; Dell, Jones, and Olken 2012). Thus, while recent studies have analyzed economic adaptation to environmental change in more developed settings, it is increasingly important to understand such adjustment in developing contexts (Hornbeck 2012). Historical episodes provide a unique opportunity to analyze both short- and (very) long-run adaptation to environmental shocks that is not possible in more contemporary studies (Reardon, Delgado, and Matlon 1992; Gine and Klonner 2005; Kazianga and Udry 2006; Duflo, Kremer, and Robinson 2008).

This paper analyzes adjustment by the undercapitalized, subsistence economy of nineteenth-century Ireland to the shock of the Great Famine of 1845-51. The Great Irish Famine was the last major famine in Western European history. Claiming more than one million victims—one-eighth of Ireland's pre-Famine population—the catastrophe ranks as one of the worst instances of mass starvation in modern history. Including more than one million who emigrated between 1845 and 1851, the island's total population fell by between 20-25%, and has never since returned to its pre-Famine level. *Phytophthora infestans*, the fungal blight that devastated Ireland's potato crop during the Famine, constituted a short- and long-run adverse shock to the staple crop of Irish agriculture, yet one that left all other crops, as well as grazing livestock, untouched. I therefore examine the short- and long-run effects of potato blight on changes in Irish population and agriculture and in particular the role of credit constraints in hindering adjustment.

I find that regions suffering more heavily from *P. infestans* experienced greater immediate population declines and short-run accumulations of buffer livestock, while over the medium and long runs adaptation occurred through substantial and permanent substitutions away from potato cultivation toward other tillage crops and grazing livestock. Specifically, baronies that were severely or considerably infected by blight in 1845-46 experienced population declines that were 17.3% and 13.0% greater between 1841 and 1851 than moderately infected baronies, with the gap persisting through the end of the century.[1] In the short run, the average farm in baronies severely or considerably affected by blight increased stocks of poultry—a traditional buffer against crop failure—relative to the average farm in moderately affected baronies, while in the long run more severe blight infection was associated with greater increases in per-farm holdings of grazing stock, particularly cattle and sheep. Only after two successive harvest failures did more adversely impacted baronies begin to substantially reduce acreage under potato crop, with the potato's share of total tillage acreage in the long run declining by 15.7 and 12.3 percentage points more in severely and considerably versus moderately impacted baronies.

I also find that microfinance lending by the Irish Loan Funds played a significant role in non-demographic adjustment to blight. The presence of at least one Loan Fund in a severely affected barony during at least one of the Famine years between 1845 and 1851 was associated with a 42.1% smaller population decline by 1851. Loan Fund lending appears both to have enabled earlier crop substitutions away from the potato and the maintenance of larger buffer livestock holdings during and immediately after the Famine. Specifically, severely affected baronies with a Loan Fund increased livestock holdings by approximately 2 more pigs and 8 more chickens per farm by 1850 than those without. Long-run adaptation through increases in per-farm holdings of grazing livestock was also greater and occurred earlier in severely infected baronies with a Loan Fund versus those without. To address potential selection bias in the location of microloan funds, I use an instrumental variables strategy that exploits the unique historical provenance of these funds. Since the first Loan Fund was established by the Dublin Musical Society, which then encouraged other Irish musical societies to launch similar microloan schemes, in robustness checks I use the location of Association of Irish Musical Societies member organizations to instrument for the location of Loan Funds.

[1] A barony is an Irish administrative unit, used mainly for cadastral purposes. It is larger than a township or civil parish, but smaller than a Poor Law Union or county.

The organization of the remainder of this paper is as follows. Section I provides a historical summary of the Great Famine and the Irish Loan Funds. Section II develops a formal model of optimal land allocation under uncertainty, with adaptive learning and in the presence of binding credit constraints. Sections III and IV detail data construction and the empirical framework, while Section V presents the results. Section VI concludes.

I. Historical Background

A. The Great Famine in Ireland

While instances of food shortages owing to periodic failure of the potato crop were not unknown in Ireland before 1845, such crises were typically geographically and temporally limited, with the statistical probability of successive failures negligible (Mokyr 1983; Solar 1989; Ó Gráda 1995, 1999; Clarkson and Crawford 2001).[2] The risk of a one-off disappointing harvest thus did little to halt what Irish economic historian Austin Bourke called "a sinister trend toward monoculture," with the potato accounting for approximately 60% of the Irish food supply, and nearly 40% of Irish depending almost exclusively on the potato by the eve of the Great Famine (Bourke 1993).

The proximate cause of the Great Famine, then, was the arrival in Ireland of the oomycte *P. infestans* in autumn 1845. The disease, which rots the tubers of infected potatoes, most likely originated in the central Mexican highlands, traveling to Ireland via West Flanders, where in 1843 the provincial government funded importation of new potato varieties from the Americas. By late summer 1845, the fungus had spread throughout Flanders and neighboring regions in the Netherlands, northwestern France, lower Rhineland, Channel Islands, and southern England (Donnelly 2001). On 6 September, press reports announced the first observations of potato disease in Ireland.

[2] Solar (1989) finds pre-blight variation in French potato crop yields suggests the probability of a singular major failure was small and that, before the arrival of *P. infestans*, the probability of two or three successive failures was essentially nil.

Affecting only potatoes, the disease was known as “late blight,” as the effects typically do not become apparent until relatively late in the growing season.[3] *P. infestans* spores germinate on the leaves of potato plants, spreading to host tubers when temperatures rise above 10º C (50º F) and humidity over 75-80% for two or more days. By the time dark blotches on leaf tips and plant stems reveal the presence of blight, infection is already terminal and the plant will quickly decay. Entire fields can thus be destroyed in a matter of days.[4] Since the potato was at the time primarily a subsistence crop, rapidly reproducing spores were typically spread by wind, traveling up to fifty miles a week (Koepsell and Pscheidt 1994).[5]

Though the relatively late arrival of blight in Ireland allowed roughly 60-70% of 1845’s above-average potato crop to survive, in 1846, after an unusually damp spring and summer, potato crop failure was catastrophic, with an estimated three quarters of the island’s harvest lost to blight (Ó Gráda 1999). Yields recovered somewhat in 1847, but the devastation of 1846 had left seed potatoes in scarce supply, which resulted in “Black ‘47” turning out to be the most deadly of the Famine years. Moreover, after two years of potato crop failure, many Irish farmers had already been compelled to sell or consume their scant livestock holdings, which meant stocks of pigs and poultry—traditional buffers against adverse harvest fluctuations—were exhausted by 1847.[6]

While blight would reassert itself in 1848 and with less intensity in 1849 and, in certain regions, 1850, the winter of 1846-47 marked the worst of the disaster. By 1851 the outbreak had essentially run its course. However, although the blight receded after 1851, it nonetheless remained a persistent threat, with yields exhibiting considerably greater volatility than before 1845. The 1872 and 1877-79 potato crops were particularly hard-hit, with many historians and contemporary observers reckoning

[3] Blight can also affect tomatoes, but tomatoes were rarely grown in pre-Famine Ireland, and there is no mention in the historical literature of the effect of blight on negligible tomato cultivation in Ireland.

[4] *P. infestans* spores winter on tubers of the previous year’s crop that have been left in the ground as seed or in cull piles. Attempts at early harvest of an infected crop are likely to be in vain, as infected tubers will deteriorate quickly in storage (Zwankhuizen, Govers, and Zadoks 1998).

[5] *P.infestans* remains difficult to manage even today. Genetic engineering of resistant varieties, proper field hygiene, and use of fungicides are common tools for preventing or combating blight, but continually evolving resistance remains a challenge (Zwankhuizen, Govers, and Zadoks 1998).

[6] Given that successive crop failures were virtually unheard of before 1845, many farmers expanded potato plantings in 1846, confident of the improbability of back-to-back failure. Livestock were rarely consumed directly, but rather sold as pork, eggs, and butter, with the proceeds used to buy cheaper food substitutes (Ó Gráda 1995, 1999).

the failure of the 1879 harvest comparable to that of 1846 (Davidson 1933; Bourke 1960).[7] Moreover, the persistent presence of blight meant a permanent drop in normal per-acre yields from pre-Famine levels (Ó Gráda 1995). Bourke (1993) estimates that save a few notable exceptions it was not until the mid-20th century that annual potato crop yields again attained pre-1845 levels.[8]

Long-run vulnerability to blight was, however, unevenly distributed. While the spread of *P. infestans* spores was indiscriminate, the severity of blight infection was not. *P. infestans* thrives in particularly moist, temperate, and humid conditions, hence why the unusually wet summers of 1846 and 1879 were exceptionally favorable to blight (Bourke 1965b). Consequently, regions whose typical climatic conditions, particularly in late summer, were especially hospitable to blight faced permanently higher probabilities of crop failure. Thus, in addition to inflicting a major transitory shock on the Irish agricultural economy, the arrival of blight also constituted a permanent, regionally variated, adverse disturbance both to normal potato yields, and to yield volatility.

B. Microcredit and the Great Famine

Given its magnitude and enduring impact, much has been written about the Great Famine.[9] Little, however, has been written of the severely underdeveloped Irish financial system, and thus the potential role of credit constraints and incomplete capital markets in hindering the ability of Irish farmers to absorb a major environmental shock. Particularly neglected are the Irish Loan Funds—privately-run microfinance funds operating throughout Ireland from the mid-18th century into the early 20th century. On the eve of the Famine there were 300 Loan Funds active in more than half of Ireland's 323 baronies, extending almost 500,000 loans a year to approximately 300,000 borrowers, or 4% of Ireland's pre-Famine population. Assuming an average family size of five, this implies Loan Funds were annually extending loans to roughly 20% of Irish households, though in some counties the figure was closer to 30-40% (Hollis and Sweetman 1998, 2004).

[7] The harvests of 1860-2, 1890, 1894, and 1897 were also especially adversely affected by blight.

[8] Before 1845, potato yields per acre averaged 6-7 tons. During the post-Famine period from 1856 to 1880, average annual yield was only 3.2 tons per acre. Even after the discovery of copper sulphate as a partially effective antidote in 1882, yields did not fully recover to pre-Famine levels; on the eve of the First World War, per-acre yields were still just under 5 tons (Ó Gráda 1995).

[9] See, in particular, Hansen (1940), Mokyr (1983), Bourke (1993), Ó Gráda, (1995, 1999).

The typical fund made 1,649 loans a year, with an average loan size of approximately £3 and a fixed maximum of £10. In comparison, by 1845 just two Irish joint-stock savings banks, the Agricultural and Commercial Bank and the Provident Bank, had ventured into the business of extending loans below £10; both had failed by 1839. Consequently, on the eve of the Famine, Loan Funds were the only formal lending institutions in Ireland extending loans in amounts smaller than per capita income, which Mokyr (1983) estimates at just under £10.[10]

To put these figures in perspective, the average price of an adult pig—a traditional buffer against crop failure—in 1845 was approximately 45s., or £2 and 5s. (Thom's 1850).[11] Thus, a farmer could take out a loan of 40s., buy a young feeder pig for 20s., use the remaining 20s. to purchase feed and meet weekly repayments totaling 1s. over 20 weeks, and in the end be possessed of a mature pig worth 45s., sufficient profit (excluding the cost of supplemental livestock feed) to purchase enough corn meal, at 2d. per quart, to feed an adult man for more than three months. Chickens, another traditional buffer, meanwhile, averaged about 1s. 9d. each, while eggs sold for approximately 5s. 9d. per long hundred (120 eggs). Given that an adequately fed chicken will lay 150 or more eggs per year, an investment in one chicken could conceivably yield an annual profit of 5s. 5d., meaning a 40s. loan, buying 23 chickens, could yield enough saleable eggs in a year to purchase, after interest, 742 quarts of meal, sufficient to sustain a family of four for six months (Dufferin and Boyle 1847; Hansard 1846).[12] Alternatively, an 18s. loan could buy enough seed oats to sow one acre, which, at a yield of five quarters per acre and an average price of 22s. per quarter, would purchase 546 quarts of meal after interest, which could support a family of four for just over four months (Thom's 1850).

All Loan Fund loans required zero collateral, with security instead provided by two cosignatories. Term was fixed at 20 weeks, with required weekly payments, enforced by penalty fines. The average annualized interest rate was 8.8%, though fines on late payments could raise the effective rate to approximately 14%. Funds were managed by paid clerks, and funded by interest-earning deposits,

---

[10] Mokyr (1983) estimates pre-Famine Irish per capita income at the 67th percentile was £4.3.

[11] An adult cow, meanwhile, sold for between £9 and £16, while an adult sheep sold for between £1 and £2, 2s., depending on gender (Thom's 1850).

[12] Assuming the daily requirement of an adult male to be 1.5 quarts, an adult female or adolescent male 1 quart, and a pre-adolescent child 1 pint (Dufferin and Boyle 1847).

retained earnings, interest-free loans, and charitable donations (Hollis and Sweetman 1998). A standard 6% annual rate on deposits—three times the rate typically offered by conventional joint-stock banks—allowed the Loan Funds to attract considerable depositor interest, with some Funds in fact being oversubscribed.[13]

The typical borrower was overwhelmingly low-income, with small farmers, cottiers, agricultural laborers, and small-scale craftsmen comprising the majority of loan recipients. Approximately 20% of borrowers were women. From 1838, funds were overseen by a central board, the Loan Fund Board, that standardized rules and accounting practices. The Board also issued annual reports, which include illustrative examples of Loan Fund lending. The 1841 report mentions a borrower who "holds a small mountain farm; got a loan, and laid out 4*l.* on flax, which enabled him to set his four girls at work, spinning; with their help, he paid the instalments, and was 4*l.* better at the end; bought a cow for that sum, which is now worth 6*l.*; has at present three cows, and says he is so well off that he may give up borrowing" (*Third Annual Report of the Loan Fund Board*, 1841). The same report describes "A.B., formerly a day labourer, and frequently assisted by a kind neighbour in the maintenance of his family, has, by means of the Loan Fund, raised himself to independence, and is now possessed of a cow, a pony, and a good cart, with a small patch of land, which he farms to good purpose."[14]

Given their low-income, agrarian clientele, many Loan Funds struggled during the Famine years as repeated crop failures generated a surge in delinquent loans and reduced available deposit capital (Hollis and Sweetman 2004). Of the 300 Funds operating in 1843, only 123 remained by 1851, while the average amount circulated per fund fell from £6,197 in 1845 to £2,438 in 1847. The following year, 58 Funds had to close. Nonetheless, many Funds remained active throughout the Famine years, and those that survived quickly recovered and returned to profitability. Even during the worst years

[13] According to an 1841 manual for the establishment of a Loan Fund, depositors were typically small merchants or craftsmen or middle income laborers, including servants (Piesse 1841).

[14] Consider also: "I. K. applies for the sum of £l to buy a pig ; he states he has sufficient food for his family, but that the offal of his house is going to loss because he has no pig to consume it ; he receives the £1 with which he purchases the pig, that which was heretofore going to loss supports it, the animal increases in value according to the ordinary calculation a shilling a-week.—if this increased value was available every week, then he might pay the instalment, and at the end of twenty weeks he would have paid the money borrowed and have the pig 'to the good;' but as the increased value of the pig is not available every week, he pays one shilling a-week out of his wages, and at the end of twenty weeks he has paid off the loan, and is in possession of a pig worth at least forty shillings" (Piesse 1841).

of 1846 and 1847, Loan Funds managed to extend 459,360 and 223,465 loans, providing, respectively, £1,712,638 and £834,855 of credit to Ireland's rural poor.[15,16]

II. Theoretical Framework

The arrival of blight in Ireland was a major shock that permanently affected potato yields. Not only were per acre potato yields permanently lower after 1845, they were also subject to much higher volatility. To motivate the empirical analysis, I therefore construct a model in which a representative farmer must determine his optimal allocation of land between alternative agricultural uses so as to maximize his net return per acre while minimizing risk, subject to constrained credit and uncertainty over whether yield shocks are permanent or transitory.[17]

For analytical purposes I initially suppose the farmer's choice to be between two crops, i and j. Whereas previous studies have assumed the crop acreage decision to consist of a choice between a "traditional" crop with a certain yield and a risky "modern" crop of uncertain yield, I instead develop a more general case in which the farmer faces a choice between two crops, both of uncertain yield but with unequal variances (Feder 1980; Foster and Rosenzweig 1995; Munshi 2004; Duflo, Kremer, and Robinson 2008). The extension of uncertainty to both crops is intended to capture the historical reality that there was no clear "risk-free" crop available to Irish farmers. Though the potato may have been the "traditional" crop, its yield, particularly after 1845, was subject to considerable volatility, the change in which had to be learned by doing. At the same time, not only were yields of alternative crops also subject to uncertainty, they too had to be learned by doing, especially as they were less familiar to Irish farmers than the potato.

[15] Hollis and Sweetman (2004) find that sound management was the most important determinant of Fund survival; the maintenance of higher capital ratios before the Famine and having non-clergy managers were strong predictors of survival, while population decline and pre-Famine measures of wealth and poverty were poor predictors.
[16] In the first two years of the Famine, Loan Funds extended an average of 2,375 and 3,297 loans in baronies with a mean pre-Famine population of 30,876. In 1849, Loan Funds still extended an average of 1,886 loans per fund. Cumulatively during the Famine years, Loan Funds extended one loan for nearly every two men, women, and children of the 1841 population in those baronies, with a mean loan size of £3.56.
[17] The model could easily, however, refer to any alternative land uses; for instance the choice between crop tillage and pasture or livestock grazing.

Assuming constant returns to scale for both crops, the yield for crop i, j in year t is specified as $Y_{i,jt} = y_{i,j}(Z) + \eta_{i,jt}$, where $y_{i,j}(Z)$ is the expected yield and Z a vector of soil and other plot characteristics. For simplicity, I assume that Z is time-invariant. $\eta_{i,jt}$ is a mean zero, serially independent disturbance term, with variance $\lambda_{i,j}^2$, that captures deviation from the true yield, $y_{i,j}(Z)$, obtaining under normal growing conditions: $E_{i,j}\left(\eta_{i,jt} \middle| y_{i,j}(Z)\right) = 0$.[18]

A. Acreage allocation with perfect information

I consider first the farmer's optimization problem assuming perfect information about true yield. In this case, $y_{i,j}(Z)$ is known with certainty. Given output prices, p_{it} and p_{jt}, and variable input costs, c_{it} and c_{jt}, the farmer chooses optimal acreage, A_{it}^*, to allocate to crop i so as to maximize the expected utility of his current profit, π_t, in each period, where $\pi_t = (p_{it} y_i - c_{it})A_{it} + (p_{jt} y_j - c_{jt})(\overline{A} - A_{it})$ and $\overline{A}$ is total farm area available for cultivation.[19] The outcome, π_t, is thus a linear function of two random variables, $y_{i,j}$. Assuming outcomes are normally distributed, meaning $\eta_{i,jt} \sim N(0, \lambda_{i,j}^2)$, we can adopt the portfolio mean-standard deviation approach, such that the farmer chooses A_{it} so as to maximize $\pi(\psi, \Sigma)$, where $\psi \equiv (p_{it} y_i - c_{it})A_{it} + (p_{jt} y_j - c_{jt})(\overline{A} - A_{it})$ and $\Sigma \equiv \lambda_i^2 A_{it}^2 + \lambda_j^2 (\overline{A} - A_{it})^2 + 2A_{it}(\overline{A} - A_{it})\lambda_i \lambda_j \rho_{ij}$, and ρ_{ij} is the correlation coefficient.[20] Assuming the farmer is risk averse, $\pi(\psi, \Sigma)$ is increasing in ψ and

[18] These assumptions imply that a permanent adverse yield shock, such as blight, will both lower $y_{i,j}$ and increase the variance $\lambda_{i,j}^2$ of the disturbance term, as normal yield fluctuations will be amplified by the severity of blight in year t.

[19] For convenience of expression, I denote $y_{i,j}(Z)$ simply by subscript, given that Z is time-invariant.

[20] Bourke (1993) finds a negative correlation between potato and grain yields before 1845, suggesting that either crop offered some hedging value against failure of the other in any given year.

decreasing in Σ; optimal acreage allocated to crop *i* is an increasing function of the profit differential between crops *i* and *j*, and a decreasing function of net portfolio variance.[21,22]

B. Acreage allocation with imperfect information

If we instead suppose that the farmer has imperfect knowledge of true yield obtained under normal growing conditions, expected yield, $y_{i,j}$, is uncertain. If $\sigma^2_{i,jt}$ is the variance of the farmer's estimates of the expected yields for crops *i*, *j*, then total crop portfolio variance is

$$\Sigma \equiv \left(\lambda_i^2 + \sigma_{it}^2\right)A_{it}^2 + \left(\lambda_j^2 + \sigma_{jt}^2\right)\left(\overline{A} - A_{it}\right)^2 + 2A_{it}\left(\overline{A} - A_{it}\right)\left(\lambda_i + \sigma_{it}\right)\left(\lambda_j + \sigma_{jt}\right)\rho_{ij}$$

Denoting estimated expected yield as $\hat{y}_{i,jt}$, optimal acreage allocation to crop *i* is

$$\hat{A}_{it}^* = A\left(\left(p_{it}\hat{y}_{it} - c_{it}\right) - \left(p_{jt}\hat{y}_{jt} - c_{jt}\right), \lambda_i, \lambda_j, \sigma_{it}, \sigma_{jt}, \rho_{ij}\right)$$

Acreage allocated to crop *i* is increasing in expected net yield, ψ, and decreasing in portfolio variance, Σ.[23] I assume the farmer bases his estimates on all information pertaining to expected yields received up to the start of year $t-1$, $\hat{y}_{i,jt-1}$, realized yield at the end of year $t-1$, $\overline{y}_{i,jt-1}$, as well as any additional information received during $t-1$, $\mu_{i,jt-1}$.[24] Applying Bayes' Rule, the

---

[21] The first-order condition is

$$\frac{\partial \pi}{\partial A_{it}} = \pi_\psi\left(\left(p_{it}y_i - c_{it}\right) - \left(p_{jt}y_j - c_{jt}\right)\right) + 2\pi_\Sigma\left(\lambda_i^2 A_{it} - \lambda_j^2\left(\overline{A} - A_{it}\right) + \left(\overline{A} - 2A_{it}\right)\lambda_i\lambda_j\rho_{ij}\right) = 0$$

The second-order condition is $\frac{\partial^2 \pi}{\partial A_{it}^2} < 0$, or $\lambda_i^2 + \lambda_j^2 > 2\lambda_i\lambda_j\rho_{ij}$. We are ignoring second-order effects of $\left(p_{it}y_i - c_{it}\right) - \left(p_{jt}y_j - c_{jt}\right)$ on π_ψ and π_Σ.

[22] Note that the model is sufficiently flexible to allow for a non-market, pure subsistence farm. In the case of pure subsistence, we can consider yields ($y_{i,jt}$) and variable costs ($c_{i,jt}$) in caloric terms, with $p_{i,jt} \equiv 1$. Adding a subsistence constraint, $y_{it}A_{it} + y_{jt}\left(\overline{A} - A_{it}\right) \geq y_{\min}\overline{A}$, where $y_{\min}$ represents the minimum per-acre yield for a farm of size $\overline{A}$ to allow for bare subsistence, we see that we must also evaluate potential corner solutions at $A_{it} = 0$, which will occur if $\left(\frac{y_{\min} - y_{jt}}{y_{it} - y_{jt}}\right) < 0$, and $A_{it} = \overline{A}$, which will occur if $y_{it} = y_{\min}$. In the event of a corner solution, the implication is that, assuming $y_{i,j}$ is fixed, adjustment will ultimately require a relaxation of the subsistence constraint, meaning either plot consolidation (an increase in $\overline{A}$), or a reduction in the number of inhabitants per acre (a fall in $y_{\min}$).

[23] With second-order condition $\left(\lambda_i^2 + \sigma_{it}^2\right) + \left(\lambda_j^2 + \sigma_{jt}^2\right) > 2\left(\lambda_i + \sigma_{it}\right)\left(\lambda_j + \sigma_{jt}\right)\rho_{ij}$.

[24] Note that $\hat{A}_{it}^*$ only converges to A_{it}^* as $\hat{y}_{i,jt}$ converges to $y_{i,j}$.

expression describing the determination of $\hat{y}_{i,jt}$ is $\hat{y}_{i,jt} = (1-\beta-\gamma)\hat{y}_{i,jt-1} + \beta\bar{y}_{i,jt-1} + \gamma\mu_{i,jt-1}$, where β and γ are the weights attached to $\bar{y}_{i,jt-1}$ and $\mu_{i,jt-1}$, respectively.[25] Intuitively, the velocity with which $\hat{y}_{i,jt}$ converges to $y_{i,jt}$ will depend upon the relative weights the farmer attaches to information conveyed by realized yield at the end of period $t-1$, additional information received during $t-1$, and all information pertaining to expected yields received up to the start of year $t-1$.[26]

C. Acreage allocation with constrained credit

Since Feder (1980), de Janvry, Fafchamps, and Sadoulet (1991), Gine and Klonner (2005), and Foster and Rosenzweig (2010) have demonstrated the importance of credit constraints in acreage allocation, I then consider the implications of the farmer facing upfront fixed costs to reallocating land from one crop to another, and constrained credit. I assume that whatever portion of the sum of fixed and variable costs exceeds the farmer's wealth at the start of year t, ω_t, he must finance via borrowing; cash expenditure cannot exceed cash availability from initial resources plus credit.

Supposing the cost of converting acreage that had been planted with crop j in $t-1$ to crop i (or vice versa) in year t is a fixed, per-acre outlay k, the rate of interest facing the farmer r, and his credit limit $\overline{K}$, his problem now becomes to maximize $\pi(\psi, \Sigma)$, subject to $\left(|A_{it} - A_{it-1}|k + c_{it}A_{it} + c_{jt}\left(\overline{A} - A_{it}\right)\right) \leq \omega_t + \overline{K}$. In this case, acreage allocated to crop i is still increasing in the profit differential between crops i and j, and decreasing in portfolio variance. Now, however, it is additionally a decreasing function of the cost of conversion and the variable cost

[25] Because the disturbance term $\eta_{i,jt}$ has a mean of zero, a permanent adverse yield shock that increases $\lambda^2_{i,j}$ also implies a lower $y_{i,j}$, the yield obtaining under typical growing conditions. In the short run, this will mean a larger $\sigma^2_{i,jt}$, as the farmer's yield estimates only converge to $y_{i,j}$ over time. Alternatively, rather than assume $\eta_{i,jt} \sim N\left(0, \lambda^2_{i,j}\right)$, we could adopt a mean-variance-skewness approach, to account for the fact that a permanent adverse shock may involve a leftward skewing of the variance of the disturbance term. The assumption of non-normality, however, introduces needless complexity, and does not fundamentally affect the conclusions of the model.

[26] Presumably, the farmer will place more weight on $\hat{y}_{i,jt-1}$ as the number of observed time periods increases, such that we would expect β and γ to be decreasing over time. I omit time subscripts here, however, to simplify exposition.

differential between *i* and *j*. It is also a decreasing function of the rate of interest, i.e. $\frac{\partial \hat{A}_{it}^{*}}{\partial r} < 0$, if the marginal cost of crop *i* (the sum of the cost of conversion and the variable cost of crop *i*) is greater than the marginal cost of crop *j*; that is, if $c_{jt} < k + c_{it}$.[27] Assuming the credit constraint is binding, a corner solution will exist at either $\hat{A}_{it}^{*} = 0$, if $\frac{\omega_t + \overline{K} + A_{it-1}k - c_{jt}\overline{A}}{k + (c_{it} - c_{jt})} < 0$, or $\hat{A}_{it}^{*} = \overline{A}$, if $\overline{A} = \frac{\omega_t + \overline{K} + A_{it-1}k}{k + c_{it}}$, with a decrease (increase) in available credit $\overline{K}$ thus in the latter case clearly decreasing (increasing) $\hat{A}_{it}^{*}$.

D. Allocation with livestock as a buffer stock

Rosenzweig and Wolpin (1993), Dercon (1996), Fafchamps, Udry, and Czukas (1998), and Kazianga and Udry (2006) have demonstrated that agricultural households often keep livestock as buffer assets to smooth consumption when income is stochastically variable and capital markets incomplete. Bourke (1993) and Rosen (1999) demonstrate that this was also true of nineteenth-century Irish agriculture, with pigs and poultry constituting the most common buffer assets. Thus, I suppose that in addition to the choice between allocating acreage between two alternative agricultural uses, the farmer can also choose to invest in L_t heads of non-grazing (and thus non-acreage consuming) livestock, at a unit price of c_{Lt}, that he can sell at any time for a guaranteed unit price of $p_{Lt} > c_{Lt}$.[28] Again, the farmer maximizes $\pi(\psi, \Sigma)$, where now

[27] For derivation, see appendix A.1.
[28] This is an admittedly unrealistic assumption, as non-grazing livestock, while they required only a negligible acreage allocation—just 150 square feet in the case of a pig—did consume some portion of tillage output as fodder. Bourke (1993) estimates that as much as one third of pre-Famine potato output was used as animal fodder. "Fattening" non-grazing livestock for future sale was thus in part a function of crop yield. Nonetheless, I assume a fixed return to livestock in order to keep the analysis simple, and to reflect the fact that livestock diets, particularly in the case of pigs, chickens, and, to a lesser extent, goats could be supplemented by foraging. In the wild, pigs will eat leaves, grasses, roots, fruits and flowers, while chickens often scratch the soil for wild seeds, insects, and occasionally even mice. Thom's farmer's almanac reports that pigs "will thrive on the refuse garbage of the farm, such as mangel, and Swedish turnip tops, and such portions of the roots as the cattle do not consume" (Thom's 1850). Pork, poultry, and eggs thus continued to be exported during the Famine years, as Irish farmers often opted to convert their livestock into cash in order to purchase cheaper food substitutes, such as Indian corn (Rosen 1999). Non-grazing stocks thereby effectively served as a highly liquid buffer asset in the event of crop failure; for a certain maintenance cost, farmers

$$\psi \equiv \psi_{it} A_{it} + \psi_{jt}\left(\overline{A} - A_{it}\right) + \left(p_{Lt} - c_{Lt}\right)L_t - r\left(\left|A_{it} - A_{it-1}\right|k + c_{it}A_{it} + c_{jt}\left(\overline{A} - A_{it}\right) + c_{Lt}L_t - \omega_t\right)$$

Optimizing A_{it} and L_t, subject to the credit constraint, we can then evaluate how the farmer's optimal allocation to livestock changes as the various parameters of the model vary.[29] In particular, we are interested in how optimal investment in livestock varies with the cost and supply of credit, estimated yield, and yield volatility. We find that $\frac{\partial L_t^*}{\partial r} < 0$ if $c_{Lt} > k + \left(c_{it} - c_{jt}\right)$ and $c_{jt} < k + c_{it}$, meaning so long as the unit cost of buffer livestock is greater than the marginal cost of converting acreage from crop *j* to crop *i*, and the marginal cost of crop *i* is greater than the marginal cost of crop *j*, optimal investment in buffer livestock will be decreasing with the cost of credit. Considering volatility, we find that assuming risk aversion, $\frac{\partial L_t^*}{\partial \sigma_{jt}}, \frac{\partial L_t^*}{\partial \lambda_{jt}} > 0$.[30] That is, optimal investment in livestock is increasing in the standard deviation of the farmer's estimated yield of crop *j* and in the standard deviation of the disturbance term of crop *j*, so any increase in the volatility of crop *j*'s yield will raise optimal buffer livestock holdings. We can also observe that optimal investment in livestock is always increasing in the farmer's available supply of credit, since $\frac{\partial L_t^*}{\partial \overline{K}} = \frac{1}{c_{Lt}}$, which is always positive.

Taken together, the theoretical model outlined here presents several key predictions. First, the model predicts that a relative decline in the expected yield of a particular crop will result in substitutions toward other forms of land use, whether other crops or grazing livestock. Second, the model similarly predicts that a relative increase in the expected yield volatility of a particular crop will likewise induce substitutions toward other crops or grazing livestock. Third, the model predicts that in the face of a binding land constraint, long-run adjustment to a relative decline in the

could ensure that when food was scarce, their livestock holdings could be easily liquidated via market sale, or else, in rare circumstances, by direct consumption.

[29] For derivation, see Appendix A.2.

[30] $\frac{\partial L_t^*}{\partial \sigma_{jt}}, \frac{\partial L_t^*}{\partial \lambda_{jt}} > 0$ if $\pi_\Sigma < \frac{\pi_\psi\left(\left(\left(\psi_{it} - \psi_{jt}\right) - (1+r)\left(k + \left(c_{it} - c_{jt}\right)\right)\right) - \left(\left(p_{Lt} - c_{Lt}\right) - (1+r)c_{Lt}\right)\right)}{2\sigma_{it}\overline{A}\left(\text{cov}\left(\eta_{it}, \eta_{jt}\right) - \left(\lambda_i^2 + \sigma_{it}^2\right)\right)}$. So long as $\sigma_{it}^2 > 0$, the denominator in this expression is always negative, while the numerator, which represents the difference in marginal net return between crop *i* and livestock holding, we can assume is always positive, as otherwise the farmer should have no incentive to cultivate a risky crop *i* versus investing in a zero-risk livestock asset.

expected yield of a given crop and/or a relative increase in the expected yield volatility of that crop will induce farm consolidation. Fourth, the model predicts that a relative decline in the expected yield of a given crop and/or relative increase in the expected yield volatility of that crop will induce larger holdings of "buffer" livestock. However, fifth, the model also predicts that this substitution effect toward buffer livestock will be particularly pronounced in the short run, since in the long run, through learning-by-doing, the variance of the farmer's estimates of expected crop yield will fall. Finally, sixth, the model predicts that all three avenues of adjustment—crop/livestock substitutions, farm consolidation, and short-run accumulation of buffer livestock—will be impeded by the presence of binding credit constraints.

III. Data Construction

This study utilizes original data from numerous archival sources. First and foremost, since there was no previous indicator of micro-variation in blight, I construct an index of blight severity at the baronial level using constabulary reports from the Distress Papers of the Parliamentary Relief Commission. The Relief Commission was established by the British government in November 1845, in response to the failure of the potato crop in Ireland, in order to advise the government concerning the extent of potato loss and distress in Ireland, to oversee the storage and distribution of emergency Indian corn and meal, and to administer the activities of local relief committees. To discharge its duties, the Commission regularly solicited information from local officials regarding the state of the potato crop, extent of blight infection, and the condition of the local populace. Reports and incoming letters were received from local constables, coast guard officials, lieutenants of counties, resident magistrates, and Poor Law guardians.

To assess the level of local blight severity, I rely on reports received between November 1845 and August 1846, when the Commission was disbanded. Based on these reports, I designate each barony as low-, medium-, or high-impact, corresponding to moderate, considerable, or severe blight infection. In the case of quantitative reports, I define a low or moderate impact barony as a barony with less than one-third of its potato crop infected by blight. Medium or considerable impact baronies are baronies with a one-third to two-thirds infection rate, and high or severe impact baronies experienced crop infection rates in excess of two-thirds. For baronies with only qualitative reports, I use language such as "very good," "trifling," and "partially infected" to designate low-impact baronies; "considerably infected" or "very much infected" to designate medium-impact baronies; and "generally very bad," "extensively infected," and "very extensively infected" to designate high-impact baronies. The geographic dispersion of blight severity is illustrated in Figure 1.[31]

Reports issued at the larger administrative unit of Poor Law Union (PLU) I assign to baronies according to the location of the reporting official. Altogether, I am thus able to assign a blight severity designation to 248 of the 323 baronies in Ireland on the eve of the Famine, representing all four Irish provinces, all 32 counties, and 105 of 163 Poor Law Unions. Several baronies were split or merged after 1851. For those that split, I sum statistics for the successor baronies to preserve continuity. For those that merged, I sum statistics for the predecessor baronies. Since some years and outcome variables lack baronial-level data, I also classify each PLU as suffering low-medium or medium-high blight severity, based on averages of constituent baronial levels.[32]

It is important to note that by the time the blight had run its course in 1851, virtually no part of Ireland had been completely spared. My index of blight severity solely measures blight severity in 1845-46 in observed baronies. Baronies designated as moderately or considerably impacted may subsequently have been severely impacted as blight spread throughout the island. However, insofar as variation in blight severity in 1845-46 reflected variation in climatic hospitability to blight, observations of blight severity in 1845-46 will reflect both short- and long-run exposure to blight.

Data on lending activity by the Irish Loan Funds is from the annual reports of the Commissioners of the Loan Fund Board of Ireland. Pre-Famine baronial valuations are from the 1845 *Appendix to the Minutes of Evidence taken before Her Majesty's Commissioners of Inquiry into the State of the Law and Practice in Respect to the Occupation of Land in Ireland*. Unfortunately, data on farm size do not exist at the baronial level before the arrival of the blight in 1845. However, the *Appendix to the Minutes of Evidence* lists the number of landholders in each PLU by holding

[31] Note that many baronies do not appear in the sample. This is because there were no surviving reports in the Relief Commission papers for these baronies. Numerous official Irish records were lost in June 1922, during the Irish Civil War, when the Public Record Office was destroyed by fire.

[32] I opt for a binary blight classification at the PLU level because my sample only includes 105 PLU's, so there are not enough strictly "low" impact PLU's to support a low, medium, high indexation.

size.[33] An additional constraint is that, for landholdings of 5 to 50 acres, while the returns listed in the *Minutes of Evidence* divide at 5, 10, and 20 acres, returns from the agricultural surveys of 1848-50 divide at 15 and over 30 acres, and returns after 1850 divide at 15, 30, and 50 acres. It is therefore only possible to consistently analyze changes in the share of total farmholdings under 1 acre or between 1 and 5 acres. All other baronial- and PLU-level data was assembled using the decennial *Census of Ireland* (1821-1891), *Returns of Agricultural Produce in Ireland* (1847-1856), and *Agricultural Statistics of Ireland* (1857-1871).

Though there is no historical evidence that either the incidence of blight severity or location of Loan Funds was correlated with non-fixed baronial or PLU characteristics that were also correlated with post-Famine outcomes, to test these identifying assumptions I regress blight severity, Loan Fund presence, and average annual Loan Fund lending during the Famine on pre-Famine baronial and PLU characteristics, with results presented in Table 1. Probit-estimated coefficients presented in columns 1 and 2 indicate that pre-Famine baronial and PLU characteristics are poor predictors of blight severity. None of the estimated coefficients for valuation, literacy, population density, potato crop, fourth-class housing, or small farm share are statistically significant, and the fit is poor. Probit-estimated coefficients presented in columns 3 and 4 indicate that pre-Famine characteristics are also poor predictors of the presence of at least one active Loan Fund during the Famine years. Higher pre-Famine baronial valuations were negatively associated with Loan Fund presence, though the estimated coefficient is statistically significant only at the 10% level. None of the other estimated coefficients are statistically significant, and the R^2 is just 0.112 and 0.043, respectively, for baronial and PLU regressions. Finally, OLS estimates presented in columns 5 and 6 show that pre-Famine characteristics also fail to explain variation in average annual Loan Fund lending during the Famine years; none of the estimated coefficients are statistically significant, and the fit is again poor.

IV. Empirical Framework

Following Hornbeck (2012), the empirical analysis is based on estimating average changes, first, for baronies more severely infected by blight relative to less severely infected baronies, and, second,

[33] The *Minutes of Evidence* were submitted to the British House of Lords on 5 May 1845, before the arrival of blight.

for more severely infected baronies with a Loan Fund relative to those without, in the same county and Poor Law Union and with similar pre-Famine characteristics.

To estimate average changes by blight severity, each outcome Y_{bt} in barony b and year t is differenced from its pre-Famine value $Y_{bt=0}$. This difference is regressed on categorical variables for medium and high blight severity (B_b^m and B_b^h), pre-Famine baronial characteristics (X_b), county-by-year (α_{ct}) and PLU-by-year fixed effects (φ_{ut}), and an error term (ε_{bt}):

$$Y_{bt} - Y_{bt=0} = \beta_{1t} B_b^m + \beta_{2t} B_b^h + \theta_t X_b + \alpha_{ct} + \varphi_{ut} + \varepsilon_{bt} \quad (1)$$

To evaluate the effect of access to credit, estimates of average changes by Loan Fund activity are then obtained by regressing each differenced outcome in barony b and year t on categorical variables for medium and high blight severity (B_b^m and B_b^h), average annual Loan Fund lending during the Famine (L_b), pre-Famine baronial characteristics (X_b), county-by-year (α_{ct}) and PLU-by-year fixed effects (φ_{ut}), and an error term (ε_{bt}). Additionally, Loan Fund lending is interacted with blight severity and lags of baronial outcomes (y_b):

$$\begin{aligned} Y_{bt} - Y_{bt=0} &= \beta_{1t} B_b^m + \beta_{2t} B_b^h + \beta_{3t} L_b + \beta_{4t}^{m,h} L_b \times B_b^{m,h} \\ &\quad + \gamma_{1t} y_b + \gamma_{2t} L_b \times y_b + \theta_t X_b + \alpha_{ct} + \varphi_{ut} + \varepsilon_{bt} \end{aligned} \quad (2)$$

In section V.B, I also estimate Eq. 2 replacing average annual Loan Fund lending during the Famine with a binary variable for Loan Fund presence during the Famine, and, separately, with the number of banks in 1843. The sample is balanced in each regression, meaning every included barony has data in every analyzed time period.[34]

First differencing allows us to control for unobservable baronial characteristics that vary across baronies but are fixed over time, while county-by-year and PLU-by-year fixed effects allow us to control for unobservable variables that vary over time but are constant across administrative units. For non-fixed but observable baronial characteristics, the included controls in Eqs. (1) and (2) are baronial valuations completed by 1845, area in 1841, adult literacy rate (reading, writing, or both) in

[34] For two time periods, first-difference and fixed effects estimators are numerically equivalent. As with fixed-effects, first-differencing eliminates time-invariant baronial characteristics and thereby yields consistent and unbiased estimators. Differencing is more efficient when the untransformed error term more closely follows a random walk. Clustering corrects for any possible serial correlation in the errors.

1841, acreage under potato crop in 1844, and the fraction of housing rated fourth-class in the 1841 census.[35] In the absence of income or wealth statistics, these variables are included as proxies for development and poverty. Acreage under potato crop as a share of total tillage acreage in 1844 is included to allow baronies similarly impacted by blight but with different pre-Famine levels of potato dependence to experience systematically different changes after 1845. Each regression also includes the outcome variable in the most proximate pre-Famine year and all available pre-Famine periods to control for possible pre-trends.[36] In Eq. (2), Loan Fund lending is interacted with lagged outcomes to allow for the possibility that Loan Fund activity may have had more or less of an effect where there were already more people, tillage acres under potato crop, larger farms, or per-farm livestock holdings.

Along these observable dimensions, in Eq. (1), baronies differentially afflicted by blight are allowed to experience systematically different changes after 1845. The identification assumption is that baronies with different blight infection rates but similar pre-Famine characteristics would have changed the same after 1845 if not for blight. In Eq. (2), baronies with different levels of Loan Fund lending during the Famine are likewise allowed to experience systematically different changes after 1845, with the identification assumption that baronies with more or less Loan Fund lending during the Famine but similar pre-Famine characteristics and levels of blight infection would otherwise have followed similar trajectories in population change and adjustment in land use if not for access to Loan Fund credit.

The coefficient β_{4t}^{h} in Eq. (2) reports whether baronies suffering from high blight infection in 1845-46 changed differently than baronies with low blight infection when there was more Loan Fund lending, compared to the difference in changes between high-infection and low-infection baronies when there was less lending (and analogously with β_{4t}^{m} for medium-infection baronies), controlling for pre-Famine characteristics. Because it is a strong assumption that other, unobservable baronial characteristics are not correlated with both Loan Fund lending and baronies' differential responses to blight, Eq. (2) is re-estimated in section V.B.3 using two-stage least squares regression.

---

[35] In the *Census of Ireland*, fourth-class houses are defined as "all mud cabins having only one room."

[36] Though the main sample of blight severity includes 248 observations, the number of observations for all regressions is less than 248. This owes to the fact that baronies missing pre-Famine observations of included outcome and control variables are automatically excluded.

Several additional estimation details are worth noting. First, regressions for livestock outcomes are weighted by number of farms in order to estimate the average effect per farm. Second, the outcome years analyzed are selected so as to, where possible, estimate average effects one, five, ten, twenty, and forty years after the end of the Famine in 1851. Where it is possible to analyze outcomes between 1845 and 1851—in other words, during the Famine years—I do so. Third, standard errors are clustered at the baronial level to adjust for heteroskedasticity and within-barony correlation over time. Fourth, to test whether observed effects were the result of microfinance lending by the Irish Loan Funds in particular or financial services more broadly, I re-estimate Eq. 2 in section V.B.2 by replacing Loan Fund variables and interactions with the number of banks.

V. Results

A. Estimated effects of blight severity

To illustrate the empirical framework and analysis, results from estimating Eqs. (1) and (3) (see section V.A.1) are presented in Figure 2. Each panel in Figure 2 graphs estimated coefficients (β's) from Eqs. (1) and (3), representing differences in changes in the indicated outcome variable in high or medium impact baronies or medium-high impact PLU's relative to low impact baronies or low-medium impact PLU's, respectively. I find that, in the short and medium runs, increases in buffer livestock holdings of poultry constituted a major response to blight. Demographic change and plot consolidations were also significant short- to medium-run margins of adjustment. Crop diversification occurred primarily over the medium run, while substitutions toward grazing livestock, particularly cattle and sheep, took place only in the long run.

1. Short and medium run

Changes in buffer livestock holdings, specifically of poultry, were a significant short-run response to blight. Table 2 reports estimates of Eq. (1) for changes in the number of livestock per farm.

Unfortunately, livestock data are only available from 1847, so first-difference estimates are of changes in livestock holdings from levels observed during the third and worst year of the Famine, and therefore reflect relative adjustments from the Famine's nadir, rather than variation in outcomes during the critical 1845-47 period.

During the Famine, baronies experiencing severe or considerable blight infection in 1845-46 increased per-farm holdings of poultry relative to baronies experiencing only moderate infection. Columns 3 and 4 report that in the year following "Black 47," baronies experiencing severe or considerable infection had increased poultry stocks by 2.048 and 1.212 more chickens per farm than baronies experiencing only moderate infection. By 1849, severely and considerably impacted baronies had increased poultry stocks by 3.356 and 2.215 more birds per farm, with the gap rising to 4.782 and 3.666, respectively, by the end of the Famine in 1852. The estimated coefficients also show that farmers in worse infected baronies continued to accumulate buffer holdings of poultry through the medium run. Five years after the Famine, in 1856, severely and considerably impacted baronies had increased poultry stocks by 21.273 and 11.877 more chickens per farm than moderately impacted baronies.

Changes in other livestock holdings do not appear to have constituted short-run responses to blight. During the Famine, there were no consistently statistically significant changes in per-farm holdings of horses, mules, asses, goats, pigs (not displayed in Table 2), cattle, or sheep. However, over the medium run, farmers in worse affected baronies did increase per-farm holdings of cattle. Estimated coefficients reported in columns 1 and 2 of Table 2 show that, by 1856, farmers in severely and considerably impacted baronies had increased cattle stock by 8.326 and 3.663 more cattle per farm than only moderately impacted baronies.

Crop substitutions were a sticky medium-run margin of adjustment, with substantial substitutions occurring only after two successive years of blight. Columns 3 through 5 of Table 3 report estimates of Eqs. (1) and (3) for changes in the share of total tillage acres under potato crop, first differenced with the potato crop share in 1845, i.e. $Y_{bt=0} = Y_{b1845}$, the last crop planted before the arrival of blight.[37] The estimated coefficients reported in columns 3 and 4 show that between

[37] These results must be treated with caution, as official published statistics on potato crop acreages do not exist prior to 1847. The 1844-1846 figures used here are thus estimates compiled by the late Irish economic historian Austin

1845 and 1846, baronies experiencing severe and considerable blight infection increased the non-potato crop share of total tillage acreage by 3.6 and 2.8 percentage points more than moderately impacted baronies. Columns 3 and 4 also indicate that by 1852, severely and considerably impacted baronies had reduced the potato's share of total crop acreage by 14.8 and 11.5 percentage points more than moderately impacted baronies. Crop substitutions continued through the medium run, with the cumulative reduction in the share of acreage under potato crop rising to 17.1 and 13.6 percentage points more in severely and considerably impacted baronies by 1856, relative to moderately impacted baronies.

Since crop data are not available from 1847-51 and after 1871 at the baronial level, I also estimate a modified Eq. (1) at the observational level of PLU. Because aggregating blight observations at the PLU level leaves no exclusively moderately affected observations, I reclassify blight severity as a single binary variable, with PLU's experiencing either medium-high (considerable to severe) or low-medium (moderate to considerable) blight infection in 1845-46.[38] Each outcome Y_{ut} in PLU u and year t is then differenced from its pre-Famine value Y_{u1845} and the difference regressed on blight severity (B_u^h), pre-Famine PLU characteristics (X_u), county-by-year fixed effects (α_{ct}), and an error term (ε_{ut}):

$$Y_{ut} - Y_{u1845} = \beta_t B_u^h + \theta_t X_u + \alpha_{ct} + \varepsilon_{ut} \tag{3}$$

Column 5 of Table 3 reports estimates of Eq. (3) for relative changes in the share of total tillage acres under potato crop after 1845.[39] Estimated coefficients indicate that the fraction of total crop acreage allocated to potato cultivation in medium-high impact PLU's was only substantially reduced after two successive potato crop failures. While Poor Law Unions suffering medium-high blight infection in 1845-46 only increased the fraction of total tillage acreage allocated to other crops in

Bourke from constabulary reports. See Bourke (1960, 1965b). The estimated coefficients on blight severity for 1846 must be considered merely indicative, as my blight severity index consists mostly of observations made in 1846. However, inasmuch as observations from late 1845 and early 1846 are included, the results are roughly informative.

[38] To reclassify blight severity at the PLU level, I average constituent baronial-level blight observations coded 0, 1, or 2 for low, medium, or high blight severity. PLU's with an average >1.5 are classified as medium-high impact PLU's (very considerably to severely impacted), while PLU's with an average of <1.5 are classified as low-medium impact (moderate to considerable infection).

[39] Sample size is limited by the fact that pre-Famine farmholding data at the PLU level includes only 130 PLU's, among which I have blight observations for 99. Sample size is then further reduced by lack of pre-Famine valuation data for all PLU's, and by the fact that several PLU's are missing data from the 1848-1850 agricultural surveys.

1846 by a non-statistically significant 1.6 percentage points more than lesser affected PLU's, by 1847 PLU's that had suffered higher infection rates in the preceding two years increased the non-potato share of total tillage acreage by a statistically significant 10.7 percentage points more than low-medium impact PLU's. Column 5 also reports that the reduction in the share of total tillage acreage under potato crop in 1848 and 1849 was 14.2 and 11.9 percentage points greater in medium-high impact PLU's, versus low-medium impacted PLU's.

Demographic change and changes in patterns of landholding appear to have constituted significant short- to medium-run margins of adjustment to blight. Columns 1 and 2 of Table 3 report estimates from Eq. (1) for changes in the log of total population in the indicated year, with $Y_{bt=0} = Y_{b1841}$. Estimated coefficients show that, relative to moderately impacted baronies, baronies that were severely or considerably affected by blight in 1845-46 experienced population declines that were 17.3% and 13.0% greater between 1841 and 1851.[40] Plot consolidation was also short-run margin of adjustment. Estimates of Eq. (3) for changes in the share of total farmholdings under 1 acre and between 1 and 5 acres are reported in columns 6 and 7 of Table 3. The estimated coefficients indicate that the decline in the fraction of all farmholdings under 1 acre was 10.9 percentage points greater between 1845 and 1848 in medium-high impact PLU's than in low-medium impact PLU's. By the end of the Famine, the under-1-acre share of all farmholdings was 8.2 percentage points lower in worse affected PLU's. Blight severity appears, however, to have had no statistically significant differential impact on the proportion of farmholdings between 1 and 5 acres, as shown in column 7.

While calculated differences (not displayed) between estimated coefficients of high versus medium blight infection on changes in population, poultry, and cattle are statistically significant at the level of $\alpha = 0.01$ or 0.05, calculated differences between estimated coefficients of high versus medium infection for potato crop share are not statistically significant. This suggests that, in the short and medium runs, baronies experiencing severe or considerable blight infection did not

[40] While general equilibrium effects cannot be entirely discounted, historical evidence, including county-level emigration statistics, indicates that internal migration during the Famine was extremely limited. This owed both to the local nature of the distribution of statutory relief, and to the numerous restrictions on rural mobility by local landlords (Cousens 1960). In any event, however, the presence or absence of general equilibrium effects is extraneous to my analysis; my concern is with the relative effect of blight severity and access to credit on net population decline, irrespective of whether that relative variation owes to excess mortality, emigration, or migration.

experience systematically different changes in crop acreage allocation, but instead responded differentially along the population and livestock margins.

2. Long run

Relative changes in livestock holdings constituted a major long-run margin of adjustment to blight. The results reported in Table 2 indicate that while in the short run, baronies worse affected by blight increased per-farm holdings of relatively cheap buffer livestock like poultry, in the long run worse affected baronies increased per-farm holdings of grazing stock, implying a long-run conversion of acreage to pasture.[41]

Estimated coefficients reported in columns 1 and 2 of Table 2 show that by 1861, relative to low-impact baronies, severely and considerably impacted baronies had increased per-farm holdings of cattle by 11.490 and 5.330 more animals, respectively, with the relative increase rising to 13.867 and 6.501 more cattle per farm by 1871. Similarly, estimated coefficients in columns 7 and 8 show that 10 and 20 years after the end of the Famine, changes in per-farm holdings of sheep were greater by 8.247 and 15.578 animals in severely impacted baronies versus moderately impacted baronies, and by 5.293 and 8.830 more animals in considerably versus moderately impacted baronies.

On the other hand, estimated coefficients in columns 3 and 4 of Table 2 show that after peaking in 1856, relative increases in per-farm poultry holdings in severely and considerably impacted baronies dissipated entirely by 1861, which suggests that poultry stocks were increased specifically during the years of particularly extreme yield volatility between 1847 and 1856 as a buffer in the event of crop failure. There were also no statistically significant long-run relative changes in per-farm holdings of horses, mules, asses, goats or pigs (not displayed in Table 2), which suggests that adjustments in holdings of these livestock did not constitute a long-run response to blight.

---

[41] Note that this result is consistent with the expected positive sign of $\frac{\partial L_t^*}{\partial \sigma_{jt}}$ presented in section II.D. In the short-run, higher variance in estimates of expected yields will induce larger holdings of buffer livestock. In the long run, however, the farmer learns from past yield data, which implies a decline in σ_{jt}. Optimal investment in buffer livestock will therefore decrease, while at the same time the permanently lower yield and higher variance of crop *j* will in the long run induce conversion of acreage previously allocated to crop *j* to other crops or to pasture.

Crop substitutions during and immediately after the Famine persisted through the long run. Estimated coefficients reported in columns 3 and 4 of Table 3 show that after peaking in 1856, the cumulative reduction in the share of acreage under potato crop was still 15.7 and 12.3 percentage points greater in severely and considerably impacted baronies in 1871 than in moderately impacted baronies. At the PLU level, estimated coefficients reported in column 5 of Table 3 reveal that as late as 1891 the cumulative reduction in the share of acreage under potato crop was 11.3 percentage points larger in PLU's suffering medium-high blight infection, relative to low-medium PLU's.

Large relative population declines during the Famine also appear to have persisted through the long run. Columns 1 and 2 of Table 3 show that while the demographic deficit peaked in 1861, by 1891 the cumulative population decline in severely and considerably impacted baronies still exceeded that in moderately impacted baronies by an estimated 17.2% and 13.2%, respectively. Meanwhile, differential relative changes in farm sizes during the Famine appear to have dissipated over the long run. Estimated coefficients reported in columns 6 and 7 of Table 3 show that though the relative reduction in the proportion of farmholdings under 1 acre remained 7.8 percentage points larger in 1861 in PLU's suffering medium-high blight infection relative to low-medium impacted PLU's, beyond 1861 there was no statistically significant relative change.

As in the short and medium runs, while calculated differences (not displayed) between estimated coefficients of high versus medium blight infection on changes in population, cattle, and sheep are statistically significant at the level of $\alpha = 0.01$ or 0.05, calculated differences in estimated coefficients of high versus medium blight infection on changes in for potato crop share are not statistically significant. This suggests that, in the long run, baronies experiencing considerable or severe blight infection did not experience systematically different changes in crop acreage allocation, but instead responded differentially by converting acreage from tillage to pasture.

B. Estimated effects of credit institutions

Results from estimating Eqs. (2) and (4) (see section V.B.1) are presented in Figure 3. Each panel graphs estimated coefficients (β's) from Eqs. (2) and (4), representing differences in changes in the indicated outcome variable in high or medium impact baronies or medium-high impact PLU's relative to low impact baronies or low-medium impact PLU's where there was at least one Loan Fund during the Famine years versus those without. To test whether observed effects were the result of microfinance lending by the Loan Funds in particular or financial services more broadly, I re-estimate Eqs. (2) and (4) in section V.B.2 by replacing Loan Fund variables and interactions with the number of banks in 1843. Results are analyzed in Sections V.B.1 through V.B.3.

1. Loan Funds

Results presented in Tables 4 and 5 reveal that Loan Funds were strongly correlated with non-demographic adjustment to blight, in particular through greater crop diversification, short-run accumulation of buffer livestock holdings, and medium- to long-run substitutions toward pasture.

Estimated coefficients reported in Table 4 indicate that Loan Funds had highly significant effects on changes in livestock holdings during and immediately after the Famine years. In particular, Loan Funds were associated with relative increases in stocks of pigs, chickens, and, to a lesser extent, goats; all traditional buffers against crop failure owing to their abilities to forage. Columns 7 and 8 show that one year on from "Black 47," in 1848, severely and considerably infected baronies with a Loan Fund had relatively increased poultry stocks by 4.184 and 3.414 more chickens, respectively, than severely and considerably infected baronies without. Estimated coefficients reported in columns 5 through 8 show that by the end of the Famine, relative increases in the number of pigs and chickens per farm were greater by 2.302 and 10.380 animals in severely impacted baronies with a Loan Fund versus those without, and by 2.088 and 9.616 more animals in considerably impacted baronies with a Fund versus those without. Relative increases in the number of goats per farm were greater by 0.817 and 0.488 animals by 1852 in severely and considerably impacted baronies with a Loan Fund versus those without.

Estimated coefficients reported in Table 4 also indicate that relative increases in poultry and goat stocks were primarily short- and medium-run responses to blight. Estimates reported in columns 3 and 4 reveal that the differential relative increases in per farm holdings of goats in severely and considerably impacted baronies with an active Loan Fund during the Famine compared to those without dissipated entirely by 1856. Meanwhile, as reported in columns 7 and 8, relative increases in per-farm poultry stocks in severely and considerably impacted baronies with a Loan Fund compared to severely and considerably impacted baronies without continued to grow for 5 years after the Famine, before partially re-converging thereafter. After peaking in 1856 at 39.913 and 29.033 more chickens per farm in severely and considerably infected baronies with a Loan Fund versus those without, the estimated gap narrows to 16.403 and 11.684, respectively, by 1861. Estimated coefficients reported in columns 5 and 6, however, show that relative increases in pig stocks in severely and considerably impacted baronies with a Loan Fund versus those without were persistent, which suggests that pigs were a long-run buffer against permanently lower average potato yields and higher yield volatility.

While Loan Funds do not appear to have been associated with short-run substitutions toward grazing stock, estimated coefficients reported in columns 1, 2, 9, and 10 of Table 4 indicate they were associated with medium- and long-run substitutions from potato cultivation to pasture. By the end of the Famine, in 1852, relative increases in per-farm holdings of cattle in severely and considerably impacted baronies with a Loan Fund versus those without were greater by 5.840 and 3.760 more animals, with the estimated gap growing through 1871. Also by the end of the Famine, relative increases in per-farm sheep stocks in severely and considerably impacted baronies with a Loan Fund during the Famine versus those without were greater by non-statistically significant estimates of 5.336 and 4.358 more animals, with the gaps growing to statistically significant estimates of 13.494 and 8.373 more sheep, respectively, by 1871. Loan Funds were not associated with any differential relative changes in per-farm holdings of horses, mules, or asses (not displayed in Table 4).

Loan Fund lending was strongly associated with larger and more rapid crop portfolio diversification. Estimated coefficients reported in Panel A, columns 3 and 4 of Table 5 show that after the first year of blight, baronies with an active Loan Fund during the preceding year suffering severe or considerable blight infection in 1845-46 experienced relative increases in the non-potato crop share of total tillage acreage that were 8.3 and 5.6 percentage points greater, respectively, than in severely and considerably infected baronies without a Loan Fund. By the end of the Famine, relative increases in the non-potato crop share were 39.0 and 28.4 percentage points greater in severely and considerably infected baronies with a Loan Fund versus those without, with the estimated relative differential persisting at a roughly constant level through 1871. Estimated coefficients reported in Panel B, columns 3 and 4 of Table 5 reveal that at the intensive margin, severely and considerably affected baronies with 1% more in average annual Loan Fund lending during the Famine increased acreage allocated to other crops by 3.4 and 2.7 percentage points more, respectively, by the end of the Famine compared to severely and considerably affected baronies without.

As in Section V.A, for the years 1847-49, 1881, and 1891 I also estimate changes at the PLU level, modifying Eq. (3) to include a binary variable for an active Loan Fund during any one of the preceding Famine years (L_u), as well as interactions of Loan Fund presence with blight severity and with lags of PLU outcomes (y_u)

$$Y_{ut} - Y_{ut=0} = \beta_{1t} B_u^h + \beta_{2t} L_u + \beta_{3t} L_u \times B_u^h + \gamma_{1t} y_u + \gamma_{2t} L_u \times y_u + \theta_t X_u + \alpha_{ct} + \varepsilon_{ut} \quad (4)$$

Estimates of Eq. (4) at the PLU level, reported in Panel A, column 5 of Table 5 indicate that Loan Fund activity had a very large effect on crop acreage reallocation during the Famine years, particularly following two successive crop failures. After a 15.9-percentage point larger relative decline in the potato crop's share of total acreage under tillage crop in 1846, in 1847, medium-high impact PLU's with a Loan Fund had relatively reduced the potato's share of total crop acreage by an estimated 54.6 percentage points more than medium-high impact PLU's without a Fund. Estimated coefficients then indicate a slight relative reallocation to the potato in 1848 and 1849, with the difference in the relative decline in potato crop share in medium-high impact PLU's with a Loan Fund versus those without dropping to 34.3 percentage points by 1852.

Estimated coefficients in Panel A, columns 1 and 2 of Table 5 show that the relative population decline between 1841 and 1851, compared to moderately infected baronies, was 42.1% and 40.3% smaller in severely and considerably infected baronies with a Loan Fund versus severely and considerably infected baronies without. These smaller relative population declines, moreover, were highly persistent, with the cumulative population decline in severely and considerably infected baronies with a Loan Fund versus severely and considerably infected baronies without, relative to moderately infected baronies, still 43.3% and 40.8% smaller, respectively, in 1891. Loan Funds were also associated with smaller relative population declines at the intensive margin. Estimated coefficients reported in Panel B, columns 1 and 2 of Table 5 show that severely and considerably affected baronies with 1% more in average annual Loan Fund lending during the Famine experienced relative population declines that were persistently 5.2% and 4.9% smaller than severely and considerably affected baronies without.

Loan Funds were also associated with greater plot consolidation during the Famine. The results from estimating Eq. (4) for farm size are reported in Panel A, columns 6 and 7 of Table 5. The estimated coefficients suggest that Loan Fund loans were used in part to finance consolidation of very small plots. During the Famine, medium-high impact PLU's with at least one active Loan Fund during at least one of the preceding Famine years experienced an 11.8 percentage point larger relative decline in the fraction of farms under 1 acre by 1848, with the relative gap widening to 12.1 percentage points by 1849 (columns 3 and 4). By the end of the Famine, the relative decline in the fraction of all farmholdings less than 1 acre was 9.3 percentage points larger in medium-high impact PLU's with a Loan Fund versus those without, dissipating somewhat by 1871 to a non-statistically significant 6.7 percentage points.

2. Banks

To explore whether observed differences in relative changes were the result of Loan Funds in particular or the presence of financial services more generally, I re-estimate Eqs. (2) and (4) using the number of banks in 1843. Estimated coefficients reported in columns 1 and 2 of Table 6 show that the presence of an additional bank appears to have had no effect on differential demographic outcomes of blight. Severely and considerably impacted baronies with an additional bank experienced no statistically significant difference in relative population decline versus those without.

Estimated coefficients reported in columns 3 through 5 of Table 6 likewise reveal that the presence of an additional bank had no statistically significant effect on differential relative changes in tillage acreage allocated to potato crop in severely and considerably infected baronies and PLU's versus those without. Banks may, however, have had a short-run effect on farm consolidation. Estimated coefficients reported in column 7 show that by 1848, the relative decline in the share of farmholdings between 1 and 5 acres was 11.9 percentage points larger in medium-high impact PLU's with one more bank, versus those without. By the end of the Famine, though, the estimated effect dissipates entirely, suggesting that banks had no long-run impact on relative farm consolidation in areas worse affected by blight.

Banks also appear to have had little effect on relative changes in livestock holdings in baronies worse affected by blight. There were no statistically significant differences, over any time horizon, in relative changes in per-farm holdings of poultry, pigs, sheep, goats, horses, mules, or asses (not displayed in Table 6) in severely and considerably impacted baronies with one more bank versus those without. Estimated coefficients reported in columns 8 and 9 of Table 6 do suggest that the presence of an additional bank in severely and considerably impacted baronies may have had an effect on relative changes in per-farm holdings of cattle, but the sign of the effect is ambiguous, with banks appearing to have had opposite relative effects in considerably versus severely impacted baronies. These estimates, however, are generally only statistically significant at the 10% or 5% level, and are small in absolute terms.

3. Two-stage least squares analysis

Because it is a strong identifying assumption that the establishment of a Loan Fund was uncorrelated with other, unobservable baronial characteristics that might have been correlated with differential responses to blight, I re-estimate Eq. (2) by two-stage least squares regression, using the presence of an Association of Irish Musical Societies (AIMS) musical society in a given barony as an instrument for the presence of a Loan Fund during the Famine. In the 1740s and 1750s, the Dublin Musical Society began extending small loans to poor Dubliners, and in 1756 incorporated a formal society for this purpose. Thereafter, the Dublin Musical Society encouraged musical societies across Ireland to launch similar funds in their locales, "To receive contributions, and to lend out such sum or sums of money interest free" to poor farmers and laborers. These constituted the first Loan Funds, which were then formally unified under the central Loan Fund Board in the 1830s (Hollis and Sweetman 1998, 2001).[42] The inclusion and exclusion restrictions are that the presence of an AIMS

[42] As data is not available on musical societies by barony in the 18th and 19th centuries, I instead use current AIMS member societies as an instrument.

musical society in a given barony is correlated with the presence of a Loan Fund in the same barony during the Famine, but is otherwise uncorrelated with ε_{bt}.[43]

The results of estimating Eq. (2) for population, potato crop share, and pig and poultry holdings by 2SLS, with the coefficients on Loan Fund presence exactly identified, are presented in Table 7. Estimated coefficients reported in columns 1 and 2 show that the estimated effect of Loan Fund presence on relative population declines in considerably and severely infected baronies was somewhat smaller than suggested by OLS results, but still large and statistically significant. Severely and considerably infected baronies with a Loan Fund during the Famine are estimated to have experienced relative population declines between 1841 and 1851 that were 38.9% and 37.2% smaller, respectively, than severely and considerably infected baronies without.

Estimated effects of Loan Fund presence on relative crop substitutions are also slightly smaller than those obtained by OLS, but remain large and statistically significant. By 1852, severely and considerably infected baronies with a Loan Fund during the Famine are estimated to have reduced the potato's share of total tillage acreage by 36.8 and 25.5 percentage points more, respectively, than severely and considerably infected baronies without (columns 3 and 4).

Estimates of the effects of Loan Fund presence on relative changes in per-farm pig and poultry holdings are also only slightly smaller than those obtained by OLS, and remain statistically significant. Columns 7 and 8 report that by 1848, severely and considerably infected baronies with a Loan Fund increased poultry stocks by 3.632 and 3.416 more chickens, respectively, than severely and considerably infected baronies without; compared to OLS estimates of 4.184 and 3.414. By the end of the Famine, relative increases in the number of pigs and chickens per farm were greater by 2.201 and 10.404 animals in severely impacted baronies with a Loan Fund versus those without (columns 5 and 7), and by 1.998 and 9.108 more animals in considerably impacted baronies with a Fund versus those without (columns 6 and 8). 2SLS estimates also confirm the trend of rising

[43] It might be objected that the use of AIMS members would involve selection-on-outcome bias, on the basis that musical societies in worse affected baronies might have been less likely to survive the Famine. This is, however, unlikely, given the class from which patrons of musical societies were typically drawn. Moreover, first-differencing eliminates omitted variable bias from unobservable fixed baronial characteristics that might be correlated with both the presence of an AIMS musical society and differential relative responses to blight.

relative increases in per-farm pig and poultry stocks through 1856, followed by partial re-convergence through 1871 (not displayed in Table 7).[44]

VI. Conclusion

The Great Famine was a devastating event that had profound and persistent effects on Irish population and agriculture. Initial short- and medium- run responses to blight, in the form of greater accumulations of buffer livestock assets and demographic decline, were eventually superceded in the medium and long runs by changes in land use, namely, substitutions away from the potato toward other tillage crops and pasture. Access to microcredit from the Irish Loan Funds was an important factor in enabling non-demographic adjustment to adverse environmental shock.

In the short run, districts that were severely or considerably afflicted by blight in the first two years of the Famine experienced 17.3% and 13.0% larger population declines between 1841 and 1851 than moderately affected regions, with stable gaps of 17.2% and 13.2% persisting even 40 years after the end of the Famine. By the end of the Famine, the fraction of farmholdings under 1 acre had declined by 8.2 percentage points more in worse affected Poor Law Unions. Blight furthermore immediately affected patterns of livestock holding. In the short run, relative to moderately impacted baronies, baronies suffering severe or considerable blight infection in 1845-46 significantly increased the number of chickens per farm as a buffer against crop failure.

In the medium and long runs, however, worse affected baronies effected larger substitutions toward other tillage crops and grazing livestock. Relative to lesser impacted areas, districts that were worse affected by blight substantially and permanently converted acreage under potato cultivation to other crops, though did so only after two successive crop failures. While PLU's suffering medium-to-high blight infection only increased the fraction of total tillage acreage allocated to other crops in 1846 by 1.6 percentage points more than lesser affected PLU's, by 1847 PLU's that had suffered higher infection rates in the preceding two years increased the non-potato share of total crop acreage by 10.7 percentage points more than lesser impacted PLU's. In the long run, worse affected PLU's

[44] 2SLS estimates of medium- and long-run effects of Loan Fund presence on relative increases in per-farm cattle and sheep holdings, though smaller than estimates obtained by OLS, also remain statistically significant, but for the sake of economy are not displayed in Table 7.

are estimated to have effected a permanent 11-percentage point relative reduction in the potato's share of total crop acreage. Long-run acreage reallocation to pasture was also significant; by 1871, severely affected baronies had increased per-farm cattle and sheep holdings by 13.867 and 15.578 more animals, respectively, than moderately affected baronies.

Microfinance credit from the Irish Loan Funds played a significant role in non-demographic adjustment to blight. Severely affected baronies with at least one active Loan Fund during the Famine years experienced a 42.1% smaller relative population decline by 1851 than severely impacted baronies without. Loan Fund lending in severely affected districts during the Famine was associated with greater immediate substitutions toward other tillage crops, consolidation of farms under 1 acre, and increases in temporary buffer stocks of pigs and poultry than in severely affected districts with less lending. Specifically, during the Famine, medium-to-high impact PLU's with a Loan Fund increased the fraction of total tillage acreage under other crops by 54.6 percentage points more by 1847 than medium-high impact PLU's without. By the end of the Famine, the potato's share of total crop acreage was 34.3 percentage points lower in medium-high impact PLU's with a Loan Fund versus those without. Meanwhile, the decline in the proportion of farms under 1 acre was 11.8 percentage points greater by 1848 in medium-high impact PLU's with a Loan Fund, compared to those without.

Finally, during and immediately after the Famine, severely infected baronies with a Loan Fund experienced significant relative increases in per-farm holdings of buffer stocks of pigs and poultry; by the end of the Famine, severely infected baronies with a Loan Fund had increased stocks of these animals relative to moderately infected baronies by 2.302 more pigs and 10.380 more chickens than severely impacted baronies without a Fund. By the end of the Famine, worse affected baronies with a Loan Fund had also increased per-farm holdings of cattle. All of these estimates are robust to analysis by two-stage least squares regression.

The results of this study suggest that access to credit plays a profound role in short- and medium-run adjustment to adverse environmental shocks in a subsistence economy. The long-run non-demographic adaptations to the arrival of blight in Ireland, particularly crop portfolio diversification, substitution away from tillage toward pasture, and consolidation in farm size, were effected earlier and to a greater extent in worse affected districts with a microcredit lender versus those without. Moreover, in the presence of incomplete capital markets, access to microcredit appears to have allowed farmers to acquire temporary stocks of buffer livestock assets that could be liquidated in the event of crop failure and thereby smooth consumption.

References

Besley, T. and A. Case. 1993. "Modelling Technology Adoption in Developing Countries." *American Economic Review Papers and Proceedings*, Vol. 83, No. 2, pp. 396-402.

Bourke, A. 1960. "The Extent of the Potato Crop in Ireland at the Time of the Famine." *Journal of the Statistical and Social Inquiry Society of Ireland*, Vol. 20, No. 3, pp. 1-35.

Bourke, A. 1965a. "The Agricultural Statistics of the 1841 Census of Ireland. A Critical Review." *Economic History Review*, Vol. 18, No. 2, pp. 376-391.

Bourke, A. 1965b. "The Potato, Blight, Weather and the Irish Famine." Ph.D. Thesis, National University of Ireland.

Bourke, A. 1993. *The Visitation of God? The Potato and the Great Irish Famine*. Dublin: Lilliput.

Campbell, D. 1984. "Response to Drought among Farmers and Herders in Southern Kajiado District, Kenya." *Human Ecology*, Vol. 12, No. 1, pp. 35-64.

Chavas, J. and M. Holt. 1990. "Acreage Decisions under Risk: The Case of Corn and Soybeans." *American Journal of Agricultural Economics*, Vol. 72, No. 3, pp. 529-538.

Clarkson, L. and E. Crawford. 2001. *Feast and Famine: Food and Nutrition in Ireland 1500-1920*. Oxford: Oxford University Press.

Conley, T. and C. Udry. 2010. "Learning about a New Technology: Pineapple in Ghana." *American Economic Review*, Vol. 100, No. 1, pp. 35-69.

Cousens, S. 1960. "The Regional Pattern of Emigration during the Great Irish Famine, 1846-51." *Institute of British Geographers Transactions and Papers*, No. 28, pp. 119-134.

Davidson, W. 1933. "History of Potato Varieties." *Journal of the Department of Agriculature, Eire*, Vol. 33, pp. 57-81.

de Janvry, A., M. Fafchamps, and E. Sadoulet. 1991. "Peasant Household Behavior with Missing Markets: Some Paradoxes Explained." *Economic Journal*, Vol. 101, No. 409, pp. 1400- 1417.

Dell, M., B. Jones, and B. Olken. 2012. "Temperature Shocks and Economic Growth: Evidence from the Last Half Century." *American Economic Journal: Macroeconomics*, Vol. 4, No. 3, pp. 66-95.

Dercon, S. 1996. "Risk, Crop Choice, and Savings: Evidence from Tanzania." *Economic Development and Cultural Change*, Vol. 44, No. 3, pp. 485-513.

Donnelly, J. 2000. *The Irish Potato Famine*. London: Sutton Publishing.

Dufferin, F.T.B. and G.F. Boyle. 1847. *Narrative of a Journey from Oxford to Skibbereen during the Year of the Irish Famine*. Oxford: John Henry Parker.

Duflo E., M. Kremer, and J. Robinson. 2008. "How High Are Rates of Return to Fertilizer? Evidence from Field Experiments in Kenya." *American Economic Review Papers and Proceedings*, Vol. 98, No. 2, pp. 482-488.

Fafchamps, M., C. Udry, K. Czukas. 1998. “Drought and Saving in West Africa: Are Livestock a Buffer Stock?” *Journal of Development Economics*, Vol. 55, No. 2, pp. 273-305.

Feder, G. 1980. “Farm Size, Risk Aversion and the Adoption of New Technology under Uncertainty.” *Oxford Economic Papers*, Vol. 32, No. 2, pp. 263-283.

Foster, A., and M. Rosenzweig. 1995. “Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture.” *Journal of Political Economy*, Vol. 103, No. 6, pp. 1176-1209.

Foster, A. and M. Rosenzweig. 2010. “Microeconomics of Technology Adoption.” Yale University Economic Growth Center Discussion Paper No. 984.

Gine, X. and S. Klonner. 2005. “Credit Constraints as a Barrier to Technology Adoption by the Poor: Lessons from South Indian Small-scale Fishery.” World Bank Policy Research Working Paper 3665.

Hansard, T. 1846. *Hansard's Paliamentary Debates*, vol. 88. London: G. Woodfall and Son, 1846.

Hollis, A. and A. Sweetman. 1998. “Microcredit in Prefamine Ireland.” *Explorations in Economic History*, Vol. 35, No. 4, pp. 347-380.

Hollis, A. and A. Sweetman. 2001. “The Life-Cycle of a Microfinance Institution: An Economic Analysis of the Irish Loan Funds,” *Journal of Economic Behavior and Organization*, Vol. 34, No. 3, pp. 291-311.

Hollis, A. and A. Sweetman. 2004. “Microfinance and Famine: The Irish Loan Funds during the Great Famine.” *World Development*, Vol. 32, No. 9, pp. 1509-1523.

Hornbeck, R. 2012. “The Enduring Impact of the American Dust Bowl: Short- and Long-run Adjustments to Environmental Catastrophe.” *American Economic Review*, Vol. 102, No. 4, pp. 1477-1507.

Kazianga, H. and C. Udry. 2006. “Consumption Smoothing? Livestock, Insurance and Drought in Rural Burkina Faso.” *Journal of Development Economics*, Vol. 79, No. 2, pp. 413-446.

Koepsell, P. and J. Pscheidt. 1994. *Pacific Northwest Plant Disease Control Handbook*, Corvallis: Oregon State University Press.

McGregor, P. 1984. “The Impact of the Blight upon the Pre-Famine Rural Economy in Ireland.” *Economic and Social Review*, Vol. 15, No. 4, pp. 289-303.

Mokyr, J. 1983. *Why Ireland Starved: A Quantitative and Analytical History of the Irish Economy, 1800-1850*. London: Allen and Unwin.

Munshi, K. 2004. “Social Learning in a Heterogeneous Population: Technology Diffusion in the Indian Green Revolution.” *Journal of Development Economics*, Vol. 73, pp. 185– 213.

Ó Gráda, C. 1995. *The Great Irish Famine*. Cambridge: Cambridge University Press.

Ó Gráda, C. 1999. *Black '47 and Beyond: The Great Irish Famine in History, Economy, and Memory*. Princeton: Princeton University Press.

Ó Gráda, C. 2008. "The Early History of Irish Savings Banks," UCD Centre for Economic Research Working Paper Series.

Piesse, C. 1841. *Sketch of the Loan Fund System in Ireland and Instructions for the Formation of a New Society*. Dublin: Alexander Thom.

Reardon, T., C. Delgado and P. Matlon. 1992. "Determinants and Effects of Income Diversification Amongst Farm Households in Burkina Faso." *Journal of Development Studies*, Vol. 28, No. 2, pp. 264-296.

Rosen, S. 1999. "Potato Paradoxes." *Journal of Political Economy*, Vol. 107, No. S6, pp. S294-S313.

Rosenzweig, M. and O. Stark. 1989. "Consumption Smoothing, Migration, and Marriage: Evidence from Rural India." *Journal of Political Economy*, Vol. 97, No. 4, pp. 905-926.

Townsend, R. 1994. "Risk and Insurance in Village India." *Econometrica*, Vol. 62, No. 3, pp. 539-591.

Solar, P. 1989. "The Great Famine Was No Ordinary Subsistence Crisis," in E. Margaret Crawford, ed., *Famine: The Irish Experience*, pp. 112-133. Edinburgh: John Donald.

Swinton, S. 1988. "Drought Survival Tactics of Subsistence Farmers in Niger." *Human Ecology*, Vol. 16, No. 2, pp. 123-144.

Thom, A. 1850. *Thom's Irish Almanac and Official Directory*. Dublin: Alexander Thom.

Udry, C. 1994. "Risk and Insurance in a Rural Credit Market: An Empirical Investigation in Northern Nigeria." *Review of Economic Studies*, Vol. 61, No. 3, pp. 495-526.

World Bank. 2009. *World Development Report 2010: Development and Climate Change*. Washington, D.C.: World Bank.

Zwankhuizen, M, F. Govers, and C. Zadoks. 1998. "Development of Potato Late Blight Epidemics: Disease Foci, Disease Gradients, and Infection Sources." *Phytopathology*, Vol. 88, No. 8, pp. 754–763.

Appendix A: Mathematical Appendix

1. *Acreage allocation with constrained credit*

The farmer's optimization problem is to maximize $\pi(\psi, \Sigma)$, where

$$\psi \equiv \psi_{it} A_{it} + \psi_{jt}\left(\overline{A} - A_{it}\right) - r\left(\left(\left|A_{it} - A_{it-1}\right|\right)k + c_{it} A_{it} + c_{jt}\left(\overline{A} - A_{it}\right) - \omega_t\right)$$

$$\text{s.t.} \left(\left|A_{it} - A_{it-1}\right| k + c_{it} A_{it} + c_{jt}\left(\overline{A} - A_{it}\right)\right) \leq \omega_t + \overline{K}$$

For $A_{it} > A_{it\text{-}1}$, the first-order condition is

$$\frac{\partial \pi}{\partial A_{it}} = \pi_\psi \left(\left(\psi_{it} - \psi_{jt}\right) - r\left(k + \left(c_{it} - c_{jt}\right)\right)\right)$$
$$+ 2\pi_\Sigma \left(\left(\lambda_i^2 + \sigma_{it}^2\right)A_{it} - \left(\lambda_j^2 + \sigma_{jt}^2\right)\left(\overline{A} - A_{it}\right) + \left(\overline{A} - 2A_{it}\right)\left(\lambda_i + \sigma_{it}\right)\left(\lambda_j + \sigma_{jt}\right)\rho_{ij}\right) = 0$$

Using $\rho_{ij} = \dfrac{\operatorname{cov}\left(\eta_{it}, \eta_{jt}\right)}{\left(\lambda_i + \sigma_{it}\right)\left(\lambda_j + \sigma_{jt}\right)}$, we can simplify this expression and solve for A_{it}:

$$\hat{A}_{it}^* = \frac{\pi_\psi \left(\left(\psi_{it} - \psi_{jt}\right) - r\left(k + \left(c_{it} - c_{jt}\right)\right)\right) - 2\pi_\Sigma \left(\overline{A}\left(\lambda_j^2 + \sigma_{jt}^2\right) + 2\overline{A} \operatorname{cov}\left(\eta_{it}, \eta_{jt}\right)\right)}{2\pi_\Sigma \left(\left(\lambda_i^2 + \sigma_{it}^2\right) + \left(\lambda_j^2 + \sigma_{jt}^2\right) - 2\operatorname{cov}\left(\eta_{it}, \eta_{jt}\right)\right)}$$

Taking the derivative of $\hat{A}_{it}^*$ with respect to *r* then yields

$$\frac{\partial \hat{A}_{it}^*}{\partial r} = \frac{\pi_\psi \left(k + \left(c_{it} - c_{jt}\right)\right)}{2\pi_\Sigma \left(\left(\lambda_i^2 + \sigma_{it}^2\right) + \left(\lambda_j^2 + \sigma_{jt}^2\right) - 2\operatorname{cov}\left(\eta_{it}, \eta_{jt}\right)\right)}$$

So long as the sum of the variances of crops *i* and *j* are greater than twice the covariance of the disturbance terms, the denominator is negative, by the assumption of risk aversion ($\pi_\Sigma < 0$). So long as the variances of the two crops are not identical, this will always be true. We thus have that $\dfrac{\partial \hat{A}_{it}^*}{\partial r} < 0$ if $c_{jt} < k + c_{it}$.

2. Allocation with livestock as a buffer stock

The farmer now maximizes $\pi(\psi, \Sigma)$, where

$$\psi \equiv \psi_{it} A_{it} + \psi_{jt}\left(\overline{A} - A_{it}\right) + \left(p_{Lt} - c_{Lt}\right)L_t - r\left(\left|A_{it} - A_{it-1}\right|k + c_{it}A_{it} + c_{jt}\left(\overline{A} - A_{it}\right) + c_{Lt}L_t - \omega_t\right)$$

and

$$\Sigma \equiv \left(\lambda_i^2 + \sigma_{it}^2\right)A_{it}^2 + \left(\lambda_j^2 + \sigma_{jt}^2\right)\left(\overline{A} - A_{it}\right)^2 + 2A_{it}\left(\overline{A} - A_{it}\right)\left(\lambda_i + \sigma_{it}\right)\left(\lambda_j + \sigma_{jt}\right)\rho_{ij}$$

Assuming the credit constraint is binding, we set up the Lagrangian

$$\min_{\lambda}\max_{\pi} \Lambda\left(\pi(\psi, \Sigma), \lambda\right) = \pi(\psi, \Sigma) + \lambda\left(\left(\omega_t + \overline{K}\right) - \left|A_{it} - A_{it-1}\right|k - c_{it}A_{it} - c_{jt}\left(\overline{A} - A_{it}\right) - c_{Lt}L_t\right)$$

For $A_{it} > A_{it-1}$, we have first-order conditions

$$\frac{\partial \Lambda}{\partial A_{it}} = \pi_{\psi}\left(\left(\psi_{it} - \psi_{jt}\right) - r\left(k + \left(c_{it} - c_{jt}\right)\right)\right)$$
$$+ 2\pi_{\Sigma}\left(\left(\lambda_i^2 + \sigma_{it}^2\right)A_{it} - \left(\lambda_j^2 + \sigma_{jt}^2\right)\left(\overline{A} - A_{it}\right) + \left(\overline{A} - 2A_{it}\right)\left(\lambda_i + \sigma_{it}\right)\left(\lambda_j + \sigma_{jt}\right)\rho_{ij}\right) = 0$$

$$\frac{\partial \Lambda}{\partial L_t} = \pi_{\psi}\left(\left(p_{Lt} - c_{Lt}\right) - \left(1 + r\right)c_{Lt}\right) = 0$$

$$\frac{\partial \Lambda}{\partial \lambda} = \left(\omega_t + \overline{K}\right) - \left(\left|A_{it} - A_{it-1}\right|\right)k - c_{it}A_{it} - c_{jt}\left(\overline{A} - A_{it}\right) - c_{Lt}L_t = 0$$

Using substitution and solving for $\hat{A}_{it}^*$ and L_t^*, we find that for $\hat{A}_{it}^* > A_{it-1}$, the derivative of L_t^* with respect to r is then

$$\frac{\partial L_t^*}{\partial r} = -\frac{\pi_{\psi}\left(k + \left(c_{it} - c_{jt}\right)\right)\left(k + \left(c_{it} - c_{jt}\right) - c_{Lt}\right)}{2c_{Lt}\pi_{\Sigma}\left(\left(\lambda_i^2 + \sigma_{it}^2\right) + \left(\lambda_j^2 + \sigma_{jt}^2\right) - 2\operatorname{cov}\left(\eta_{it}, \eta_{jt}\right)\right)}$$

So long as the sum of the variances of crops i and j is greater than twice the covariance of the disturbance terms (which, assuming the variances are unequal, is always true), the denominator is negative, by the assumption of risk aversion ($\pi_{\Sigma} < 0$). We thus see that $\frac{\partial L_t^*}{\partial r} < 0$ if $c_{Lt} > k + \left(c_{it} - c_{jt}\right)$ and $c_{jt} < k + c_{it}$ or $c_{Lt} < k + \left(c_{it} - c_{jt}\right)$ and $c_{jt} > k + c_{it}$. Substituting the fourth expression into the third, we see that the second inequality pair implies a negative unit cost of livestock, which we can realistically assume will never be the case.

The derivative of L_t^* with respect to σ_{jt} is

$$\frac{\partial L_t^*}{\partial \sigma_{jt}} = \left(\pi_\psi\left(\left(p_{Lt} - c_{Lt}\right) - \left(\psi_{it} - \psi_{jt}\right) + r\left(k + \left(c_{it} - c_{jt}\right) - c_{Lt}\right)\right)\right.$$

$$\left. + 2\sigma_{jt}\overline{A}\pi_\Sigma\left(\operatorname{cov}\left(\eta_{it}, \eta_{jt}\right) - \lambda_i^2 - \sigma_{it}^2\right)\right)\left(\frac{\left(k + \left(c_{it} - c_{jt}\right)\right)}{c_{Lt}\pi_\Sigma\left(\left(\lambda_i^2 + \sigma_{it}^2\right) + \left(\lambda_j^2 + \sigma_{jt}^2\right) - 2\operatorname{cov}\left(\eta_{it}, \eta_{jt}\right)\right)^2}\right)$$

By the assumption of risk aversion ($\pi_\Sigma < 0$), the common denominator is negative, which means, provided $c_{jt} < k + c_{it}$, if $\frac{\partial L_t^*}{\partial \sigma_{jt}} > 0$, then

$$\pi_\Sigma < \frac{\pi_\psi\left(\left(\left(\psi_{it} - \psi_{jt}\right) - r\left(k + \left(c_{it} - c_{jt}\right)\right)\right) - \left(\left(p_{Lt} - c_{Lt}\right) - rc_{Lt}\right)\right)}{2\sigma_{it}\overline{A}\left(\operatorname{cov}\left(\eta_{it}, \eta_{jt}\right) - \left(\lambda_i^2 + \sigma_{it}^2\right)\right)}$$

As long as $\sigma_{it}^2 > 0$, the denominator of the above expression is always negative. The numerator, which represents the difference in the marginal net benefit between crop *i* and livestock holding, we can assume is positive, as otherwise the farmer should have no incentive to cultivate a risky crop *i* versus raising assumed zero-risk livestock. Thus, the right-hand side of the above expression is negative, consistent with the assumption of risk-aversion ($\pi_\Sigma < 0$).

The derivative of L_t^* with respect to λ_{jt} can be obtained analogously, with $\frac{\partial L_t^*}{\partial \lambda_{jt}} > 0$ if

$$\pi_\Sigma < \frac{\pi_\psi\left(\left(\left(\psi_{it} - \psi_{jt}\right) - r\left(k + \left(c_{it} - c_{jt}\right)\right)\right) - \left(\left(p_{Lt} - c_{Lt}\right) - rc_{Lt}\right)\right)}{2\sigma_{it}\overline{A}\left(\operatorname{cov}\left(\eta_{it}, \eta_{jt}\right) - \left(\lambda_i^2 + \sigma_{it}^2\right)\right)}.$$

Appendix B: Data Sources

Blight Severity: Blight severity in 1845-46 is obtained from the Famine Relief Commission Papers, 1845-1847. RFLC3/2, Incoming Letters: Baronial Sub-series. The National Archives of Ireland, Dublin Ireland. Observations made at the civil parish, township, or PLU level are assigned to their corresponding baronies.

Population: Population data are from the decennial *Census of Ireland*, 1821-1891. After 1891, data are no longer available at the baronial level.

Loan Funds: Data on Loan Fund activity are from the annual reports of the Loan Fund Board of Ireland, 1843-1851, compiled by Aidan Hollis and Arthur Sweetman (see Hollis and Sweetman 1998, 2001, 2004). Association of Irish Musical Societies member societies are assigned to the barony in which they are based.

Agricultural Data: Livestock and baronial-level crop data are from *Returns of Agricultural Produce in Ireland* (1847-1856) and *Agricultural Statistics of Ireland* (1857-1871). Potato crop acreages for 1844-1846 are from tabulated constabulary returns in the Public Record Office of Ireland assembled by Austin Bourke (see Bourke 1960, 1965b). Subsequent crop acreage data are from *Returns of Agricultural Produce in Ireland* (1847-1856) and *Agricultural Statistics of Ireland* (1857-1871). Landholding data at the Poor Law Union level is from the 1845 *Appendix to the Minutes of Evidence taken before Her Majesty's Commissioners of Inquiry into the State of the Law and Practice in Respect to the Occupation of Land in Ireland*.

Control Variables: Adult literacy and fourth-class housing share at the baronial level and barony and PLU area in statute acres are taken from the 1841 *Census of Ireland*. Pre-Famine baronial and PLU valuations are from partial returns from Griffith's *Valuation of Ireland* and Her Majesty's Poor Law Commissioners, as presented in the 1845 *Appendix to the Minutes of Evidence taken before Her Majesty's Commissioners of Inquiry into the State of the Law and Practice in Respect to the Occupation of Land in Ireland*.

Figure 1: Geographic Distribution of Blight Severity

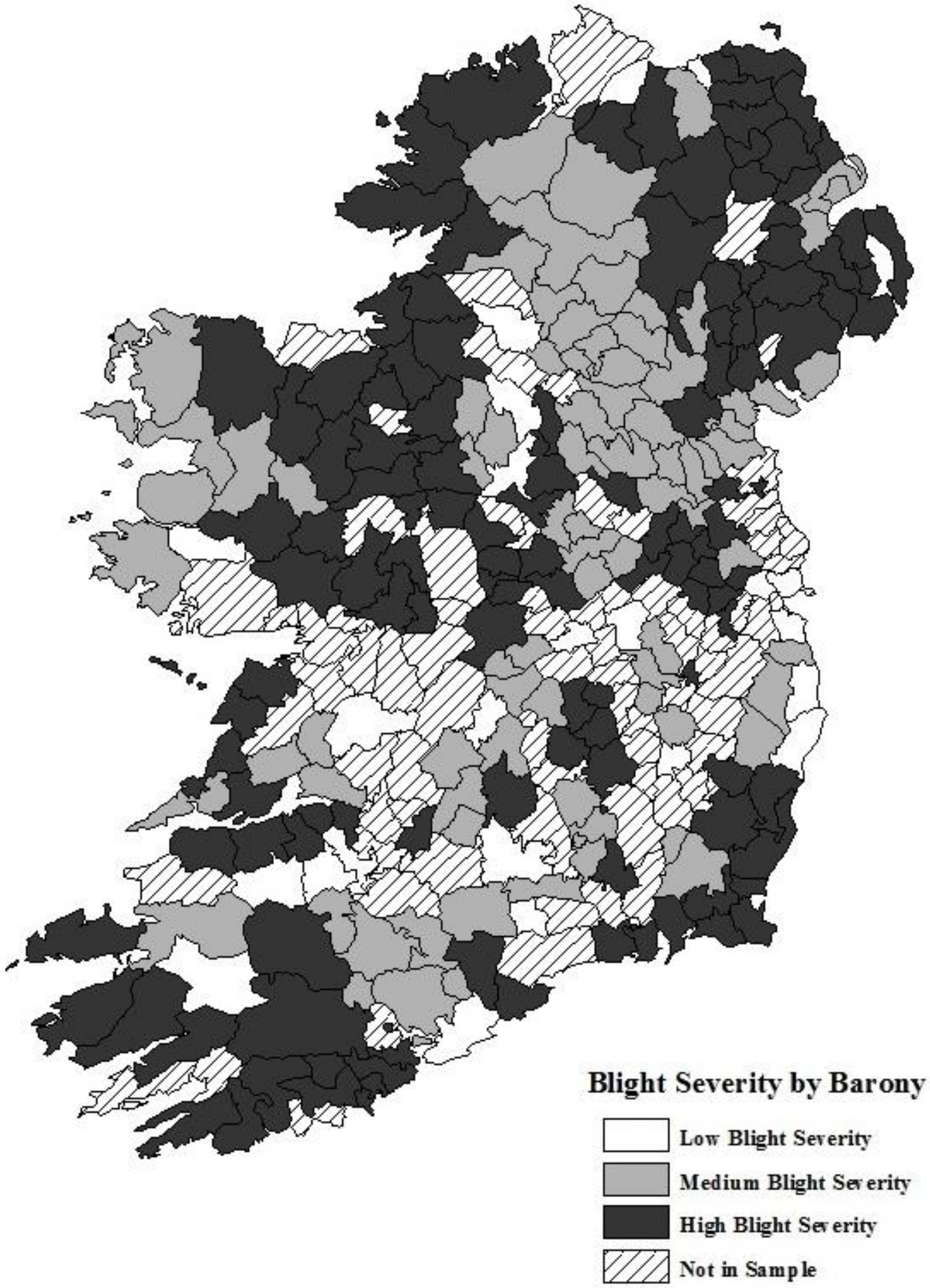
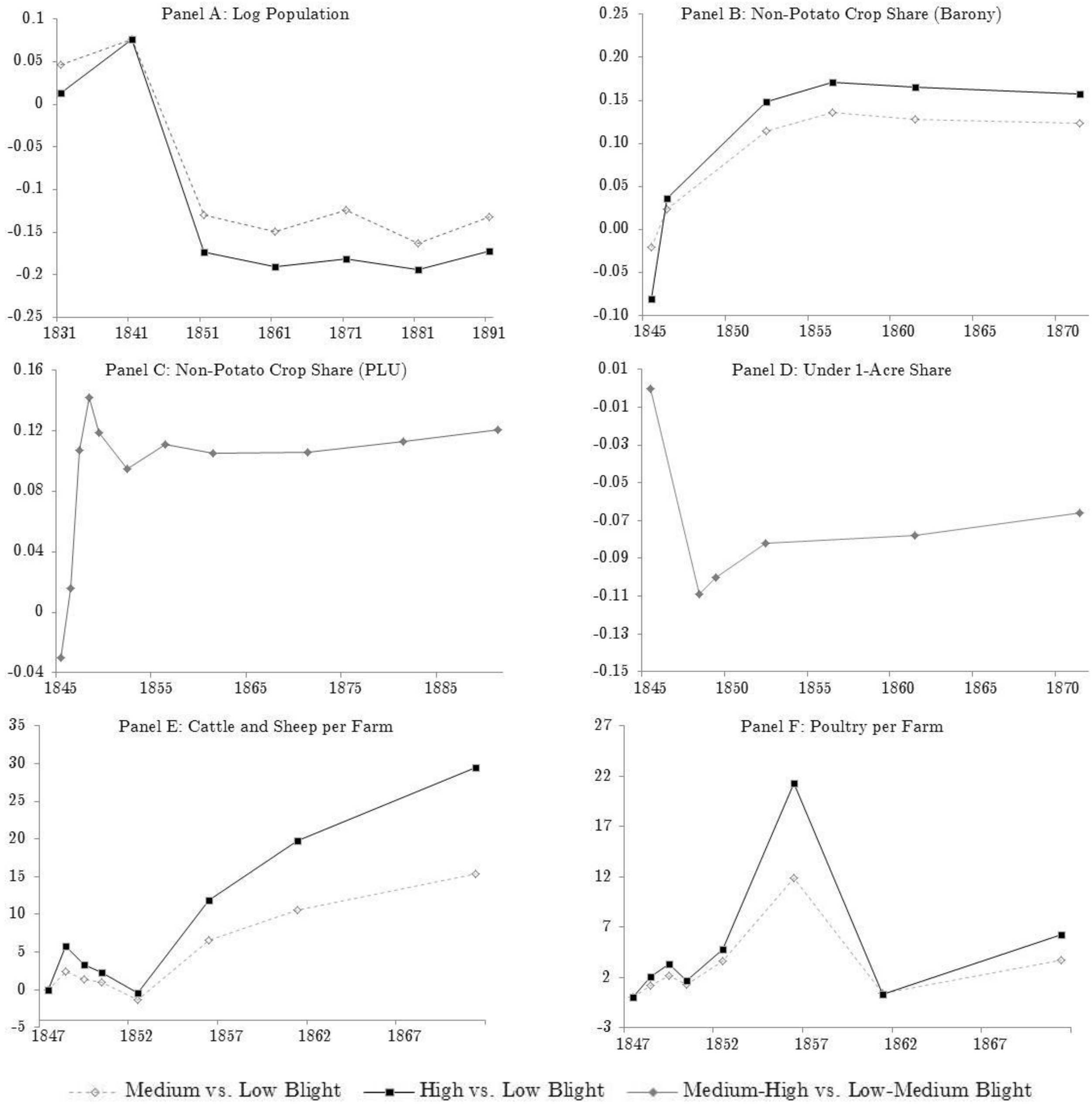
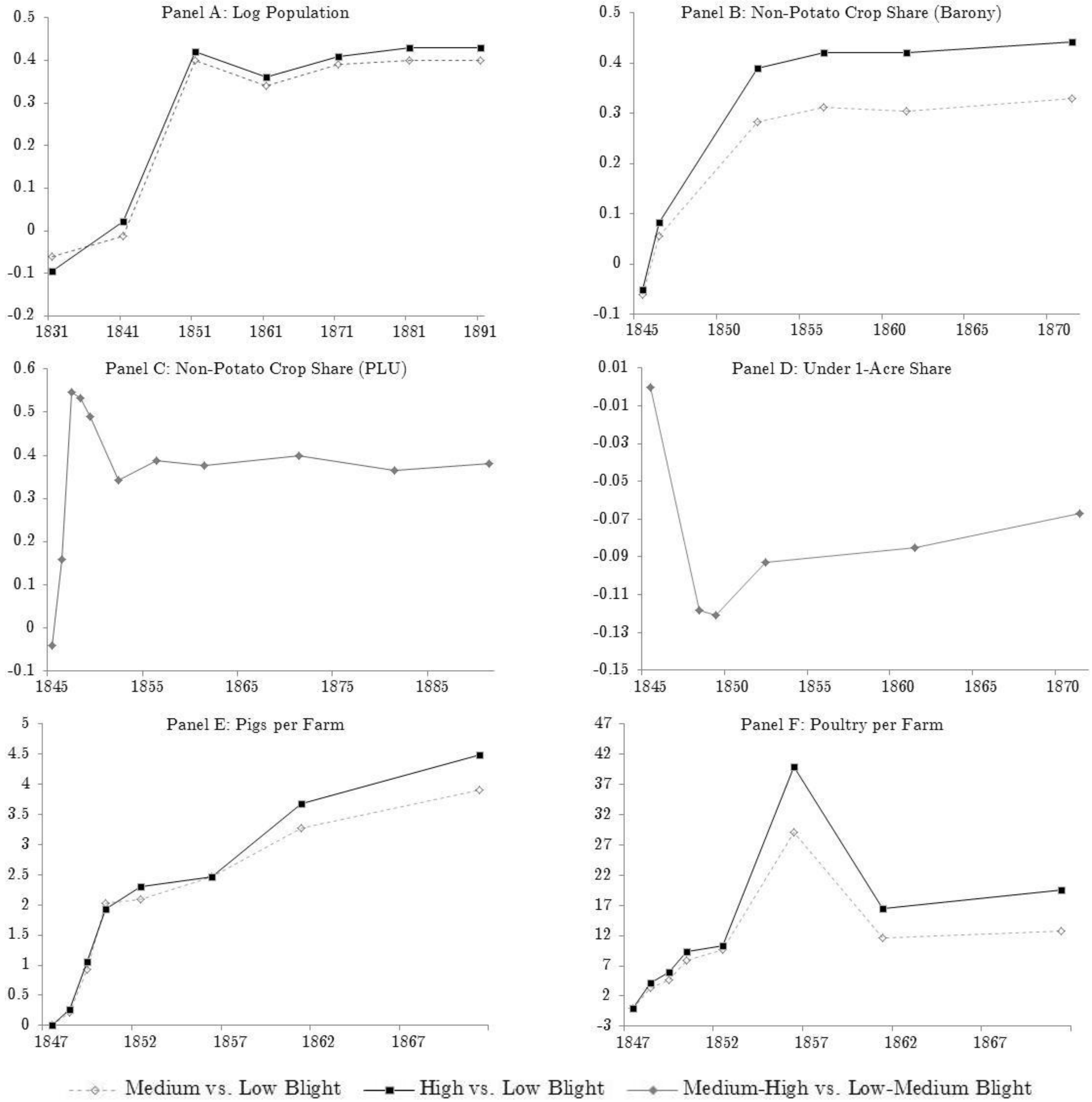


Figure 2: Estimated Changes by Blight Severity by Blight Severity



Notes: Each panel graphs estimated coefficients (β's) from Eqs. (1) and (3) in the text, representing differences in changes in the indicated outcome variable in high or medium impact baronies or medium-high impact PLU's relative to low impact baronies or low-medium impact PLU's, respectively. For illustrative purposes, in Panels B and C I reverse the sign on the estimated coefficients for blight severity so as to present estimated relative changes in the fraction of total tillage acreage not under potato crop.

Figure 3: Estimated Changes by Blight Severity by Loan Fund Presence



Notes: Each panel graphs estimated coefficients (β's) from Eqs. (2) and (4) in the text, representing differences in changes in the indicated outcome variable in high or medium impact baronies or medium-high impact PLU's relative to low impact baronies or low-medium impact PLU's where there was at least one active Loan Fund during the Famine years versus those without. For illustrative purposes, in Panels B and C I reverse the sign on the estimated coefficients so as to present estimated relative changes in the fraction of total tillage acreage not under potato crop.

Table 1: Estimated Blight Severity, Loand Fund Presence, and Loan Fund Lending by Pre-Famine Characteristics

	Blight Severity		Loan Fund		Lending	
	(1)	(2)	(3)	(4)	(5)	(6)
Valuation	-0.105	0.284	-0.358*	0.215	-0.412	0.564
	(0.16)	(0.17)	(0.20)	(0.17)	(0.53)	(0.51)
Literacy Rate	0.284		0.303		1.204	
	(0.53)		(0.59)		(1.62)	
Population Density	-0.012	-0.273	1.447	0.725	0.323	0.917
	(0.14)	(0.54)	(1.21)	(1.04)	(0.20)	(1.67)
Fourth-Class Housing	1.76		0.146		-4.114	
	(1.24)		(1.47)		(4.02)	
Potato Crop Share	427.764	0.695	-78.900	-0.146	-18.185	-2.373
	(343.23)	(0.29)	(184.58)	(0.68)	(353.17)	(1.98)
<1-acre Share		1.690		-0.395		-1.755
		(1.30)		(1.21)		(3.56)
1-5 acre Share		0.912		1.377		4.846
		(1.87)		(2.06)		(5.79)
N	206	93	206	93	206	93
R2	0.042	0.073	0.112	0.043	0.074	0.045

Notes: Each column reports estimated coefficients for differences in blight severity, Loan Fund presence, and average annual Loan Fund lending by pre-Famine baronial (columns 1, 3, and 5) or PLU (columns 2, 4, and 6) characteristics. Coefficients reported in columns 1-4 are estimated by probit, while coefficients reported in columns 5 and 6 are estimated by OLS. Robust standard errors are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 2: Estimated Changes in Livestock Holdings by Blight Severity

	Cattle		Poultry		Sheep	
	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low
	(1)	(2)	(3)	(4)	(5)	(6)
1848	2.538	1.096	2.048**	1.212**	3.309**	1.267*
	(1.58)	(0.78)	(0.96)	(0.58)	(1.38)	(0.74)
1849	0.000	-0.128	3.356***	2.215***	3.274	1.529
	(0.88)	(0.48)	(1.27)	(0.77)	(2.21)	(1.10)
1850	3.337***	1.301**	1.661***	1.296**	-1.051	-0.326
	(0.99)	(0.53)	(0.60)	(0.50)	(1.66)	(0.86)
1852	0.692	-0.036	4.782*	3.666***	-1.132	-1.344
	(1.60)	(0.89)	(2.51)	(1.33)	(3.41)	(1.88)
1856	8.326***	3.663***	21.273***	11.877***	3.577	2.964
	(2.57)	(1.39)	(5.54)	(3.37)	(3.60)	(1.95)
1861	11.490***	5.330***	0.380	0.478	8.247**	5.293**
	(2.89)	(1.51)	(3.61)	(2.37)	(4.02)	(2.11)
1871	13.867***	6.501***	6.290	3.780	15.578***	8.830***
	(3.45)	(1.86)	(4.12)	(2.56)	(4.78)	(2.56)
N	210		210		210	
R2	0.508		0.457		0.342	

Notes: Each column reports estimated coefficients for changes in livestock holdings in the indicated year by blight severity, weighted by farm. All regressions control for area, partial adult literacy in 1841, pre-Famine baronial valuation, the share of housing rated fourth class, farm size distribution in 1847, and PLU-by-year and county-by-year fixed effects. Robust standard errors are reported in parentheses and clustered at the baronial level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 3: Estimated Changes in Population, Potato Crop Share, and Farm Size by Blight Severity

	Population		Potato Crop Share			Farm Size	
						< 1 Acre	*1-5 Acre*
	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low	Med-High vs. Low-Med	Med-High vs. Low-Med	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1846			-0.036***	-0.024**	-0.016		
			(0.01)	(0.01)	(0.02)		
1847					-0.107*		
					(0.06)		
1848					-0.142**	-0.109**	-0.036
					(0.06)	(0.05)	(0.04)
1849					-0.119*	-0.100**	-0.034
					(0.07)	(0.05)	(0.04)
1851	-0.173***	-0.130***					
	(0.06)	(0.04)					
1852			-0.148***	-0.115***	-0.095*	-0.082**	-0.003
			(0.05)	(0.04)	(0.05)	(0.04)	(0.03)
1856			-0.171***	-0.136***	-0.111**		
			(0.05)	(0.04)	(0.05)		
1861	-0.190***	-0.149***	-0.165***	-0.128***		-0.078*	0.020
	(0.07)	(0.05)	(0.05)	(0.05)		(0.04)	(0.03)
1871	-0.181***	-0.124***	-0.157***	-0.123***		-0.066	0.016
	(0.05)	(0.04)	(0.05)	(0.04)		(0.04)	(0.03)
1891	-0.172**	-0.132**			-0.113**		
	(0.08)	(0.05)			(0.05)		
N	188		206		93	93	93
R2	0.660		0.477		0.119	0.224	0.212

Notes: Each column reports estimated coefficients for changes in log population, the fraction of total tillage acres under potato crop, and the fraction of all farms under 1 acre and between 1 and 5 acres in the indicated year by blight severity. Baronial-level regressions control for available pre-Famine observations of outcome variables, area, partial adult literacy in 1841, pre-Famine baronial valuation, the share of housing rated fourth class, and PLU-by-year and county-by-year fixed effects. PLU-level regressions control for available pre-Famine outcome variable observations, area, pre-Famine valuation, and county-by-year fixed effects. Robust standard errors are reported in parentheses and clustered at the baronial or PLU level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4: Estimated Changes in Livestock Holdings by Loan Fund Presence

	Cattle		Goats		Pigs		Poultry		Sheep	
	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1848	2.297***	0.768	0.139	0.045	0.270	0.208	4.184**	3.414*	2.000	-1.426
	(0.86)	(0.73)	(0.13)	(0.13)	(0.51)	(0.51)	(2.00)	(1.93)	(1.63)	(1.40)
1849	1.132	0.767	0.312*	0.221*	1.059**	0.935***	5.899***	4.718***	1.748	0.448
	(1.10)	(0.74)	(0.17)	(0.13)	(0.42)	(0.36)	(1.53)	(0.99)	(1.80)	(0.86)
1850	3.765**	1.983	0.315*	0.253	1.935***	2.032***	8.289***	7.881***	0.284	1.037
	(1.48)	(1.50)	(0.17)	(0.16)	(0.59)	(0.53)	(2.18)	(1.85)	(1.43)	(1.13)
1852	5.840***	3.760*	0.817**	0.488*	2.302***	2.088***	10.380***	9.616***	5.336	4.358
	(2.23)	(2.13)	(0.34)	(0.29)	(0.75)	(0.60)	(3.46)	(2.62)	(4.43)	(3.61)
1856	7.985***	2.526	0.364	-0.144	2.464***	2.031**	39.913***	29.033***	5.312	6.292*
	(2.96)	(2.85)	(0.46)	(0.49)	(0.91)	(0.92)	(9.07)	(8.17)	(4.71)	(3.37)
1861	10.505***	3.479	0.085	-0.214	3.671***	3.272***	16.403***	11.684**	7.952*	6.050*
	(2.50)	(2.16)	(0.33)	(0.32)	(0.94)	(0.83)	(6.29)	(5.13)	(4.77)	(3.62)
1871	12.048***	3.604	0.014	-0.184	4.484***	3.904***	19.519***	12.762***	13.494**	8.373*
	(3.60)	(3.16)	(0.41)	(0.33)	(1.27)	(1.16)	(5.59)	(4.32)	(6.75)	(5.00)
N	210		210		210		210		210	
R2	0.391		0.330		0.478		0.513		0.347	

Notes: Each column reports estimated coefficients for changes in the number of livestock per farm in the indicated year by blight severity by Loan Fund presence during the Famine. All regressions control for available pre-Famine observations of outcome variables, area, partial adult literacy in 1841, pre-Famine baronial valuation, the share of housing rated fourth class, farm size distribution in 1847, and PLU-by-year and county-by-year fixed effects. Robust standard errors are reported in parentheses and clustered at the baronial or PLU level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 5: Estimated Changes in Population, Potato Crop Share, and Farm Size by Loan Fund Activity

	Population		Potato Crop Share			Farm Size	
						< 1 Acre	*1-5 Acre*
	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low	Med-High vs. Low-Med	Med-High vs. Low-Med	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Loan Fund							
1846			-0.083***	-0.056***	-0.159***		
			(0.02)	(0.02)	(0.00)		
1847					-0.546**		
					(0.22)		
1848					-0.532**	-0.118*	-0.033
					(0.21)	(0.07)	(0.04)
1849					-0.490**	-0.121**	-0.043
					(0.23)	(0.06)	(0.04)
1851	0.421***	0.403***					
	(0.13)	(0.14)					
1852			-0.390***	-0.284***	-0.343*	-0.093*	-0.017
			(0.08)	(0.06)	(0.18)	(0.05)	(0.05)
1856			-0.422***	-0.312***	-0.388*		
			(0.07)	(0.06)	(0.20)		
1861	0.369**	0.344**	-0.421***	-0.304***		-0.085	0.004
	(0.15)	(0.15)	(0.08)	(0.06)		(0.05)	(0.05)
1871	0.416***	0.391***	-0.443***	-0.330***		-0.067	0.004
	(0.15)	(0.15)	(0.08)	(0.07)		(0.05)	(0.05)
1891	0.433***	0.408***			-0.382*		
	(0.15)	(0.16)			(0.20)		
B. Log Annual Lending							
1846			-0.005***	-0.006***			
			(0.00)	(0.00)			
1851	0.052***	0.049***					
	(0.02)	(0.02)					
1852			-0.034***	-0.027***			
			(0.01)	(0.01)			
1856			-0.040***	-0.032***			
			(0.01)	(0.01)			
1861	0.050***	0.046***	-0.041***	-0.032***			
	(0.02)	(0.02)	(0.01)	(0.01)			
1871	0.056***	0.052***	-0.042***	-0.033***			
	(0.02)	(0.02)	(0.01)	(0.01)			
1891	0.061***	0.057***					
	(0.02)	(0.02)					
N	188		206		93	93	93
R2	0.691		0.786		0.377	0.225	0.215

Notes: Each column reports estimated coefficients for changes in log population, the fraction of total tillage acres under potato crop, and the fraction of all farms under 1 acre and between 1 and 5 acres in the indicated year by blight severity by Loan Fund presence during the Famine (Panel A) and log of average annual Loan Fund lending during the Famine (Panel B). Baronial-level regressions control for available pre-Famine observations of outcome variables, area, partial adult literacy in 1841, pre-Famine baronial valuation, the share of housing rated fourth class, and PLU-by-year and county-by-year fixed effects. PLU-level regressions control for available pre-Famine outcome variable observations, area, pre-Famine valuation, and county-by-year fixed effects. Robust standard errors are reported in parentheses and clustered at the baronial or PLU level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6: Estimated Changes in Population, Potato Crop Share, and Farm Size by Number of Banks

	Population		**Potato Crop Share**			**Farm Size** *< 1 Acre*	*1-5 Acre*	**Cattle**	
	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low	Med-High vs. Low-Med	Med-High vs. Low-Med		High vs. Low	Medium vs. Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1846			-0.003	-0.005	0.008				
			(0.00)	(0.00)	(0.02)				
1847					-0.011				
					(0.01)				
1848					-0.014	-0.07	-0.119**	0.037	0.061
					(0.02)	(0.07)	(0.05)	(0.03)	(0.04)
1849					-0.015	-0.055	-0.118**	0.084*	0.148***
					(0.02)	(0.07)	(0.05)	(0.05)	(0.05)
1851	0.158	0.154							
	(0.13)	(0.13)							
1852			-0.013	-0.012	-.008	-0.032	-0.008	-0.011	0.221**
			(0.01)	(0.01)	(0.05)	(0.06)	(0.04)	(0.08)	(0.11)
1856			-0.013	-0.009	-0.003			-0.194*	0.184*
			(0.01)	(0.01)	(0.01)			(0.11)	(0.10)
1861	0.139	0.129	-0.014	-0.01		-0.022	0.006	-0.309**	0.120
	(0.13)	(0.13)	(0.01)	(0.01)		(0.06)	(0.03)	(0.13)	(0.08)
1871	0.124	0.114	-0.016	-0.009		0.003	-0.001	-0.435**	0.100
	(0.13)	(0.13)	(0.01)	(0.01)		(0.06)	(0.04)	(0.18)	(0.11)
1891	0.163	0.155			-0.01				
	(0.12)	(0.13)			(0.02)				
N	188		206		93	93	93	210	
R2	0.627		0.756		0.307	0.259	0.242	0.357	

Notes: Each column reports estimated coefficients for changes in log population, the fraction of total tillage acres under potato crop, and the fraction of all farms under 1 acre and between 1 and 5 acres in the indicated year by blight severity by the number of banks in 1843. Baronial-level regressions control for available pre-Famine observations of outcome variables, area, partial adult literacy in 1841, pre-Famine baronial valuation, the share of housing rated fourth class, and PLU-by-year and county-by-year fixed effects. PLU-level regressions control for available pre-Famine outcome variable observations, area, pre-Famine valuation, and county-by-year fixed effects. Robust standard errors are reported in parentheses and clustered at the baronial or PLU level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 7: 2SLS Estimated Changes in Population, Potato Crop Share, and Livestock by Loan Fund Presence

	Population		**Potato Crop Share**		**Pigs**		**Poultry**	
	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low	High vs. Low	Medium vs. Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1846			-0.058***	-0.044**				
			(0.02)	(0.02)				
1848					0.236	0.183	3.632*	3.416*
					(0.55)	(0.54)	(1.89)	(1.98)
1849					1.037**	0.972**	3.323***	2.808**
					(0.40)	(0.40)	(1.22)	(1.26)
1850					2.010***	1.872***	8.182***	7.878***
					(0.65)	(0.61)	(1.86)	(1.97)
1851	-0.389***	-0.372**						
	(0.15)	(0.15)						
1852			-0.368***	-0.255***	2.201***	1.998***	10.404***	9.108***
			(0.08)	(0.08)	(0.55)	(0.52)	(2.39)	(2.46)
1856			-0.423***	-0.314***	2.169***	2.005**	27.514***	26.070***
			(0.09)	(0.08)	(0.78)	(0.78)	(7.13)	(7.22)
N	188		206		210		210	
R2	0.704		0.732		0.245		0.272	

Notes: Each column reports estimated coefficients for changes in the number of livestock per farm in the indicated year by blight severity by Loan Fund presence during the Famine instrumented by the presence of an Association of Irish Musical Societies musical society. All regressions control for available pre-Famine observations of outcome variables, area, partial adult literacy in 1841, pre-Famine baronial valuation, the share of housing rated fourth class, farm size distribution in 1847 (for pig and poultry regressions), and PLU-by-year and county-by-year fixed effects. Robust standard errors are reported in parentheses and clustered at the baronial or PLU level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$