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Working Paper

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QUCEH Working Paper Series, No. 2017-08

Provided in Cooperation with:

Queen's University Centre for Economic History (QUCEH), Queen's University Belfast

Suggested Citation: Blum, Matthias; Colvin, Christopher L.; McLaughlin, Eoin (2017) : Scarring and selection in the Great Irish Famine, QUCEH Working Paper Series, No. 2017-08, Queen's University Centre for Economic History (QUCEH), Belfast

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SCARRING AND SELECTION IN THE GREAT IRISH FAMINE

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Working Paper 2017-08

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September 2017

Scarring and Selection in the Great Irish Famine^{*}

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29 September 2017

Abstract

What impact do famines have on survivors? We use individual-level data on a population exposed to severe famine conditions during infancy to document two opposing effects. The first: exposure to insufficient food and a worsened disease environment is associated with poor health into adulthood – a scarring effect. The second: famine survivors do not themselves suffer any health impact – a selection effect. Anthropometric evidence from records pertaining to over 21,000 subjects born before, during and after the Great Irish Famine (1845-52), one of modern history's most severe famine episodes, suggests that selection is strongest where famine mortality is highest. Individuals born in heavily-affected areas experienced no measurable stunted growth, while significant scarring was found only among those born in regions where the same famine did not result in any excess mortality.

Keywords: famine, fetal origins hypothesis, anthropometrics, economic history, Ireland.

JEL Classification: I15, I32, N33, Q54.

^{*}We thank conference, workshop and seminar participants at the Economic History Society (Telford, March 2015), the University of Oxford (May 2015), the University of St Andrews (July 2016), the Irish Economic and Social History Society (Maynooth, November 2016), Queen's University Belfast (April 2017) and the London School of Economics (September 2017) for their comments and suggestions. We are especially grateful to Sascha Becker, Nick Hanley, Peter Koudijs, Lyndon Moore and John Turner for reading an earlier draft of this paper. Findmypast Ireland Ltd. gave us access to digitised prison registers for Clonmel and Kilmainham Gaols, and Eneclann Ltd. assisted in expanding their content. Financial assistance was provided by the Economic History Association (Colvin) and the University of Edinburgh (McLaughlin).

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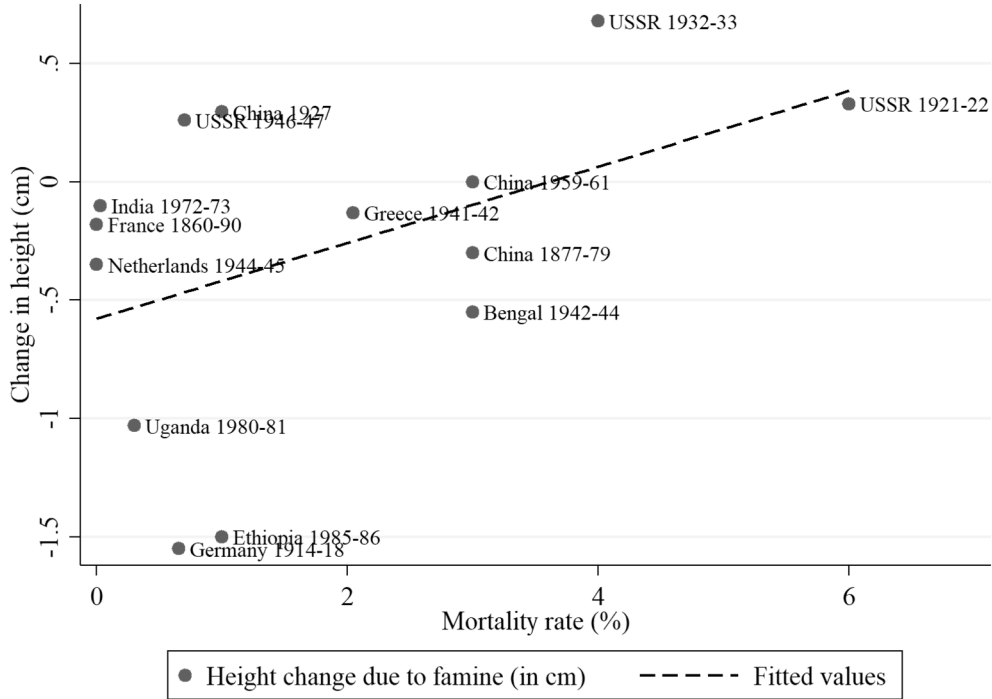
1. Introduction

One of the universal features of famines is the immediate and devastating human tragedy they bring. Another, apparently, is the subsequent deterioration in the health and human capital of survivors. A plethora of case studies document the scale of famines and analyse their long-run consequences. A perusal of these works gives the overall impression that the more severe the famine, the more catastrophic its impact must be on a society's subsequent wellbeing, and thus the more detrimental the consequences for that society's productivity and economic output. However, when comparing famine severity and health capital, measured by famine-period excess mortality and the average adult height of the generation born in famine conditions, this negative relationship is not at all obvious. Indeed, using the famines listed in Ó Gráda (2007), we find a *positive* correlation: *low* famine-related mortality, not the highest on record, appears to be associated with the most severe drops in the average adult height of the populations most exposed to famine-induced hunger and disease during infancy (Figure 1).

We call for a shift in focus and argue that not only scarring, but also selection due to, for example, mortality and emigration needs to be explicitly incorporated in any future economic study of famines. The *residual* population may be less affected than mortality rates and other metrics of devastation would otherwise suggest; these measures by and large reflect the impact on the *pre-famine* population, not on those that survived. Yet, it is the health and human capital of this residual population that is crucial in understanding a society's *post-famine* economic performance, and the ancestry of future generations. Those that perished, or migrated away, do not, by definition, contribute directly to the subsequent wealth of the nation. Focussing specifically on survivors helps us to gain a crucial new insight into the nature of famines and their long-run economic legacy. The relevance of this new focus on survivors goes far beyond the study of famines; demographic, development, health and historical economists, among others, regularly fail to take unobserved and non-obvious sample selection issues into consideration (cf. Bodenhorn et al. 2017).

We use one of the most severe and lengthy famines in modern human history to discuss scarring and selection: the Great Irish Famine, 1845-52, which killed approximately 12 per cent of Ireland's population, and forced many more to emigrate. Most other economic studies rely on either international comparisons of famines, or country-wide samples. Our micro-study offers new insights because we can analyse the health capital of a very large dataset containing over 21,000 subjects born in different geographic locations across one famine episode. Our individual-level data are drawn from archival records pertaining to Ireland's capital city, Dublin, in addition to a rural sample from Clonmel, County Tipperary. Our historical context is particularly well

Figure 1: Change in average adult height and mortality in 14 famines



Sources: Excess mortality figures are listed in Ó Gráda (2007); corresponding height changes, defined as the difference in final adult height between the pre-famine born and the famine-born cohorts, are taken from the following: Bengal 1942-44 (Guntupalli and Baten 2006); China 1877-79 (Baten et al. 2010); China 1927 (Morgan 2004); China 1959-61 (Gørgens et al. 2012); Ethiopia 1985-86 (Dercon and Porter 2014); France 1860-90 (Banerjee et al. 2010); Germany 1914-18 (Blum 2011); Greece 1941-42 (Valaoras 1970); India 1972-73 (Guntupalli 2007); the Netherlands 1944-45 (Van Wieringen 1972); Uganda 1980-81 (Umana-Aponte 2011); USSR 1921-22, USSR 1932-33 and USSR 1946-47 (Wheatcroft 2009).

suited to the economic study of famines because it permits the ecological identification of famine impact. Our data also allow us to construct an instrumental variable that exploits spatial differences in people’s access to the country’s pre-famine healthcare infrastructure.

Our findings represent an important contribution to the economic study of famines. In short, we find the same famine severity/health capital correlation described above occurring within this one famine episode. Most famine deaths were recorded in rural parts of the island; direct famine-related mortality in Dublin was largely absent. And while we find few signs of early childhood malnutrition in the residual population of rural Tipperary, we *do* find evidence of scarring in urban Dublin (Figure 2). Our estimates of the extent of this scarring range between 0.7 cm and 2.2 cm.¹ This is a large effect: Baten and Komlos (1998) would associate a 2.2 cm decline with a reduction in average life expectancy by at least 2.6 years, in addition to reduced levels of societal human capital, lower average labour productivity during the affected individuals’ shortened

¹ We find a similar pattern among those who experienced the Famine during adolescence, another important period of human growth: scarring in the urban-born sample, but selection among rural-born individuals.

lifespans, and thus, on aggregate, reduced national income compared to a no-scarring counterfactual.

To further illustrate this point, we compare our results to a completely different historical famine, one that was associated with a much lower death toll: Germany during the First World War (Figure 3).² While excess civilian deaths were well below one per cent of the German population, the average male height of the generation born during this conflict dropped by approximately 1.5 cm. In other words, the German case implies scarring, but only minimal selection. Meanwhile, the average adult height of Dublin-born males born during the Great Irish Famine reveals an almost identical pattern; we observe a height drop of similar magnitude, despite mortality directly attributable to malnourishment in Dublin being near-zero. And by contrast, we find average heights in rural Tipperary, where excess mortality was nearly 30 per cent, tended to stagnate, or even increase.

Understanding the mechanisms linking famine intensity and the scarring of the residual population helps us to assess the long-run consequences and the economic burden of famines. In particular, health and development economists have attempted to use a variety of prenatal shocks, such as malnutrition, war, disease, pollution and famine, as “natural experiments” to test the so-called “Barker thesis”, or “fetal origins hypothesis” (FOH) (Currie and Vogl 2013). The FOH stresses the link between low birth weight and later adult health outcomes (Barker 1990, 2004).³ Famine episodes have been one of the main testing grounds for the FOH;⁴ a series of studies have focused on famine survivors in nineteenth and twentieth century Europe and Asia.⁵ Probably the most widely studied famine is the Chinese Great Leap Forward of the late-1950s, as many argue that this was the “worst in history” measured by levels of mortality and length (Gørgens et al. 2013; Kim et al. 2013; Kim et al. 2016; Xu et al. 2016). However, when deaths are considered relative to overall population levels, the Great Irish Famine of the mid-1840s (12 per cent death rate) overshadows the Great Leap Forward famine (two per cent) (Ó Gráda 2007: Tab. 3). Given the severity of Ireland’s famine episode (henceforth referred to simply as “the

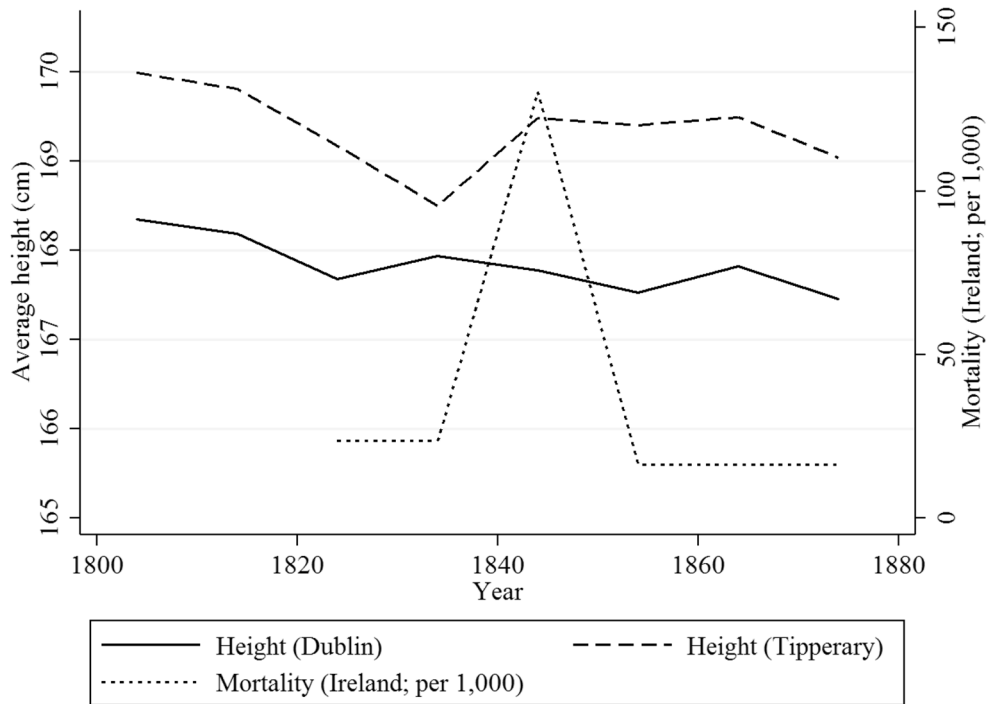
² While famine-related mortality was negligible, foodstuff did become increasingly scarce in Germany during this conflict due to the reallocation of economic resources towards the war economy and a naval blockade imposed by Britain (Blum 2011).

³ Specifically to chronic diseases such as coronary heart disease, type 2 diabetes, cancer, and osteoporosis, as well as psychiatric illnesses such as schizophrenia (Calkins and Devaskar 2011; Almond and Currie 2011). Other documented effects include reduced labour supply and cognitive ability (see, e.g., Majid 2015).

⁴ Other types of *in utero* shocks, such as maternal stress, have recently become popular in FOH studies (see, e.g., Class et al. 2011; Class et al. 2014; Persson and Rossin-Slater 2016).

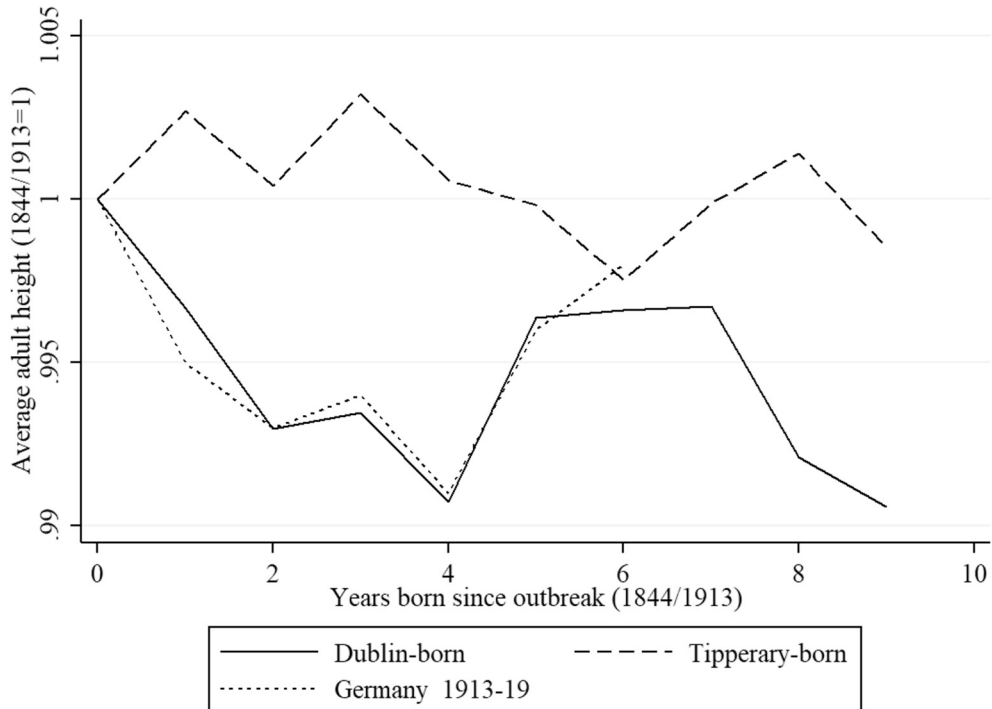
⁵ Including the Dutch potato famine of 1846-47 (Lindelboon 2010), the Finnish famine of 1866-68 (Kannisto et al. 1997), the Siege of Leningrad famine of 1941-44 (Stanner et al. 1997), the Dutch Hongerwinter of 1944-45 (Roseboom et al. 2001), and the Chinese Great Leap Forward famine of 1958-61 (Gørgens et al. 2013; Kim et al. 2013).

Figure 2: Height and famine-related mortality in Ireland



Sources: Authors' calculations, using Clonmel and Dublin prison registers, pre-Famine mortality estimates from Mokyr (1985), Famine mortality estimates from Boyle and Ó Gráda (1982, 1986), and post-Famine mortality data computed from BPP (1868-69, 1874).

Figure 3: Height impact of two famines compared, Ireland 1845-52 and Germany 1914-18



Sources: Authors' calculations, using Clonmel and Dublin prison registers and Blum (2011).

Famine”), it is somewhat surprising that there is no economic study of the long-run impact of prenatal and early life famine exposure on the health of the island’s residual population.

The biological mechanisms underpinning the FOH relate to fetus growth *in utero*, especially the ability of a mother to nourish her fetus, and thus the standard of living enjoyed by the mother’s household.⁶ Ideally, to observe and test for the FOH requires longitudinal data tracking individuals from birth to adulthood. However, in most countries such rich data sources are unavailable. Instead, scholars use stature as a proxy for health and net nutrition. This is because a population’s average terminal adult height reflects the specific facet of that population’s living standards which is related to nutrition and health *in utero* and in early life, with the crucial period being approximately up to the age of two (Currie and Vogl 2013). A large literature also suggests that adult height proxies other health and human capital-related traits, such as cognitive abilities (Schick and Steckel 2015), mental health (Case and Paxson 2008a), and the ability to generate a wage premium (Persico et al. 2004; Paxson et al. 2009). A population’s average height is highly sensitive to nutritional and disease shocks, and so a dataset of the terminal heights of individuals born during Ireland’s famine, and who survived into adulthood, allows us to use the Irish experience to test the FOH with a high-mortality famine episode.

To gain an insight into the health conditions of the Irish population requires the use of archival sources in which stature was consistently recorded for cohorts born before, during and after the Famine. In terms of data, the contribution of our study is the use of anthropometric information extracted from one such source: prison registers. These unique and rich historical documents facilitate a direct inference of the impact of famine-related nutritional and dietary change. This study samples cohorts born before, during and after the Famine from the complete population of prisoners incarcerated for any period of time between 1854 (after the Famine had ended) and 1910 in two locations in Ireland: Dublin and Clonmel. These registers provide very detailed information on every prisoner that entered the prison system on categories including their height, age, crime, location of birth and residence, occupation, religion and level of literacy.⁷ It is appropriate to consider this population a “targeted sample” in that it enables us to track exactly those who Malthus (1798) believed were most affected by a positive check: ‘the lowest orders of society’. It is important to note that our data do not constitute only hardened criminals; “drunkenness” was criminalised and punished with a custodial sentence.⁸

⁶ This, in turn, depends on a mother’s diet, the placenta’s ability to supply nutrients, and a mother’s own *in utero* experience (Calkins and Devaskar 2011). Prenatal shocks can be counteracted by compensatory growth, but this catch-up growth is still associated with negative adult health outcomes (Barker 2004: p. 592S).

⁷ The present work follows Ó Gráda’s (1991, 1994, 1996) use of prison registers from Dublin’s Kilmainham Gaol and Tipperary’s Clonmel Gaol. But while these studies examine criminals *imprisoned* during the Famine, our study looks at those *born* during the Famine and institutionalised later.

⁸ Drunkards represent approximately 40% of our sample, while 41% of the all prisoners in Ireland were drunkards in 1878-79 (BPP 1878-79, pp. 40-41), and 47% in 1889-90 (BPP 1890, pp. 38-39). See Appendix A for further discussion.

Famines exacerbate the mortality of specific elements of the population (young and old), and they also see reductions in birth rates as people are unwilling or unable to procreate; afterwards, birth rates tend to rebound (Ó Gráda 2009). Both the selection in mortality and fertility are issues that can affect the attributes of a population after a famine. A poor childhood nutritional and disease environment can therefore have either one of two effects: scarring or selection (Deaton 2007). In the scarring outcome, surviving children do not realise their adult height potential, with the degree of the reduction in their height depending on the severity of the nutritional and disease shock. This, in turn, lowers societal average height. By contrast, selection occurs when a high disease and low nutritional environment raises the survival cut-off threshold and fewer (potentially low-height/low-health) children survive into adulthood, thereby *increasing* the average height and health of survivors (Alter 2004). We argue that such extreme selection explains the absence of scarring in Ireland’s rural, famine-born population.

Using samples from a range of countries, Bozzoli et al. (2009) explore scarring versus selection effects with data on heights, mortality and income. They find suggestive evidence that selection may be stronger than scarring when mortality levels are high and income levels are low. Indeed, as Almond (2005) and Almond and Currie (2011) highlight, if excess mortality rates are high, negative scarring effects may be crowded out by the positive selection effects. Studies which have found scarring due to famines have had to employ sophisticated econometric techniques to “correct” for any such selection (e.g., Gørgens et al. 2013). Our argument is that such correction techniques are unnecessary and anyway undesirable if we want to find out about the *survivors* of famines, the very people who are responsible for the wealth of the nation after the dead have long been buried.

This paper proceeds as follows. Section 2 provides the necessary background on the Great Irish Famine with which to understand the economic contribution of our findings. Section 3 discusses the limitations of previous anthropometric studies of Ireland, and thus demonstrates how our unique data source and econometric approach represent a significant improvement to this literature. Section 4 sets out the issue of selection in individual-level data in more detail, including how this affects previous studies of the FOH. Section 5 outlines our data source, including its limitations. Section 6 defines our various empirical strategies, including our instrumental variable setup. Section 7 presents our main findings, and Section 8 discusses a set of additional tests. Section 9 summarises our results and restates our overall contribution. Appendices A and B provide additional institutional and historical details to aid in the interpretation of our findings. Finally, Appendices C, D, E and F are a series of further robustness exercises.

2. Ireland's Famine

Ireland experienced Western Europe's last great subsistence crisis: back-to-back harvest failures between 1845 and 1852 caused by the fungus *phytophthora infestans*, or potato blight. Farmers had come to rely exclusively on the Irish Lumper variety of potato because it was particularly well suited to poor-quality soil. The Lumper proved to be very susceptible to blight, and there existed few alternative sources of sustenance for the majority of rural folk; rural Ireland had become a monoculture. Approximately 20 per cent of Ireland's population either perished or migrated as a result of this blight-induced famine, reducing the island's population from 8.17 to 6.53 million between the recorded censuses of 1841 and 1851 (BPP 1851).

Mokyr and Ó Gráda (2002) estimate that only half of the deaths during the Famine were associated directly with malnutrition, while the other half were caused by indirect effects on personal behaviour and social structure. These authors' estimates of the causes of death indicate five mainly famine-related illnesses: dysentery, diarrhoea, dropsy, starvation, and fever.⁹ Famine mortality figures were highest in Munster and Connacht (west and south-west of the island), followed by Leinster (east). The lowest mortality was observed in Ulster (north-east). Figure 4 locates the regional impact of the Famine in terms of excess mortality, using county-level estimates from Mokyr (1985).

In terms of this study, the relevant populations relate to the counties in which our criminals were imprisoned: the Munster county of Tipperary (Clonmel Gaol), and the Leinster county of Dublin (Kilmainham Gaol). Contrasting population trends can be seen. The population of Tipperary was ravaged by the Famine: in 1841 the population stood at 0.44 million, but by 1851 this had fallen by a quarter to 0.33 million. Lower and upper bound estimates of excess mortality in Tipperary during the Famine are 24 and 35 per 1,000 population (Mokyr 1985). This compares to the all-island median of between 19 and 26 deaths per 1,000.

Meanwhile, Greater Dublin (city and surrounding county) had a population of 0.37 million in 1841. This increased slightly to 0.40 million in 1851 as migrants from elsewhere in Ireland fled the famine conditions. The increase in the population of Greater Dublin masks the growing "slumification" of the city. Dublin's plight was somewhat atypical for nineteenth-century British cities as its population was not sustained by growing industrialisation; the city was increasing in population size without consummate improvement in the quantity or quality of its housing stock. The slumification also had an influence on the general disease environment, with persistent outbreaks of disease – so much so that Dublin had one of the lowest life expectancy of comparable cities (Prunty 1998: p. 74).

⁹ 'Fever' includes deaths from typhoid, typhus and relapsing fever (MacArthur 1956: pp. 265-68).

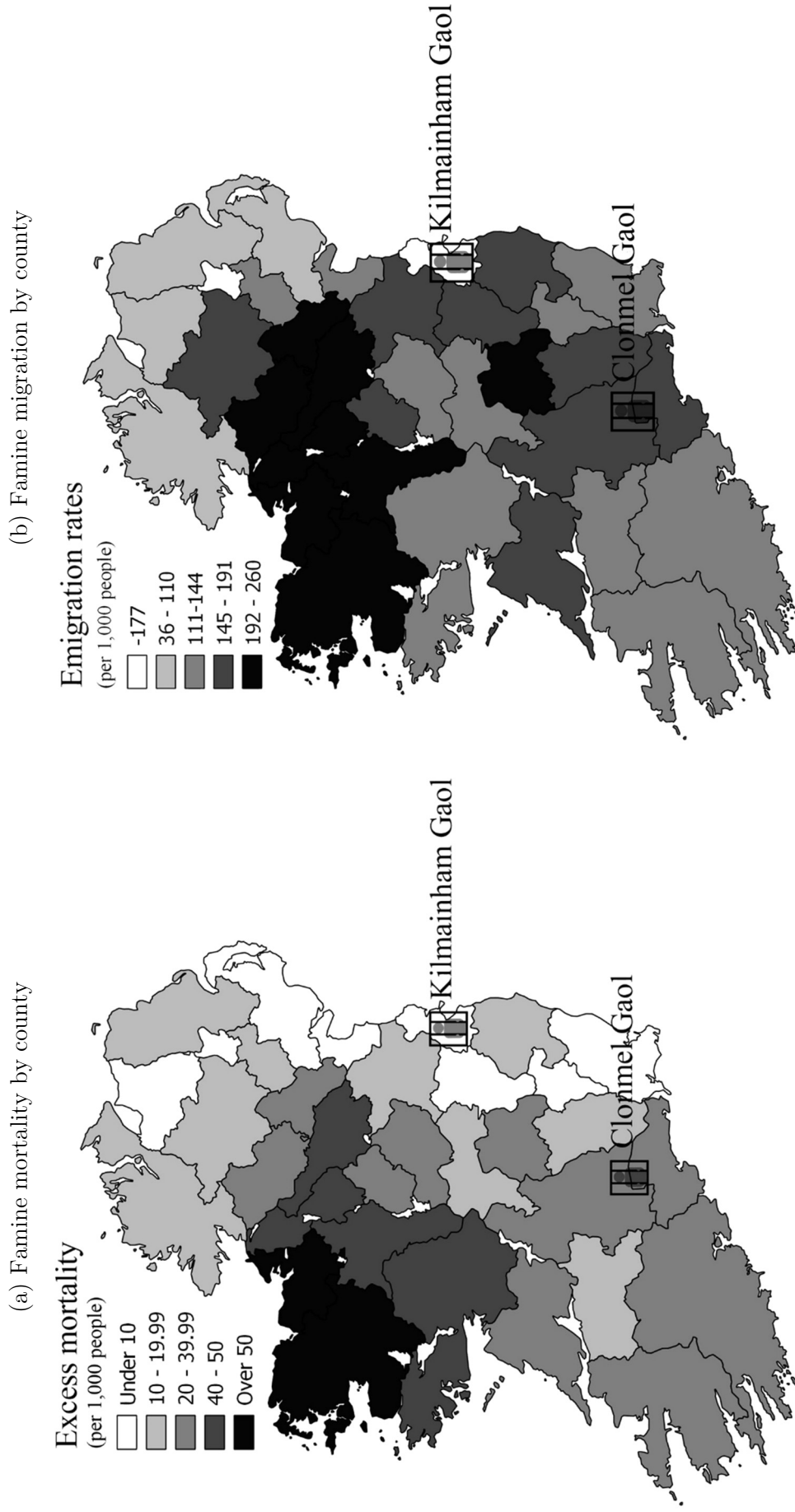
As the population of Greater Dublin expanded over the decade 1841-51, an older strand of literature saw Dublin (as well as Cork City and Belfast), as being ‘unaffected directly’ by the Famine as these were centres of industrial growth (Lynch and Vaizey 1960). Ó Gráda (1997: pp. 157-193) challenges this view, although he concedes that the famine mechanism was indirect. One such mechanism was through increases in food prices and resulting falls in entitlements, as the inhabitants of Dublin were less likely to be affected by absolute decline in food availability – the diet there was as much based on wheat (bread) as potatoes (Ó Gráda 1999: p. 163). Data on urban wages suggest a slight decline in real terms (D’Arcy 1989; Kennedy and Solar 2007).¹⁰ The second mechanism was through immigration of famished rural-folk into the city. Indeed, Ó Gráda (1999) finds evidence of increases in excess mortality in the city during the peak famine years and concludes that many of the famished were rural immigrants, who died of fever and dysentery rather than starvation. Together, these indirect famine effects make the Dublin-born population a useful comparison *vis-á-vis* the more directly-exposed rural population of Tipperary.

Internal and international migration was one of the main non-governmental responses to famine conditions in Ireland (Kenny 2000; Donnelly 2001; Ó Murchadha 2011). Migration enabled the famished to go to sources of food located in urban centres in Ireland, Britain, and North America. The Irish-born population of Britain almost doubled between the 1841 and 1851 censuses, from 415,725 to 727,326 (Macraird 2006). North America was the main destination for international migration.¹¹ After the Famine, Ireland had the highest migration rates of Western Europe (Hatton and Williamson 1994). As with famine-related mortality, famine-induced migration differed regionally. Ó Gráda and O’Rourke (1997) estimated the ratio of migration to mortality for all counties in Ireland. Tipperary experienced higher emigration relative to mortality, with a ratio of 1.18, whereas Dublin was an anomaly in the sense that it was a net-recipient of migrants during the Famine (see Figure 4).

¹⁰ Stagnant nominal wages coupled with price increases for wheat, flour, potatoes and oats.

¹¹ Mokyr and Ó Gráda (1982) find that Ireland’s emigrants to North America exhibited high levels of age heaping, a measure of numeracy (see Blum et al., 2017), leading Mokyr (1985: p. 246) to conclude that emigrants tended to have lower levels of human capital ‘than those who remained behind’.

Figure 4: Famine maps of Ireland, with geographic location of two prisons



Notes: Excess mortality rates are an average annual estimated total; emigration rates are totals expressed relative to the 1841 population.

Sources: Mortality data from Mokyr (1985), migration data from Ó Gráda and O'Rourke (1997), and GIS shapefile adapted from Gregory and Eil (2004).

3. Anthropometric Histories of Ireland

Malthus (1798: p. 44) viewed the incidence of famine as ‘the last and most dreadful mode by which nature represses a redundant population’. The work of this Anglican cleric and demographer has cast a long shadow over Irish economic history, with pre-Famine rural Ireland often viewed as having had unsustainable population levels, and the Great Irish Famine interpreted as a Malthusian catastrophe.¹² Modern growth models implicitly assume Malthus’s ‘positive check to population’ to mean premature death (e.g., Galor 2005, 2011). But Malthus, himself took a more nuanced perspective: a generational lowering of living standards that manifests itself in bad health, where mortality is just an extreme case of bad health. While the generation directly affected by a positive check may eventually die prematurely, they also suffer health and social consequences in their own, shortened, lifetime. And one manifestation of such a check, which Malthus highlights explicitly in his work, is stunted body growth.

Today, stature is widely used as an anthropometric indicator of the health status of a population in both the economic history and economic development literatures (e.g., Fogel 2004; Deaton 2013). Heights reflect health and living standards from an outcome-oriented viewpoint. The mean stature of a population is a function of official income and unofficial income, such as subsistence farming, public goods, and illicit trading (Steckel 1995). Heights also have been found to be sensitive to the level of income inequality (Deaton 2008). The height of a generation is determined around the time of its birth, with health standards of mothers as well as nutritional and health standards of infants playing a crucial role (Eveleth and Tanner 1976; Steckel 1995).

Deaton (2007) argues that cross-country evidence on height is difficult to interpret. His case in point is Africa, where the population is the poorest in the world but also the tallest of all developing regions. Deaton (2007) disregards genetics as an explanation in the African case, and suggests instead that selection may be greater than scarring. He also highlights the variation in heights across social groups within poor countries as evidence against a genetic explanation. Similarly, in our study we disregard genetic determinants as we are focusing on the population of one specific island that shares the same “gene pool”. An additional advantage is that our sample is drawn from a single social group: the least successful in Irish society, those selecting or selected into the criminal population that were subsequently caught and incarcerated as punishment for their crimes.

A number of studies have already used anthropometric indicators, and especially average societal height, as a way of analysing Ireland’s past. Most have collected data recorded during the period 1800-50, such as Australian transportation records, East India Company registers, Royal Marine and Army records and prison registers (Nicholas and Steckel 1997; Mokyr and Ó

¹² See Mokyr (1984), McGregor (1989) and Kelly and Ó Gráda (2015) for discussion of the Malthusian debate.

Gráda 1996; Floud et al. 1990). However, these studies do not contain much, if any, information regarding the cohorts born *during* the Famine itself. Moreover, they do not refer to samples derived from the population resident *in* Ireland, but rather to the Irish-born found elsewhere. None explicitly take account of the various selection biases that may occur, most notable due to migration. A consistent finding of these studies is that the pre-Famine Irish enjoyed a considerable height advantage over the peoples of Great Britain, despite their relative poverty – a result many attribute to the superior nutritional diet composed primarily of potatoes and butter milk. A key facet overlooked in these studies, however, is how the changing diet in the Famine and post-Famine periods might have influenced these observed trends.¹³

Findings from several studies that have used military data suggest that there is a noticeable scarring effect from the Famine. Floud et al. (1990: p. 205), who use data from volunteer army and navy recruits, find a significant decline in the average height of Irishmen born in the 1840s.¹⁴ In the subsequent decades they find that heights rebound among Irish families that ‘survived and stayed’. Using the same data, but different methods, Komlos (1993: pp. 133-136) finds that the downturn in average heights had already begun in the 1830s, which he attributes to Malthusian pressures foreshadowing the Famine.¹⁵ However, neither Floud et al. (1990) nor Komlos (1993) dealt with the selection biases inherent in the volunteer army sample, such as changes to the supply and demand for soldiers over time and the place of origin of recruits in Ireland.¹⁶ This point is addressed by Mokyr and Ó Gráda (1988, 1994, 1996), who use comparable volunteer army recruits, this time from the East India Company over the period 1800 to 1860.¹⁷

Studies using anthropometric data from the penal system find declining height trends before the Famine. Nicholas and Steckel (1997) use a sample of Irish-born men and women transported to New South Wales between 1817 and 1840. They find a modestly declining height trend for male cohorts born in the 1770s through to the 1820s. Greggs (1994) uses decadal samples from prisons in Glasgow over the period 1840 to 1880, which includes Irish-born migrants. He finds that trends in mean heights were declining for those born in the 1810s to the 1830s, but that

¹³ Clarkson and Crawford (2001) note that potato consumption declined as tillage land dropped by 50% between the 1860s and 1910.

¹⁴ This famine effect was noticeable when estimating long-run trends, so much so that Floud et al. (1990: pp. 211-212) decreed that those born in famine years should be omitted as outliers.

¹⁵ Komlos is critical of the underlying methods used by Floud et al. (1990) to address the truncated height distribution resulting from minimum height requirements

¹⁶ The sampling strategy of 5,000 observations-per-decade may influence this trend; a larger share of Irish-born were recruited in the 1860s than in the 1870s (Floud et al. 1990: p. 90). Furthermore, they fail to distinguish between urban and rural-born in among Irish recruits; most Irish-born recruits were from urban centres (McLaughlin 2017).

¹⁷ Drawing on Mokyr and Ó Gráda, Bodenhorn et al. (2017) make a wider point about selection in anthropometric samples across unobservable characteristics. See Appendices A and B for a discussion of this issue in our context.

these rebounded for those born in the 1840s. Greggs interprets his results to indicate that the nutritional status of the Irish-born in Scotland was already under pressure *before* the Famine.

New life was given to the debate by a series of studies exploiting data from the 1930 *Harvard Anthropological Survey of Ireland*.¹⁸ Relethford (1995) and Young et al. (2008) use these data to answer whether there was an observable increase in stature in post-Famine Ireland. Both studies find evidence to support scarring, which Young et al. (2008) attribute to relief of Malthusian pressures. However, as Relethford (1995: p. 252) notes, to fully address the ‘potential impact of the Famine’, data on heights before, during and after the Famine are needed, which the Harvard survey does not fully contain. Using a small dataset collected by Beddoe (1870) from the voluntary measurement of men and women in the 1860s, they suggest that pre-Famine height trends were not too dissimilar from post-Famine trends and tentatively concluded that ‘the Famine did not have a dramatic effect on adult stature’. The present study extends these works by tracking and explaining trends in height using a considerably more extensive dataset pertaining to exactly that segment of society most exposed to famine conditions: the poor and least successful.

4. Understanding Selection

In Lumey et al.’s (2011) comprehensive review of the effects of famine on prenatal and adult health outcomes, the most consistent findings across studies relate to body size (height and BMI), diabetes and schizophrenia. The reviewed studies share many similarities with our own study: they are observational and not experimental in nature; they focus on outcomes at future points in time; they are cohort studies; and they use population-based registries to trace people. Lumey et al. (2011) outline the analytical strategies that have been applied to date, which include simple cohort analysis, difference-in-difference estimation and sibling designs. Across studies definitions of famine exposure are ecological rather than based on individual food consumption as these data are unavailable. Within a famine period, primary exposure to food shortages are difficult to disentangle from other associated famine effects. Furthermore, chronologies of famine episodes vary from the well-defined (the Dutch Hongerwinter famine lasted exactly six months) to others that are much less so (seasonal famines in The Gambia between 1949 and 1994).

A key issue in the literature on the health effects of early life exposure to famine relates to scarring versus selection. In their analysis of a sample of survivors of the Leningrad siege, Stanner et al. (1997) found no difference between exposure *in utero* and exposure during infant life on various health outcomes. However, they failed to acknowledge the possibility of selection bias

¹⁸ See Hooton and Dupertuis (1955) for description of these data.

emanating from selective mortality (Rich-Edwards and Gillman 1997). Recent studies of the Chinese Great Leap Forward famine of 1959-61 have attempted to address the issue with more robust methods. Gørgens et al. (2012) look at growth stunting in this famine, using data from the *China Health and Nutrition Survey*. They find that the famine cohort was stunted by 1 to 2 cm, but that this was offset by selection of equal magnitude, leading to no overall effect on the average (Gørgens et al. 2012: Fig. 1).¹⁹

Kim et al. (2016) also look at the long-run health impact of the Great Leap Forward, this time using the *China Health and Retirement Longitudinal Study*. They find that cohorts born during the famine years had poorer health and lower cognitive ability. They outline a number of selection issues (selective mortality, fertility and migration) which may influence their results, but are unable to address these empirically and instead suggest their findings are a lower bound of their true effects. Using the same dataset, Xu et al. (2016) attempt to see whether fetal famine exposure had a long-run health impact, measured by biomarkers and anthropometric characteristics. Their innovation is to use multiple estimation strategies which take account of selective mortality. Their primary method of estimation uses the simple cohort difference, which compares the cohort born during the famine with cohorts born before and after. They also adopt additional estimators: the deviation from cohort trend that considers outlying cohorts; a difference-in-difference estimator that exploits regional variation in famine severity; and an instrumental variable which uses official exaggerations of grain yields as instruments for famine severity. Using a simple cohort approach appears to indicate a famine effect, but this disappears with the alternative estimators. They conclude this to be evidence of selective mortality; those most likely have been affected by the famine had already died (“survival of the fittest”).

As a way to overcome sample selection biases from selective mortality in famines, scholars have attempted to test the FOH using non-famine natural experiments, such as pandemics and income shocks. Almond’s (2006) landmark study uses samples from the 1960, 1970 and 1980 US censuses to ascertain the impact of prenatal exposure to the Influenza Pandemic of 1918-19 on later life outcomes. He finds increased likelihood of disability, lower income and lower education of those exposed to the pandemic *in utero*. Meanwhile, Banerjee et al. (2010) focus on the long-run health effects of income shocks at birth, proxied using adult male height and life expectancy. Their empirical strategy exploits the differential incidence of *phylloxera*, an insect that destroyed large segments of the French grape crop between 1863 and 1890. Their empirical strategy uses a difference-in-difference methodology to compare children born in *phylloxera*-affected departments with those born before and after *phylloxera* exposure, and also relative to departments not

¹⁹ Kim et al. (2013) focus on second-generation human capital outcomes from the Great Leap Forward famine, using data from the 2000 census. Their identification strategy instruments for the estimated death rates of place of parental birthplace and they find significant second-generation effects in terms of secondary school attendance.

exposed in the same years. Every additional hectare of land used for vineyards is associated with a three per cent decline in height, approximately 1 cm (Banerjee et al. 2010: p. 723).

Evidence from archaeological studies of institutional grave sites give indications as to the selective famine mortality conditions in Ireland. The main archaeological evidence comes from the 2006 excavation of the Kilkenny Workhouse intramural burial ground, 33 km from Clonmel Gaol (Geber 2016).²⁰ A high proportion of skeletal remains had evidence of scurvy rather than any infectious disease, and this disproportionately affected the young.²¹ Comparisons with other burial sites, some including famine emigrants, show that the skeletal remains in Kilkenny had a much less varied diet (Beaumont et al. 2013).²² However, the representativeness of the data is uncertain due to the so-called “osteological paradox”: demographic non-stationarity, selective mortality, and hidden heterogeneity in risks (Wood et al. 1992). From the perspective of our study, the most important of these is selective mortality, as osteological data can only give information about those that died at a given age, but nothing about survivors. For example, deaths of children are selective as those most frail are more likely to die. Those that survive early life conditions are more likely to survive longer (Wood et al. 1992). These issues aside, what the archaeological evidence suggests is that famine mortality in Ireland may have been higher amongst the young, and that survivors would have been a highly-selected group.

An additional selection issue relates to the representativeness of prisoners. This has recently become a key concern in the anthropometrics literature (Bodenhorn et al. 2017): were prison inmates representative of the general population, a *lumpenproletariat* criminal class, or selecting into crime differently over time? Ó Gráda (1991) argues that the type of crimes committed, and the fact that the majority were one-time offenders, suggests prisoners were representative of the wider population and not simply a reflection of the lowest social groups. Appendix A provides context of the institutional structure of law enforcement and punishment, custodial sentences were used for both serious and petty criminal offences and the majority of prisoners were convicted for being drunk and disorderly. Elsewhere, we suggest that the working class is somewhat overrepresented in Irish prison samples (Blum et al. 2017). In this present work we argue that this is a desirable feature of our data, and can anyway be addressed by applying appropriate econometric methods.

²⁰ 970 skeletal remains were exhumed and examined, representing just under half of the known deaths from the incomplete workhouse records (estimated 2,234 deaths) (Geber 2016).

²¹ 33% of the skeletal remains were aged under five and 48% of the remains were under 12 (Geber 2011).

²² Beaumont et al. (2013) compare the Kilkenny sample with a sample from the Lukin Street Catholic graveyard in London. They find that the Kilkenny sample had a lower d_{15n} value, indicating lower variance in diet. However, the lack of supporting epigraphic evidence renders it difficult to establish whether the skeletal remains were native-born Londoners, first or second-generation Irish, or spouses of Irish (cf. Morgan 2013).

5. Data

The data sources used in this study are prison registers from two distinct locations on the island of Ireland: Clonmel Gaol in County Tipperary, and Kilmainham Gaol in County Dublin. The locations of these prisons are shown in Figure 4. Our data constitutes the complete population that was incarcerated in each prison over the nineteenth century.²³ The prison records consistently provide information regarding the heights of male prisoners *born* before, during and after the Famine and this enables us to treat the Famine as a “natural experiment”, influencing living standards, and therefore height, of various populations in Ireland.²⁴ The data were recorded by prison administrators and are standardised and rich in nature; new inmates were required to undergo an obligatory medical examination by a prison doctor (Breathnach 2014).

Over the period of our study, there were effectively three “prison regimes”. The first, from 1791 to 1853, saw the removal of a segment of criminals from the UK as a punishment for what were deemed the most severe crimes: over this period, 26,500 convicts were transported to Australia (Kilcommins et al. 2004: p. 17).²⁵ Transportation was replaced with penal servitude and this was accompanied by the opening of the first “state prison”, Mountjoy, in 1850. A further administrative change occurred in 1877, when prisons throughout Ireland were centralised under the General Prisons Board. This resulted in a change in the classification of prisoners being held in Kilmainham and Clonmel: they were to be used for ‘untried and prisoners under sentence, males for sentences not exceeding 12 months and females not exceeding 6 months’ (BPP 1878-79, p. 37). From 1877 onwards, prisoners serving longer-term sentences were sent to specialist convict prisons: Lusk (Dublin), Mountjoy (Dublin), and Spike Island (Cork). Appendices A and B discuss the institutional context of these data in more detail, and conclude that there is little evidence of selection into crime across variables other than these institutional changes.

The personal characteristics used in our study include height, age, year of birth, literacy status, religion and nature of crime committed.²⁶ Our key variable used to identify any possible famine effect is average adult height. For Kilmainham Gaol, mean male height, after excluding children and adolescents below the age of 17, is 168.1 cm (see Table 1 for summary statistics). Height in Clonmel is somewhat higher, at 170.0 cm. This reflects generally superior biological

²³ For Clonmel the years of incarceration are 1840 to 1928, and for Kilmainham it is 1798 to 1910. We exploit only those records pertaining to individuals incarcerated after the Famine had ended.

²⁴ A precedent for using Irish prison registers comes from Ó Gráda’s study of Clonmel and Kilmainham inmates’ heights in the 1840s (Ó Gráda, 1991, 1994: App. 4.1).

²⁵ The cumulative figure for transportation is eye-catching, but it was less dramatic on an annual basis; over the period 1839-44 transportation accounted for just 9% of all sentences.

²⁶ All prisoners’ heights were recorded in Imperial measurements using a yardstick, a vertically-mounted measuring rod. We convert all measurements to the metric system to aid with interpretation.

living standards in rural Ireland.²⁷ The average year of birth is 1850, with sufficient variation to capture living standards before, during and after the Famine. At point of incarceration, males were on average aged 33.1 years in Kilmainham and 38.5 years in Clonmel. For Kilmainham Gaol, Protestants make up 9.4 per cent, while for Clonmel Gaol this is 1.7 per cent, reflecting the larger share of Protestants in the Greater Dublin area. The data provide for each individual their ability, separately, to read and write; we classify individuals who are able to read and write as “literate”, and “illiterate” otherwise. We find that inmates of Kilmainham Gaol were generally more likely to be literate than their rural counterparts.

A different set of control variables is based on the type of offence an individual was imprisoned for, following Blum et al. (2017). Offences are distinguished into seven sub-categories, adapting a contemporary criminal classifications (see Appendix A): offences against the person, violent and non-violent offences against property, begging and prostitution, drunkenness, rioting, treason and a category for offences related to indecency. Duplicate observations due to multiple imprisonment of recidivists are excluded from the analysis to avoid double counting. We categorise all prisoners according to the nature of their crime to be able to control for offence-specific effects in the regressions performed below.²⁸

Finally, the main analysis is restricted to a sub-group of individuals older than 17 years-of-age. Populations exposed to low biological standards of living usually reach their final adult height in their late-teen years, in extreme cases even later than that (see Eveleth and Tanner 1976). We add variables to control for, and observe, any such catch-up growth in our samples. Similarly, the effect of shrinking among individuals aged 50 and above are corrected using the formula provided by Fernihough and McGovern (2015),²⁹ which allows us to extend average height trends further back in time.

²⁷ For exemplary studies on this widely-observed phenomenon, see Martínez-Carrión and Moreno-Lázaro (2007) on Spain; Riggs and Cuff (2013) on Scotland; Baten (2009) on Bavaria; and Zehetmayer (2017) on the US.

²⁸ We categorise recidivists by the first crime for which they were imprisoned.

²⁹ Fernihough and McGovern (2015) estimate men above the age of 50 experience an annual decline in physical stature of approximately 0.09%.

Table 1: Descriptive statistics

	Kilmainham Gaol (males)			Clonmel Gaol (males)		
	N	mean	sd	N	mean	sd
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Birth cohorts: 10-year famine window</i>						
1834 - 1843	4,143	0.244	0.430	983	0.208	0.406
1844 - 1853 (famine)	5,704	0.336	0.472	1,469	0.311	0.463
1854 - 1863	7,130	0.420	0.494	2,272	0.481	0.500
<i>Birth cohorts: 5-year famine window</i>						
1835 - 1839	1,867	0.110	0.312	406	0.086	0.280
1840 - 1844	2,479	0.146	0.353	652	0.138	0.345
1845 - 1849 (core famine)	2,733	0.161	0.370	642	0.136	0.343
1850 - 1854	3,090	0.182	0.386	836	0.177	0.381
1855 - 1859	3,548	0.209	0.407	983	0.208	0.406
<i>Birth details</i>						
Year of birth	16,977	1850	8.293	4,724	1852	8.357
Local-born	9,467	1851	7.937	3,315	1852	8.379
Non-local Irish-born	7,510	1850	8.575	1,409	1852	8.301
<i>Personal characteristics</i>						
Height	16,977	168.10	6.66	4,724	170.00	6.09
Age	16,977	33.05	12.41	4,724	38.45	11.62
Protestant	16,977	0.058	0.235	4,724	0.017	0.130
Catholic	16,977	0.942	0.235	4,724	0.983	0.130
<i>Literacy</i>						
Illiterate	16,977	0.327	0.469	4,724	0.390	0.488
Literate	16,977	0.673	0.469	4,724	0.610	0.488
<i>Offence</i>						
Offence against property (malicious)	16,977	0.011	0.103	4,724	0.006	0.078
Offence against property (violent)	16,977	0.036	0.187	4,724	0.025	0.157
Offence against property (non-violent)	16,977	0.142	0.349	4,724	0.111	0.315
Begging and prostitution	16,977	0.064	0.244	4,724	0.034	0.182
Offence against a person	16,977	0.264	0.441	4,724	0.227	0.419
Drunkenness	16,977	0.332	0.471	4,724	0.455	0.498
Riot	16,977	0.011	0.103	4,724	0.076	0.265
Treason	16,977	0.042	0.200	4,724	0.087	0.282
Indecency	16,977	0.125	0.331	4,724	0.053	0.225
Unknown	16,977	0.113	0.316	4,724	0.056	0.231
<i>Conviction</i>						
Year of conviction	16,977	1883	12.490	4,724	1890	8.595
Convicted during 1877-82	16,977	0.222	0.416	4,724	0.199	0.399
Convicted during 1886-91	16,977	0.153	0.360	4,724	0.225	0.418
<i>Famine and relief</i>						
Excess mortality during famine	16,977	2.578	8.308	4,724	8.351	13.360
Fever hospitals per capita	16,977	1.662	0.585	4,724	1.521	0.343

Sources: Authors' own calculations, using hand-collected dataset pertaining to all available Clonmel and Dublin prison registers held at the National Archives of Ireland (reference NAI/Pris1/3 and NAI/Pris1/33).

6. Empirical Strategy

The empirical strategy used to test for a “famine effect” relies on a test of differences in final average male height between the Famine-born cohort and the cohorts born in the decades prior to and immediately after the Famine. This strategy aims to capture the effect of malnutrition and worsening disease environment experienced by the Famine-born cohort, i.e., stunted growth. Our working hypothesis is that this effect should result in a height drop for individuals in locations where famine conditions were most severe, in rural Ireland (see Figure 4). Our alternative hypothesis is that we find no effect, which implies that there was “extreme selection”.

We use a broad definition of the Famine. While the main famine years are 1845 to 1852, we include the birth years 1844 and 1853 to account for famine exposure during infancy (1844 birth cohort) and *in utero* (1853 birth cohort). The following formula outlines the testing framework:

$$H_{ict} = \alpha + \beta_1(T_t) + \beta_2(X_{ic}) + \varepsilon \quad (1)$$

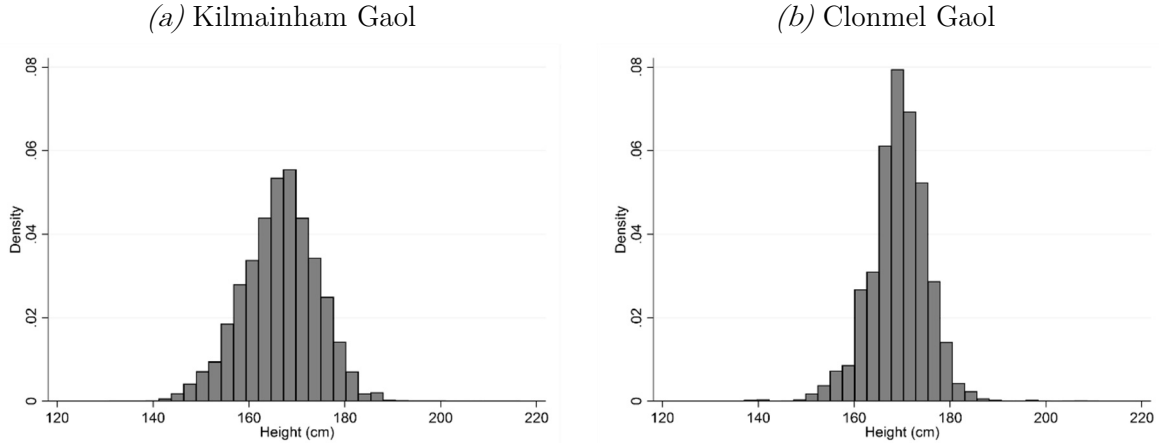
where H denotes height of individual i who was born in county c at time t . All results are conditional on a time trend that tests for differences in height between the cohorts born before, during and after the Famine, indicated by vector T . Other control variables, denoted by vector X , include literacy, religion, birth county-fixed effects, and the type of crime committed. X also contains controls for conviction periods when selection into the prison sample might have differed from normal times. We run our analysis separately for each prison.

We use the aforementioned framework to test for a famine effect in two different OLS settings. Our first strategy uses the rationale of a structural break to test for differences in height between a sequences of birth cohorts. This is also known as calculating the simple cohort difference. Our second strategy is based on the idea of a difference-in-difference approach, where the rate of excess mortality in individual i 's county during the Famine proxies famine exposure, i.e., the level of malnutrition and disease environment. In this setup, mortality rates help to distinguish high excess mortality regions of birth, such as rural Munster and Connaught, from low mortality regions, such as parts of Ulster and the Greater Dublin area.

$$H_{ict} = \alpha + \beta_1(M_c \times F_{it}) + \beta_2(T_t) + \beta_3(X_{ic}) + \varepsilon \quad (2)$$

In this latter framework we keep controls for time (T) to capture general time-specific effects, but add an interaction term ($M_c \times F_{it}$) combining famine-related mortality (M_c) and information about whether an individual was born during the Famine (F_{it}). This term is equal to the excess mortality (in per cent) in an individual's birth county if this individual was born during the Famine, and zero otherwise. To obtain a total effect in this setup, we combine all mortality-related effects obtained in the regression analyses with the general height trend estimated using

Figure 5: Height histograms, male prisoners



Sources: Authors' calculations, using Clonmel and Dublin prison registers.

birth cohort dummies. In models that solely use birth period effects, this combined metric is equal to the difference in height between pre-Famine and Famine-born cohorts. For models based on a combined strategy using birth period dummies in combination with excess mortality, we compute the aggregate effect by entering the observed excess mortality into Formula 2.

Additional results constitute a set of Tobit and instrumental variable regressions, which we use to assess the robustness of our findings when using Formulas 1 and 2. We run these tests separately for males from Leinster (the province in which Dublin is located) and rural Ireland. Geary (2012) reports that “famine fever” affected all parts of society, regardless of income and wealth. However, malnutrition was most severe in rural Ireland and among the poor; society’s most physically weak were more vulnerable during the Famine and were more likely to die, potentially leading to positively-skewed height distributions.³⁰

Tobit regression models address the presumption that selective mortality and selective migration disproportionately affected the left-hand-side of the height distribution (see Figure 5). We use Tobit regression techniques to address this potential selection bias, choosing a cut-off point that is below, but close, to the analysed samples’ median height. If the Tobit specification leads to substantially different results compared to the OLS results, we can conclude that selective mortality and selective migration disproportionately affects the left-hand-side of height distribution. We use Formula 4, assuming the specification of individual height outlined in Formula 3.

$$H_{ict} = \begin{cases} H_{ict}^* & \text{if } H_{ict}^* > H_L \\ H_L & \text{if } H_{ict}^* \leq H_L \end{cases} \quad (3)$$

where H_L is censored from below, and H_{ict}^* is a latent variable specified as:

³⁰ Indeed, mean height for adults imprisoned in Kilmainham is lower than mean height in Clonmel (Table 1).

$$H_{ict}^* = \alpha + \beta_1(M_c \times F_{it}) + \beta_2(T_t) + \beta_3(X_{ic}) + u_{it}, \text{ where } u_{it} \sim N(0, \sigma^2) \quad (4)$$

Another way to test the robustness of the relationship between excess mortality caused by famine conditions and the final average height of the Famine-born cohort is to use an instrumental variable approach. An instrument helps to address potential omitted variable bias resulting from unobserved individual characteristics. We use the number of so-called “fever hospitals” per 10,000 families (henceforth hospitals per capita) in an individual’s county of origin in the era *before* the Famine to proxy a county’s capacity to address famine fever *during* the Famine. Fever hospitals were part of the medical infrastructure of pre-Famine Ireland, established from the 1830s to prevent the increase of infectious fevers (Geary 2012). In the first stage (Formula 5) of this 2SLS procedure, we use the per capita availability of hospitals (K) that each individual enjoyed in any given county of birth as an instrument to explain excess mortality, resulting in $(M_c \times F_{it})'$. In the second stage, we re-estimate the relationship between excess mortality and average height (Formula 6).

$$(M_c \times F_{it})' = \alpha + \gamma K_c + \vartheta \quad (5)$$

$$H_{ict} = \alpha + \beta_1(M_c \times F_{it})' + \beta_2(T_t) + \beta_3(X_{ic}) + \varepsilon \quad (6)$$

A central requirement of the exclusion restriction is that the instrument must affect the left-hand-side variable only through its effect on the potentially-endogenous right-hand-side variable, i.e., excess mortality. Indeed, the history literature does not suggest a direct link between hospitals and the height of the Famine-born cohort, except through their beneficial effects on mortality and living standards during the Famine years (Geary 2012: p. 202). The presence of a hospital was not a sign of a county’s wealth; rather it was a consequence of a locality’s strong social hierarchy and the patronage of landlords, who were responsible for their funding. Fever alone accounted for almost a third of the excess mortality during the Famine (Mokyr and Ó Gráda 2002: p. 352), and so this medical infrastructure suddenly found itself at the centre of famine relief efforts. While hospitals existed before, during and after the Famine, their role in treating fever and limiting fever-related mortality was most pronounced during the Famine.

Fever hospitals were distributed highly unevenly, with the south of the island having a larger number. We consider this another piece of evidence that these hospitals were not a sign of economic development or living standards in general; if hospitals had been related to income or wealth, we would expect the typical east-west division in terms of economic development observable in historical Ireland, not the north-south division visible for hospitals (Ó Gráda 1994).

7. Principal Results

Table 2 reports origin and measurement of the individuals in each sample used, and separate city-born and rural-born individuals to enable a precise analysis of the effects of famine in this historical setting.³¹ Regression coefficients reported indicate the magnitude of the famine effect according to Formulas 1 and 2, the number of observations, and the coefficient of determination.³² In addition, we report famine-related mortality in the birth counties of the individuals in each sample, and the total estimated change in height due to exposure to the Famine. These results are shown on the bottom line of each table.

For males born in Dublin County, our results suggest a modest height decline throughout the 30-year period under observation. Height declined by 0.3 cm during the Famine, and by an additional 0.4 cm after the Famine (Model 1, Table 2A). We compare this Dublin-born, Dublin-imprisoned group with another sample that consists of within-Ireland migrants. We run separate tests for Leinster-born individuals and others born in more distant locations, to differentiate between living conditions in urban and rural locations. For these groups, we do not find any change in height between the pre-Famine cohort and the Famine-born cohort; regression coefficients suggest hardly any difference from zero, and standard errors suggest these coefficients are not statistically significant (Models 3, 6 & 7, Table 2A). These findings are inconsistent with our working hypothesis in that the observed famine effect is relatively small and that Leinster experienced a larger height decline than more heavily-affected rural locations. Instead, our results are consistent with our alternative hypothesis: extreme selection, particularly the selective mortality of the very young.

For the period after the Famine, we find that the height of those born in locations closer to Dublin tended to decrease, while height in areas that were most heavily affected by the Famine stagnated or even increased. Height in Leinster tends to stagnate, judging from the small coefficients that are not statistically significant (Model 4, Table 2A). The height of individuals born outside Dublin County stagnated during, and gained approximately 0.7 cm after, the Famine (Model 6, Table 2A). When we use mortality in an individual's county of birth to proxy for famine severity, our results are generally confirmed (Models 3, 5 & 7, Table 2A). The coefficients of the mortality variable are marginally insignificant; mortality has a negative effect on height in Leinster and the Greater Dublin area, but a positive effect in rural Ireland (compare Model 5 with 3 & 7).

³¹ We report only key indicators, such as the estimated height change due to famine.

³² Approximately 80% of an individual's height is determined genetically (Silventoinen 2003). We expect that R-squared value of 0.2 is the theoretically maximum possible obtainable value for this goodness-of-fit estimator.

We use another sample, inmates of Clonmel Gaol in County Tipperary, to gain insights into height developments in rural Ireland (Table 2B). We separately assess the heights of those hailing from the town of Clonmel and those born in the rest of the province of Munster, and those from Ireland in general. As for Tipperary’s urban-born individuals, we find an *increase* of 0.7 cm for the Famine-born cohort, and stagnation afterwards (Model 8, Table 2B). While mortality figures imply a significant famine effect, there was no corresponding drop in height (Model 10, 12 & 14, Table 2B); indeed, combining the mortality and height coefficient implies a stagnation or even an increase in height for the Famine-born generation. If the Famine left its mark on the Irish population, we expect to find signs of stunting in this rural sample of Munster-born prisoners. But here, results suggest a small *increase* of 0.5 to 0.6 cm in height during the Famine (Models 11 & 12, Table 2B). Again, this finding is consistent with selection rather than scarring.

8. Additional Results

In addition to our principal results, we run a series of additional analyses in order to ascertain the robustness of our findings. In the first such exercise, reported in Table 3, we define a core famine period as running from 1845 to 1849; we adopt a shorter, 5-year, window for our difference-in-difference analysis. These robustness tests follow the same rationale as before, and the results are consistent with our earlier findings. We find evidence of a drop in height of 0.7 cm for Dublin-born individuals (Model 1, Table 3A); we also find a decrease for Leinster-born individuals, but of a smaller magnitude of 0.4 cm (Model 4, Table 3A). Meanwhile, rural Irish-born individuals imprisoned in Dublin do not show such an effect (Models 2 & 6, Table 2A). Similarly, we do not find a decrease in heights for individuals imprisoned in Clonmel Gaol (Models 8 to 14, Table 3B). Using excess mortality (Models 3, 5 & 7, Table 3A, and Models 10, 12 & 14, Table 3B) does not suggest that famine conditions brought about a height drop; only the sub-sample used in Model 14 show any signs of height deprivation brought on by the Famine, while the combined mortality and cohort effects rather indicate a stagnation.

For Kilmainham Gaol, Tobit results are generally consistent with the OLS results in that male heights stagnated during the Famine and substantially increased thereafter (Table 4). Leinster-born males indicate a 1.1 cm decline in height for the Famine-born generation (Model 2, Table 4A). If the Tobit estimator is the appropriate tool for accounting for selective mortality, then Dublin-born individuals *were* affected by famine conditions. The combined famine effect, taking both birth period effects and mortality-related effects into consideration, are: -0.6 cm for Leinster-born individuals (Model 2), +0.3 cm for rural Ireland-born individuals (Model 6) and -0.4 cm for the all-Ireland sample (Model 10).

The first stage results in the IV specification confirm a relationship between fever hospitals and mortality (Table 4A). Male mortality is systematically lower where hospitals were more abundant. Apart from Model 16, where there is little variation in famine-related mortality, F-statistics generally suggest this instrument is strong enough to be used in this setting. For males imprisoned in Kilmainham Gaol, IV results are similar to Tobit results and reveal that males born in Leinster during the Famine were approximately 1.4 cm shorter (Model 3, Table 4A). Results for those born outside Leinster are not statistically significant, and the combined effect (regardless of standard errors) suggest height stagnation during the Famine.

We applied the same methodology to the Clonmel sample; we report baseline OLS results, Tobit results and IV results for three different sub-sets of the data (Table 4B). For our Munster-born sub-sample, while the baseline OLS results suggest an increase in height during the Famine, our Tobit and IV results indicate stagnation. In general, however, these results are consistent with our earlier findings for Clonmel Gaol: the absence of scarring, suggesting, therefore, extreme selection.

In addition to the analyses described above, we carry out four further robustness exercises. The first, described in Appendix C, exploits the religious affiliation and literacy status of prison inmates to disentangle whether scarring and selection may be cancelling one another out. Contrary to economic intuition, we find that Catholics and illiterates in the residual population were *less* affected by the Famine, not more, despite their somewhat lower socioeconomic status.

In the second exercise, described in Appendix D, we re-weight our prison sample to better reflect the attributes of the general population, taken from census summaries compiled for Parliament. The new results are consistent with our baseline results.

The third robustness exercise, in Appendix E, further redefines our birth cohort window length to track year-on-year height differences. However, to do so we must remove those individuals born in round years due to a phenomenon known as “age heaping”. Again, our baseline results are confirmed by this analysis in that we find no famine effect for rural Ireland, but rather a drop in height among the urban famine-born cohorts.

Finally, the fourth exercise, Appendix F, attempts to account for possible famine stunting experienced during adolescence. We re-run our analysis with new samples of individuals who were 3-7, 8-12 and 13-17 at the end of the Famine. Much like for infants, we find a famine adolescence effect for Dublin-born individuals, but no such effect for those born elsewhere.

Table 2: Principal results, 10-year famine window

<i>Panel A: Kilmainham Gaol (males)</i>							
Measurement:	Dublin	Dublin	Dublin	Dublin	Dublin	Dublin	Dublin
Sample origin:	Dublin	Ireland (excl. Dublin)	Ireland (excl. Dublin)	Leinster (incl. Dublin)	Leinster (incl. Dublin)	Ireland (excl. Leinster)	Ireland (excl. Leinster)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>Birth period</i>							
1834 - 1843	0.27*** (8.38)	-0.06 (-0.26)	0.27 (0.88)	0.13 (0.84)	0.05 (0.29)	-0.20 (-0.68)	0.74 (0.96)
1844 - 1853 (famine)	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>
1854 - 1863	-0.41*** (-22.04)	0.46** (2.53)	0.79*** (3.00)	-0.09 (-0.38)	-0.16 (-0.88)	0.66 (1.42)	1.60* (1.85)
<i>Famine effect</i>							
Mortality in %			0.02 (1.61)		-0.02 (-1.37)		0.03 (1.36)
Observations	9,467	7,481	7,481	14,937	14,937	2,011	2,011
R-squared	0.06	0.06	0.07	0.08	0.08	0.09	0.09
<i>Famine mortality in area under observation (in %)</i>	<i>-0.7</i>	<i>19.0</i>	<i>19.0</i>	<i>4.3</i>	<i>4.3</i>	<i>33.6</i>	<i>33.6</i>
<i>Estimated height change due to famine (in cm)</i>	<i>-0.27</i>	<i>0.06</i>	<i>0.11</i>	<i>-0.13</i>	<i>-0.14</i>	<i>0.20</i>	<i>0.27</i>
<i>Panel B: Clonmel Gaol (males)</i>							
Measurement:	Clonmel	Clonmel	Clonmel	Clonmel	Clonmel	Clonmel	Clonmel
Sample origin:	Clonmel	Ireland (excl. Dublin)	Ireland (excl. Dublin)	Munster (incl. Clonmel)	Munster (incl. Clonmel)	Ireland (excl. Munster)	Ireland (excl. Munster)
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
<i>Birth period</i>							
1834 - 1843	-0.70** (-2.35)	-0.47** (-2.09)	-0.67 (-1.04)	-0.53** (-2.58)	-1.19*** (-6.17)	-0.41 (-0.41)	-1.53 (-1.20)
1844 - 1853 (famine)	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>
1854 - 1863	-0.12 (-0.50)	0.06 (0.34)	-0.14 (-0.22)	-0.07 (-0.65)	-0.72** (-3.12)	0.20 (0.15)	-0.90 (-0.61)
<i>Famine effect</i>							
Mortality in %			-0.01 (-0.33)		-0.02** (-3.42)		-0.07 (-1.44)
Observations	3,318	4,589	4,589	4,223	4,223	501	501
R-squared	0.03	0.04	0.04	0.03	0.03	0.09	0.10
<i>Famine mortality in area under observation (in %)</i>	<i>29.4</i>	<i>27.5</i>	<i>27.5</i>	<i>28.0</i>	<i>28.0</i>	<i>16.9</i>	<i>16.9</i>
<i>Estimated height change due to famine (in cm)</i>	<i>0.70</i>	<i>0.47</i>	<i>0.40</i>	<i>0.53</i>	<i>0.63</i>	<i>0.41</i>	<i>0.35</i>

Notes: The dependent variable is final adult height. Birth periods are binary variables identifying if an individual was born during one of the nominated time periods. Famine effect is proxied by excess mortality during the Famine in % of the population. Control variables include age at measurement, time of imprisonment (prison regime dummies), religion, literacy status, birth-county fixed effects and the type of offence. Robust t-statistics in parentheses; where relevant, standard errors are corrected for clustering and autocorrelation by clustering at the birth-county level; *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Additional results 1, 5-year famine window

<i>Panel A: Kilmainham Gaol (males)</i>							
Measurement:	Dublin	Dublin	Dublin	Dublin	Dublin	Dublin	Dublin
Sample origin:	Dublin	Ireland (excl. Dublin)	Ireland (excl. Dublin)	Leinster (incl. Dublin)	Leinster (incl. Dublin)	Ireland (excl. Leinster)	Ireland (excl. Leinster)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>Birth period</i>							
1840 - 1844	0.70*** (22.08)	0.03 (0.16)	0.47 (1.40)	0.44** (2.18)	0.42** (2.20)	-0.09 (-0.24)	0.88 (1.10)
1845 - 1849 (core famine)	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>
1850 - 1854	0.23*** (7.05)	-0.02 (-0.08)	0.41 (1.38)	0.16 (1.69)	0.14** (2.38)	0.17 (0.23)	1.13 (1.39)
1855 - 1859	-0.36*** (-13.23)	0.64** (2.33)	1.07*** (3.35)	-0.03 (-0.10)	-0.05 (-0.18)	0.91 (1.39)	1.87** (2.42)
<i>Famine effect</i>							
Mortality in %			0.02* (1.78)		-0.00 (-0.22)		0.03 (1.66)
Observations	9,467	7,481	7,481	14,937	14,937	2,011	2,011
R-squared	0.06	0.07	0.07	0.08	0.08	0.10	0.10
<i>Famine mortality in area under observation (in %)</i>	<i>-0.7</i>	<i>19.0</i>	<i>19.0</i>	<i>4.6</i>	<i>4.6</i>	<i>33.3</i>	<i>33.3</i>
<i>Estimated height change due to famine (in cm)</i>	<i>-0.70</i>	<i>-0.03</i>	<i>-0.09</i>	<i>-0.44</i>	<i>-0.42</i>	<i>0.09</i>	<i>0.12</i>
<i>Panel B: Clonmel Gaol (males)</i>							
Measurement:	Clonmel	Clonmel	Clonmel	Clonmel	Clonmel	Clonmel	Clonmel
Sample origin:	Clonmel	Munster (incl. Clonmel)	Munster (incl. Clonmel)	Ireland (excl. Dublin)	Ireland (excl. Dublin)	Ireland (excl. Munster)	Ireland (excl. Munster)
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
<i>Birth period</i>							
1840 - 1844	-0.35 (-0.89)	-0.10 (-0.43)	-0.16 (-0.30)	-0.10 (-0.41)	-0.70 (-0.94)	-0.43 (-0.27)	-2.04 (-1.60)
1845 - 1849 (core famine)	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>
1850 - 1854	0.49 (1.26)	0.83* (2.56)	0.77 (1.38)	0.76*** (2.92)	0.16 (0.21)	0.32 (0.30)	-1.29 (-1.36)
1855 - 1859	0.32 (0.86)	0.50* (2.50)	0.44 (0.76)	0.66** (2.18)	0.06 (0.09)	0.93 (0.48)	-0.72 (-0.43)
<i>Famine effect</i>							
Mortality in %			-0.00 (-0.11)		-0.02 (-0.83)		-0.10** (-2.17)
Observations	3,318	4,223	4,223	4,589	4,589	501	501
R-squared	0.03	0.04	0.04	0.04	0.04	0.10	0.10
<i>Famine mortality in area under observation (in %)</i>	<i>29.4</i>	<i>27.7</i>	<i>27.7</i>	<i>27.4</i>	<i>27.4</i>	<i>17.2</i>	<i>17.2</i>
<i>Estimated height change due to famine (in cm)</i>	<i>0.35</i>	<i>0.10</i>	<i>0.16</i>	<i>0.10</i>	<i>0.15</i>	<i>0.43</i>	<i>0.32</i>

Notes: The dependent variable is final adult height. Birth periods are binary variables identifying whether an individual was born during one of the nominated time periods. Famine effect is proxied by excess mortality during the Famine in % of the population. Control variables include age at measurement, time of imprisonment (prison regime dummies), religion, literacy status, birth-county fixed effects and the type of offence. Robust t-statistics in parentheses; where relevant, standard errors are corrected for clustering and autocorrelation by clustering at the birth-county level; *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Additional results 2, 10-year famine window

Measurement:	Dublin				Dublin				Dublin			
	Leinster (incl. Dublin)		Ireland (excl. Leinster)		Ireland (excl. Leinster)		Ireland		Dublin (excl. Leinster)		Dublin	
	Height OLS (1)	Height Tobit (2)	Height OLS (5)	Height Tobit (6)	Height OLS (8)	Height Tobit (9)	Height OLS (11)	Height Tobit (10)	Height OLS (4)	Height Tobit (3)	Height OLS (7)	Height Tobit (8)
Sample origin:	1834 - 1843											
Dependent variable:	Mortality IV (1st stage) IV (2nd stage)											
Estimator:	reference											
<i>Birth period</i>	1844 - 1853 (famine)											
1854 - 1863	0.05 (0.29) reference	1.07*** (6.66) reference	0.74 (0.96) reference	1.01 (1.41) reference	-0.38 (-0.44) reference	0.03 (0.23) reference	0.94*** (2.44) reference	0.30** (2.09) reference	0.62 (0.94) reference	0.09* (0.52) reference	-3.80*** (-3.83) reference	16.997 (16.997) reference
<i>Famine effect</i>	Mortality in %											
1854 - 1863	-0.16 (-0.88) reference	0.27* (1.81) reference	1.60* (1.85) reference	1.79** (2.50) reference	0.37 (0.53) reference	-0.05 (-0.19) reference	0.30** (2.09) reference	0.06*** (8.35) reference	0.62 (0.94) reference	0.09* (0.52) reference	-3.80*** (-3.83) reference	16.997 (16.997) reference
<i>Famine effect</i>	Fever hospitals (per capita)											
1854 - 1863	-0.02 (-1.37) reference	0.11*** (8.71) reference	0.03 (1.36) reference	0.04** (2.42) reference	-0.01 (-0.19) reference	0.05*** (3.78) reference	0.06*** (8.35) reference	0.06*** (8.35) reference	0.62 (0.94) reference	0.09* (0.52) reference	-3.80*** (-3.83) reference	16.997 (16.997) reference
Observations	14,937											
R-squared	0.08											
Kleibergen-Paap Wald rk F-statistic	7.5											
<i>Famine mortality in area under observation (in %)</i>	4.6											
<i>Estimated height change due to famine (in cm)</i>	-0.1											
Sample origin:	1834 - 1843											
Dependent variable:	Mortality IV (1st stage) IV (2nd stage)											
Estimator:	reference											
<i>Birth period</i>	1844 - 1853 (famine)											
1854 - 1863	-1.19*** (-6.17) reference	-0.16 (-0.18) reference	19.73 (0.46) reference	-1.44 (-1.50) reference	-2.57 (-1.42) reference	0.03 (0.23) reference	-0.67 (-1.30) reference	-4.02 (-0.84) reference	-0.72* (-3.12) reference	-0.01 (-0.01) reference	-0.02** (-3.42) reference	16.997 (16.997) reference
<i>Famine effect</i>	Mortality in %											
1854 - 1863	-0.72* (-3.12) reference	-0.01 (-0.01) reference	20.21 (0.47) reference	-1.17 (-1.49) reference	-2.32 (-1.55) reference	-0.05 (-0.19) reference	-0.28 (-0.57) reference	-3.55 (-0.75) reference	-0.13 (-0.74) reference	-0.01 (-0.31) reference	-3.22*** (-2.75) reference	16.997 (16.997) reference
<i>Famine effect</i>	Fever hospitals (per capita)											
1854 - 1863	4.223 (0.03) reference	4.223 (0.32) reference	4.223 (0.10) reference	5.01 (0.8) reference	5.01 (0.2) reference	4.724 (0.02) reference	4.724 (0.4) reference	4.724 (0.5) reference	4.724 (0.5) reference	4.724 (0.5) reference	4.724 (0.5) reference	16.997 (16.997) reference
Observations	4,223											
R-squared	0.03											
Kleibergen-Paap Wald rk F-Statistic	28.1											
<i>Famine mortality in area under observation (in %)</i>	1.8											
<i>Estimated height change due to famine (in cm)</i>	0.4											

Notes: The dependent variable is final adult height. Birth periods are binary variables identifying if an individual was born during one of the nominated time periods. Famine effect is proxied by excess mortality during the Famine in % of the population, and instrumented using the per capita availability of fever hospitals prior to the Famine. Control variables include age at measurement, time of imprisonment (prison regime dummies), religion, literacy status and the type of offence. This IV strategy works well for samples that provide sufficient variation in the exogenous and potentially endogenous variable, such as in the case of the Kilmainham sample; the Clonmel sample provides less geographical variation and accordingly F-statistics remain somewhat below the threshold of 10. Robust t-statistics in parentheses; where relevant, standard errors are corrected for clustering and autocorrelation by clustering at the birth-county level; *** p<0.01, ** p<0.05, * p<0.1.

9. Conclusion

We find a positive correlation between famine severity and the health of the populations most exposed to famine-induced hunger and disease during infancy; low famine-related mortality is associated with the most severe drops in average adult height. This is a surprising result. How could it be that an incidence of famine has no long-run health consequences? Our research, in which we use unique and extensive hand-collected anthropometric data on populations most exposed to famine conditions in different geographic locations across one famine episode, is consistent with the idea that the answer lies in the severity of the famine. We suggest that those individuals that were most affected by Ireland’s nineteenth-century famine saw an “extreme selection”; those most exposed did not themselves survive long enough to have their measurements taken; those that died, or migrated, do not, by definition, enter our samples.

The Great Irish Famine has left an indelible mark on the Irish psyche. It remains the key watershed in Irish economic and social history. It is still today invoked in political discourse. And it has undoubtedly had a lasting effect on the island’s culture. But what apparently is far less obvious was its impact on the health and wellbeing of Ireland’s *residual* population, those that did not themselves succumb to starvation and disease. Indeed, we find that only famine survivors hailing from those parts of the country that were *least* affected by famine experienced any detectable permanent health consequences. From this we surmise that only those individuals born in heavily-affected that were most resilient survived into adulthood. And in areas that were least-affected by famine, mortality did not select the population as *everyone* survived into adulthood, including society’s least healthy, i.e., those individuals who during infancy, and relative to their peers, did not have access to enough nutrition.

The Famine resulted in, or at the very least accelerated the process of, economic change across Ireland. Post-Famine Ireland was in many respects a very different place than Ireland before the potato became blighted. The elimination through death or migration of vast swathes of society permanently changed the structure of Irish agriculture. The collective realisation that the reliance on a single crop can have devastating consequences also changed the nation’s eating habits. Land reforms precipitated by, and even instigated as a direct result of, the Famine accelerated the process of urbanisation and helped to provide industrialising cities with cheap labour inputs. But for those that lived long enough to tell the tale of the Great Irish Famine to the next generation, its effect on their physical health was apparently relatively benign.

We find that Dublin-born Irishmen, who did not suffer a direct *in utero* or early childhood “mortality effect”, were shorter in stature on average. Our estimate for some sub-groups suggests that their final adult height was impaired by as much as 2.2 centimetres. The magnitude of this effect suggests a substantial drop in biological living standards, including up to 2.6 years of life.

This bad health also has implications for human capital, labour productivity and total output. This represents an economically significant effect that is comparable to other anthropometric studies of *in utero* health shocks. Meanwhile, we find that Tipperary-born Irishmen, whose neighbours would have either experienced a very severe and direct *in utero* or early childhood mortality effect or would subsequently have migrated out of the area, grew *taller* than the typical urban dweller from Dublin. The rural, Famine-born generation that survived into adulthood did not experience any permanent stunting in their growth. Those that were affected in this rural area either left, died, or failed to be born in the first place; those that survived selection due to famine conditions differed significantly from their dead peers.

We conclude that famine severity and its associated selective mortality effect must be included much more explicitly in any future economic studies of famines and health. Less severe famines, like other *in utero* and early childhood health shock, can have long-lasting scarring effects on survivors. But more severe famines, like the Great Irish Famine experienced in rural areas, can act as Malthusian catastrophes in that they eliminate society's most vulnerable and leave behind only its fittest. Without accounting for severity, anthropometric studies of the health and welfare of the survivors of natural or man-made disasters cannot draw meaningful inferences about their long-run impact on society. Individual-level research in other fields of economics must also better account for these selection effects.

Appendix A: Crime, Law Enforcement and Punishment

Two separate selection issues must be better understood in order to understand our findings: (1) selection from the general population into crime; and (2) selection from crime into our prisons. Bodenhorn et al. (2017), applying a Becker (1968) style approach, see individuals as being influenced by the net present value of the benefits and costs of committing crime. This benefit-cost matrix can vary temporally depending on, for example, institutional change, or fluctuations in the business cycle. Different individuals may select into crime at different times, depending on the prevailing benefit-cost matrix. In order to fully address this selection issue, we must understand whether this type of benefit-cost matrix is evident in the underlying population. In this appendix, we describe Ireland's criminal justice system, catalogue the types of crime individuals committed and were imprisoned for, and discuss whether and how this changed over the period under investigation. We also outline how any resulting selection issues are addressed in the analysis of our study. In the next appendix, Appendix B, we discuss additional facets of these selection issues associated with the institutions of the prison system itself.

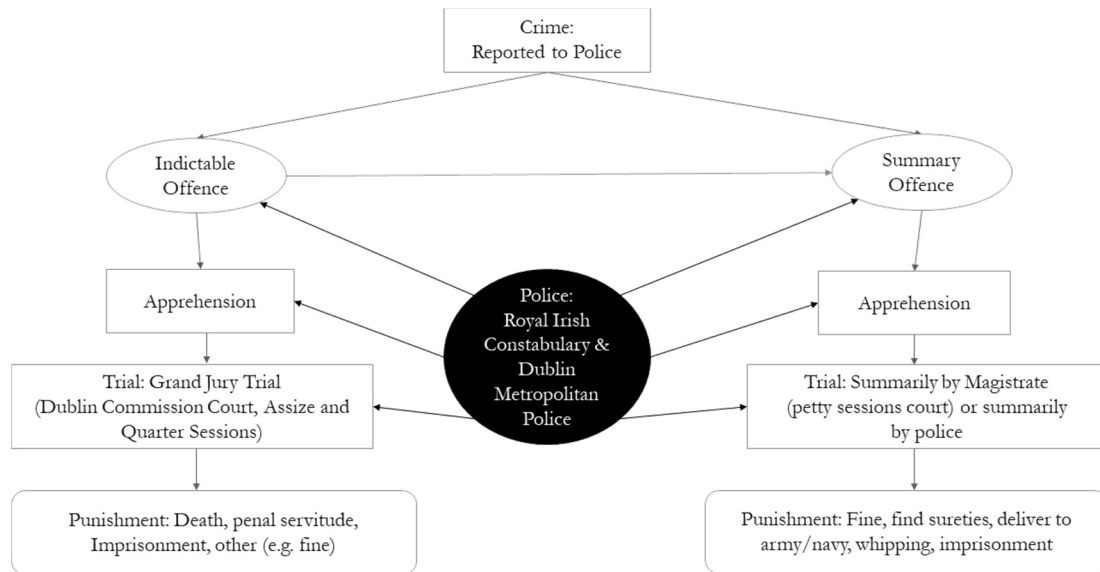
Ireland's criminal justice system was highly sophisticated; Kilcommins et al. (2004) note it was 'incongruous with its level of industrialisation'. Figure A1 outlines our schema of this system. Crimes were either reported or observed by police. How they were subsequently dealt with depended on how they were classified. Essentially, there were two types of offence, and the demarcation depended on the crime's severity: indictable offences (trial-by-jury) and summary offences (non-jury cases). Indictable offences related to more serious offences, such as murder, manslaughter, rape and grand larceny.³³ Summary offences were often petty crimes, such as drunkenness, common assault, vagrancy, petty theft, and transgressions of acts of parliament, such as infringements against the poor law acts, revenue laws and food adulteration. Toward the end of the century, summary offences were regarded as 'civil transgressions' or 'quasi-criminal offences' (BPP 1892: p. 17; BPP 1902: p. 11). Nevertheless, summary offences comprised the majority of crimes prosecuted in Ireland over the entire nineteenth century.³⁴

The police were the central point of any criminal investigation and they acted as prosecutors. County constabularies were established in 1822. Paramilitary forces modelled on the French *gendarmerie*, these were centralised into an Irish constabulary in 1836. Dublin City maintained its own police force, the Dublin Metropolitan Police. Ireland was heavily policed, with three times

³³ Although some indictable offences were dealt with summarily, these constitute a very small share.

³⁴ Prison inspectors in 1824 noted that most prisoners had committed minor offences (BPP 1826). Later prison reports emphasised that 'drunkenness is the main source and cause of crime' (BPP 1874: p. 13; BPP 1875: p. 13).

Figure A1: Criminal justice system schema



Sources: Authors' summary, using the annual *Criminal and Judicial Statistics* that were published as parliamentary papers cited in text.

as many police per capita as England and Wales (Kilcommins et al. 2004: p. 13).³⁵ This disparity of policing levels persisted over time.³⁶ Constabulary returns from census occupations and other sources suggest rural areas of the island were similarly highly policed.³⁷ The high police manifestation suggests a strong law enforcement presence throughout the period of our study.

Apprehension rates were high (75 per cent), consistently higher than contemporary apprehension rates in England and Wales (50 per cent) (BPP 1874: p. 28). The higher police presence led contemporaries to argue that the Irish police force had better knowledge of the character of those apprehended for crimes committed. The majority of those apprehended were previously known to police and, of those known, the majority were of previous good character, primarily because many had committed only minor offences.³⁸ If we assume that law enforcement officers were equally efficient throughout Ireland, this implies that the likelihood of being detected, and penalised, for committing a crime was uniformly distributed through the island.

Tracing levels of criminality over the period of our study is made difficult by the fact that what was deemed a criminal offence varied over time. For example, a person who selects into a

³⁵ E.g., in the 1860s, the number of police in Ireland were approximately half the number of those in England and Wales (13,812 versus 22,622) but the population of Ireland was only a quarter (BPP 1864).

³⁶ E.g., in the 1880s, the Dublin Metropolitan Police had more police per capita (336 per 100,000 capita) than the London Metropolitan Police (230 per 100,000 capita), and much higher police per capita compared with similarly-sized cities, such as Manchester and Leeds (230 and 120 per 100,000 capita) (BPP 1888).

³⁷ Tipperary, the county in which Clonmel Gaol was situated, had a large police presence relatively to the population (442 per 100,000 capita according to the 1891 census).

³⁸ The English police forces had less knowledge of the character of those proceeded (30% versus 15% in Ireland), a factor that was attributed to 'the greater number of foreigners and the greater aggregation of the people in cities and towns in England than in Ireland' (BPP 1872: p. 30).

criminal activity in 1841 may repeat the same activity in 1891, but no longer be deemed to be a criminal for doing so. Also, the social tolerance for types of behaviour can change, and some minor offences can be punished with greater or less vigour depending on prevailing social norms. Perhaps the case in point was drunkenness, which was punished with greater intensity following the 1872 Licencing Act (BPP 1872: pp. 31-32; BPP 1874: p. 13).

Criminal justice statistics, published annually from 1864, were intended to make comparisons between Ireland and England, but their function evolved to provide comparison of prevailing crime trends. These data show that over the period 1864 to 1910, summary offences vastly outnumbered indictable offences by a ratio of 28-to-1. Figure A2 shows trends in indictable offences for this period.³⁹ There is significant variation in the data, with clear peaks (1864, 1881, 1882, 1898, 1908) and troughs (1888-1894).⁴⁰ Figure A3 shows the distribution of indictable offences, the overwhelming majority of which were classified as ‘offences against property without violence’. While non-violent larceny was the main crime in this period, during the spike in crime in 1881 and 1882 the majority of these were for offences such as writing threatening letters, the most common form of ‘agrarian outrage’ during the Land War (McLaughlin 2015). Summary offences, shown in Figure A4, do not display such extreme variability.⁴¹ Of the 206,193 summary offences proceeded against in 1881, 78,573 were for ‘drunkenness and drunk and disorderly’. The second-most common offence was common assault, with 30,088 cases proceeded against, and it was observed that both were ‘closely connected with one another’ (BPP 1892: p. 17).⁴² Data from parliamentary returns of the number of people arrested for drunkenness show that it was a common offence throughout the island (BPP 1877; BPP 1883).⁴³

Contemporaries were aware that summary offences dominated the criminal justice system, and argued that other indicators of crime were more appropriate to gauge the level of criminal activity. Their view was that summary offences were primarily of a ‘civil nature’, and so should be excluded from the statistics.⁴⁴ Another approach was to assess “fresh crime” in a year: ‘the statistics of commitments of persons not previously committed to any prison afford the best goal

³⁹ The number of offences averaged 8,146 per year and 168 per 100,000 capita.

⁴⁰ The coefficient of variation for both the number of offences and offences per capita was 21% and 24%.

⁴¹ The number of summary offences averaged 220,092 and the number of offences per capita averaged 4,490 per 100,000. The coefficient of variation for the number of summary offences and the number of summary offences per 100,000 capita was 11% and 8%.

⁴² Drunkenness and common assault together accounted for 53% of all summary offences.

⁴³ In the 1877 and 1883 the mean arrests per 100,000 capita was 1,902 and 1,745, with standard deviation of 694 and 623. Arrests per 100,000 capita in 1883 there were 3,604 in Dublin versus 2,162 in Tipperary.

⁴⁴ The ‘number of “indictable offences” may be taken as the more correct standard by which to measure the prevalence of crime in relation to the population’ (BPP 1902: p. 10).

Figure A2: Indictable offences, 1864-1910



Sources: Authors' calculations, using the annual *Criminal and Judicial Statistics*.

test of the amount of fresh crime in the year' (BPP 1873: p. 45).⁴⁵ An approach used by criminologists to measure crime more consistently across time is to use homicides (see, e.g., McMahon 2013). Homicide has the attraction of having a consistent definition (i.e., a body count), is less subject to under-reporting, and is correlated with other forms of crime (Fajnzylber et al. 2002). Homicide rates in nineteenth-century Ireland were low by modern standards.⁴⁶

The final issue to understand is how crime was tried and punished. Both indictable and summary offences were punished with a mixture of custodial and non-custodial sentences. Custodial sentences were the predominant punishment for indictable offences; fines had a similar function for summary offences. Legislation stipulated specific fines for breaches for many summary offences (BPP 1872: p. 39). There was a much greater reliance on fines in Ireland than in England for comparable offences.⁴⁷ This, contemporaries suggested, was because Petty Sessions, the court that heard such cases, had a financial interest in the fines imposed (BPP 1882: p. 18).

⁴⁵ First-time offenders were 68% of total offenders imprisoned in 1873, 77% in 1881 and 44% in 1891. However, the data do not provide details of those deemed to have committed "fresh crime" who received non-custodial sentences.

⁴⁶ For Ireland as a whole, the rate ranged between 1.44 to 1.85 per 100,000 capita. In the early period of our study, Tipperary was the more violent of the two locations, with homicide rates of 5.92 and 3.60 in the 1840s and 50s, but this fell to 2.51 by the end of the century. Dublin increased from 1.44 in the 1840s to 4.13 in the 1890s.

⁴⁷ In England the ratio of fines to imprisonment was 1-to-3.5; in Ireland this was 1-to-8 (BPP 1882: p. 30).

While a greater proportion of summary offences were dealt with using fines rather than prison, overall, however, most of the prison population consisted of summary offenders. The most severe punishment, execution, was rare, with only 0.01 per cent of indictable offences receiving the death penalty in 1881. Shorter sentences (under six months) were more widely allocated as a punishment for indictable offences. With respect to summary offences, fines were the most common punishment for all offences, even in the case of drunkenness and common assault. However, ten per cent of drunkenness and common assault offences received custodial sentences. The custodial sentences given for drunkenness in particular put enormous strain on the prison system and accounted for 50 per cent of all prisoners in Ireland in 1900 (BPP 1900: p. 9).

The average daily imprisonment rate from 1839 to 1909 is shown in Figure A5. The average daily rate was 62 per 100,000 capita, with a noticeable peak during the Famine. The reports from the inspector generals of prisons outline three reasons why the prison population increased: distress from the Famine, the sudden cessation of transportation to Australia as a form of punishment, and the Vagrancy Act, which criminalised vagrancy and prescribed a custodial sentence (BPP 1847-48). The effect of the Famine was said to have ‘quadrupled the evils occasioned by the two last’.⁴⁸ All these factors led to overcrowding of the prison system, with 12,883 prisoners held in prisons designed to hold 5,655 prisoners. The Famine period withstanding, the data indicate that custodial sentences were quite common. For the purpose of our study, it is important that we exclude those incarcerated during the Famine because this period saw individuals selected into prison in ways that are difficult to quantify. Any results that include such individuals would be rendered difficult to interpret.⁴⁹

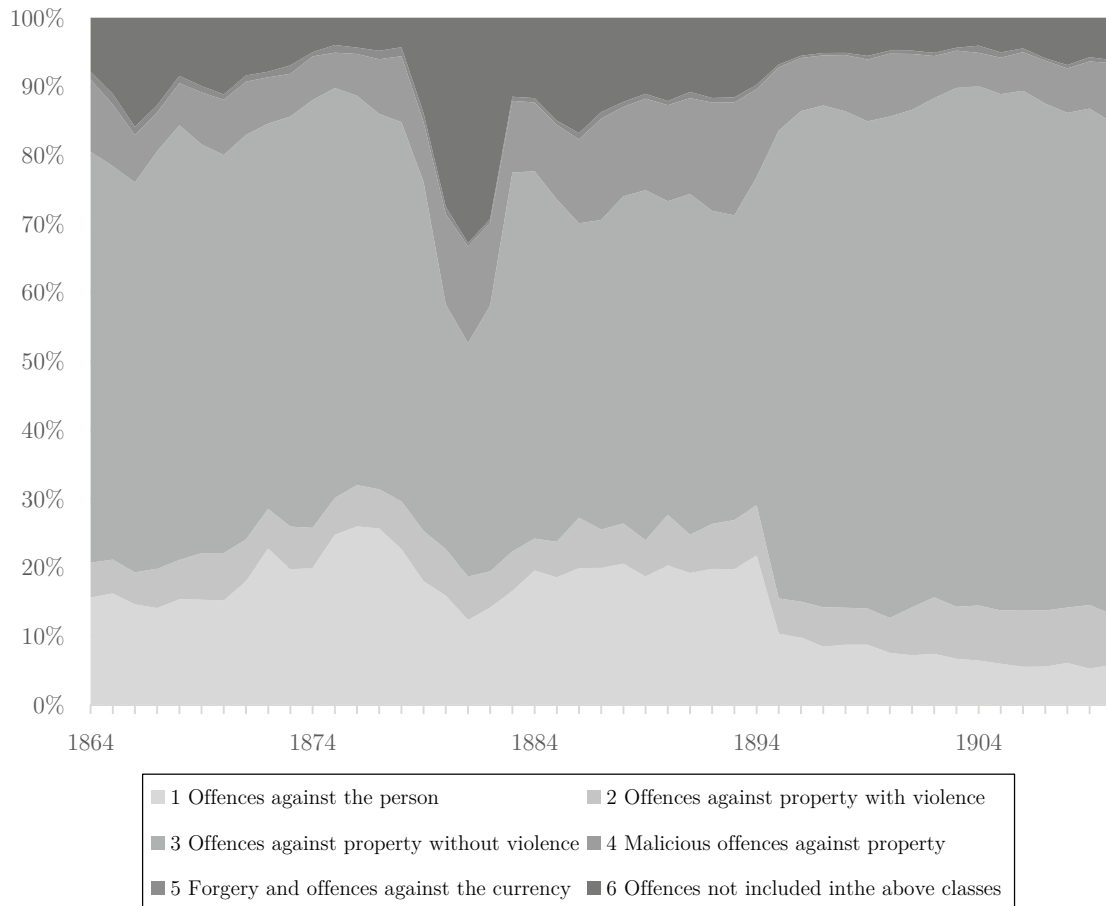
A more pertinent issue is how individuals selected into crime across the post-Famine era, between the 1860s and 1910s. It is this period from which we draw the samples for our anthropometric study. How responsive was crime to year-on-year fluctuations in economic and social conditions, such as to the business cycle? Bodenhorn et al. (2017) describe a mechanism which suggests economic opportunity may alter the composition of prison samples. Contemporaries were also interested in this question. For example, the criminal justice statistics compilers remarked how ‘notwithstanding the unfavourable character of the harvest last year, producing pressure on the poor and withdrawal of saving’ there was a decrease in year-on-year crime; ‘the pressure has been attended with a diminution of crime’ (BPP 1873: p. 10).⁵⁰

⁴⁸ Another factor was that people that were receiving indoor poor relief were rioting in an attempt to get transferred from the workhouse to the prison system, where conditions were considered better (BPP 1847-48: p. 8).

⁴⁹ Very few such individuals are eligible for inclusion in our sample anyway, as they would have been too young to be eligible for prison, even when adopting our 10-year study window.

⁵⁰ During the Land War period, comparisons were made between the crime statistics and falls in bank deposits and use of the poor law as indicators of ‘pressure’ (BPP 1882: p. 15).

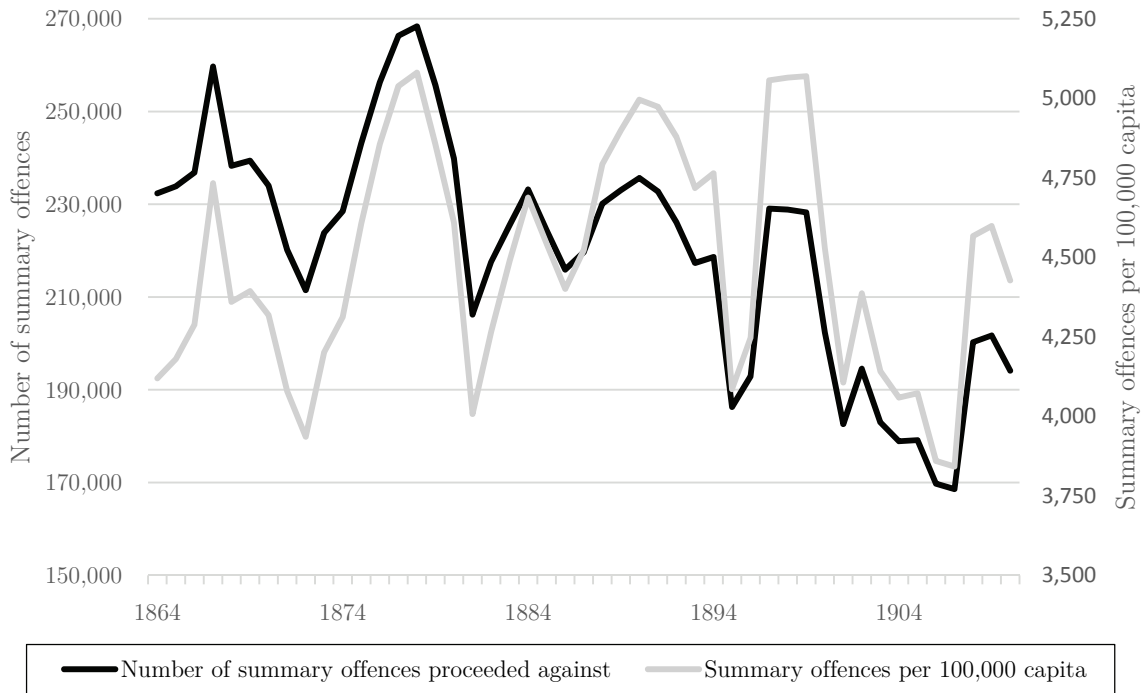
Figure A3: Distribution of indictable offences committed, 1864-1911



Notes: Indictable offences were comprised of 6 categories: (1) Offences against the person: Murder of infants aged one year and under; Other murders; Attempts to murder; Shooting at wounding, Stabbing &c, to do bodily harm; Manslaughter; Attempts to procure miscarriage; Concealing the births of infants; Sodomy and bestiality; Attempts to commit and other unnatural misdemeanours; Rape; Assaults with intent to ravish and abuse; Defilement of girls under 13; Defilement of girls between 13 and 16 years of age; Abduction; Bigamy; Child stealing; Unlawful abandoning of Children under 2 years of age; Endangering the safety of passengers on railways; Assault and inflicting bodily harm; Assaults, common; Assaults on Peace officers. (2) Offences against property with violence: Sacrilege; Burglary and housebreaking; Breaking into shops, warehouses &c; Attempts to break into houses, shops, warehouses &c; Robbery on the highway; Attempts to rob on the highway, and demanding money by menaces. (3) Offences against property without violence: Cattle Stealing; Horse Stealing; Sheep Stealing; Larceny to the value of £5 in dwelling houses; Larceny from the Person; Larceny by servants; Larceny, simple; Larceny on rivers, canals, wharfs &c.; Stealing fixtures, shrubs growing, &c.; Attempts to steal; Embezzlement; Larceny by servants in the post office; Receiving Stolen goods; Fraudulently obtaining goods by false pretences and attempts to defraud. (4) Malicious offences against property: Arson and other wilful burning; Felonies riot and demolishing buildings &c.; Destroying goods in process of manufacture; Destroying trees, shrubs &c. growing; Killing and maiming cattle; Malicious Injuries to property exceeding £5 in value; Other wilful and malicious injuries to property. (5) Forgery and offences against the currency: Forging and uttering forged instruments; Having in possession forged bank notes; Coining, and having implements for coining in possession; Uttering, printing off and having in possession counterfeit coin. (6) Offences not included in the above classes: Offences against the Queen as Authority and Person; Intimidation by threatening letters, notices, or otherwise; Having arms or ammunition without licence in a proclaimed district; Offences against game laws; Being at large under sentence of transportation or penal servitude; Perjury and subordination of perjury; Riot, breach of the peace etc; Keeping disorderly houses; Indecently exposing the person; Suicide, attempting to commit; Other felonies not included in the above; Other misdemeanours not included in the above.

Sources: Authors' calculations, using the annual *Criminal and Judicial Statistics*.

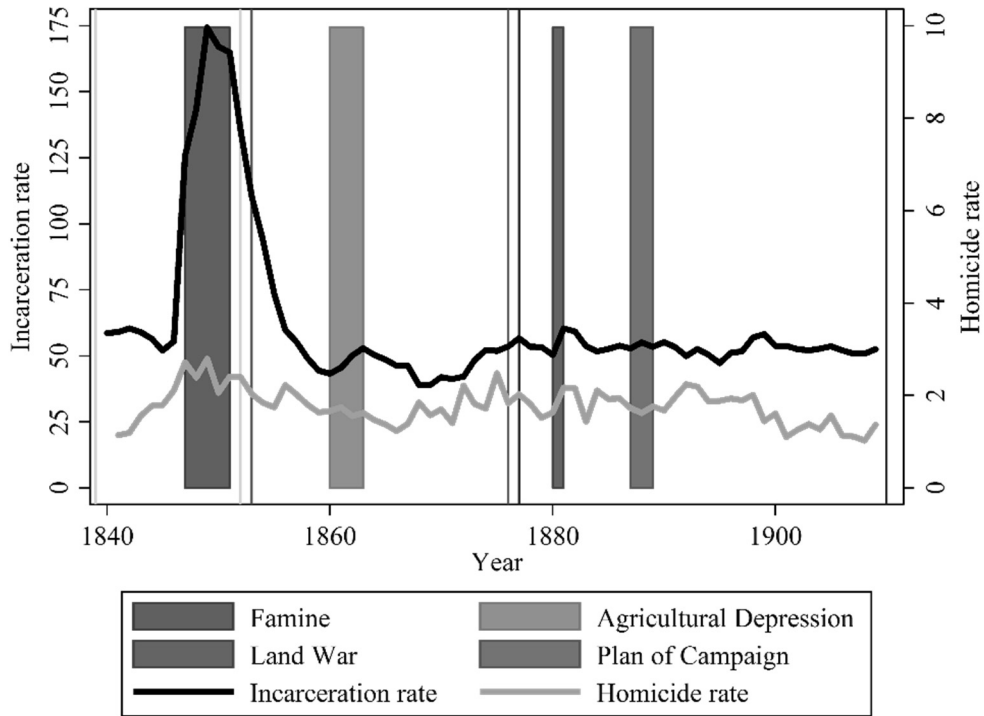
Figure A4: Number of summary offences, 1864-1910



Notes: Summary offences related to petty crime: Adulteration of food, & c, Act; Assaults, aggravated, on women and children; Assaults, on peace officers, resisting, obstructing & c.; Assaults, common; Bastardy orders, disobeying; Breaches of the peace, want of sureties & c.; Cattle plague orders, offences against; Chimney sweepers act, offences against; Cruelty to animals; Embezzlement; Employers and workmen act, 1875; Factory acts, offences against; Fisheries Acts, offences against; Game acts, offences against viz: Trespassing in the day time in pursuit of game, Night poaching and destroying game, Illegally selling or buying game, Poaching act, 1862, Other offences against game acts; Licencing acts, 1872-74 offences against, viz: Drunkenness and drunk and disorderly, Permitting drunkenness and disorderly conduct in licensed houses, Illegally selling intoxicating drinks, Adulteration of intoxicating liquors, Beerhouse Act offences against, Other offences under the licensing acts; Lord's Day Act, offences against; Local acts and borough bye-laws, offences against; Maliciously destroying fences, walls, gates, & c.; Maliciously destroying fruit and vegetable productions; Maliciously destroying trees, shrubs &c.; Other malicious and wilful damage and trespass; Mutiny acts, offences against: Army Act, Navy Act, Militia Act, Mercantile marine acts, offences against; Nuisance and offences against health, viz: Public health acts; Smoke acts; Sewers act; Nuisance, removal act.; Common lodging houses acts; Selling and exposing for sale unsound food; Other sanitary offences; Pawnbrokers act, offences against, viz: By pawnbrokers, By persons unlawfully pledging or disposing, Other offences; Police acts, offences against: Unlawfully possessing goods, Offences punishable as misdemeanours, Constables neglecting their duty, Other offences, not falling under special heads, Prevention of crime act, 1871, sec 7 (special offences by persons twice committed); Poor law acts, offences against: Deserting or neglecting to support family, Disorderly conduct in the workhouse, Damaging workhouse clothing, bedding etc; Refreshment houses and wine licences act; Revenue laws, offences against: Customs acts; Excise acts (including Hawkers and peddlers act); Salmon fisheries act, offences against; Stealing or attempts to steal, viz. -: Larceny, by offenders under 16 years (Juvenile offenders act), Larceny, under value of 5s and on pleading guilty (Criminal Justice Act), Larceny, above value of 5s, on pleading Guilty (criminal justice act), Larceny, or larceny from person, attempting to commit (Criminal Justice Act), Dogs, birds, or beasts (&c), Fruit or vegetable productions, Fences, wood & c., Trees, Shrub, etc.; Vagrancy acts, offences against: Prostitutes, Begging, Having no visible means of subsistence & c., Having implements for homebreaking, etc., Found in enclosed premises for unlawful purposes, Frequenting places of public resort, &c, to commit felony, Incurable rogues, Other offences against Vagrant Act; Vaccination Acts, offences against; Ways acts, offences against: Stage and Hackney Carriage Acts, Highway Act (including road nuisances), Watermen's Act, Railway Acts; Weights and Measures Act, offences against; Other offences (not included under the above heads).

Sources: Authors' calculations, using the annual *Criminal and Judicial Statistics*.

Figure A5: Prison regimes, incarceration rate and homicide rate, 1840-1920



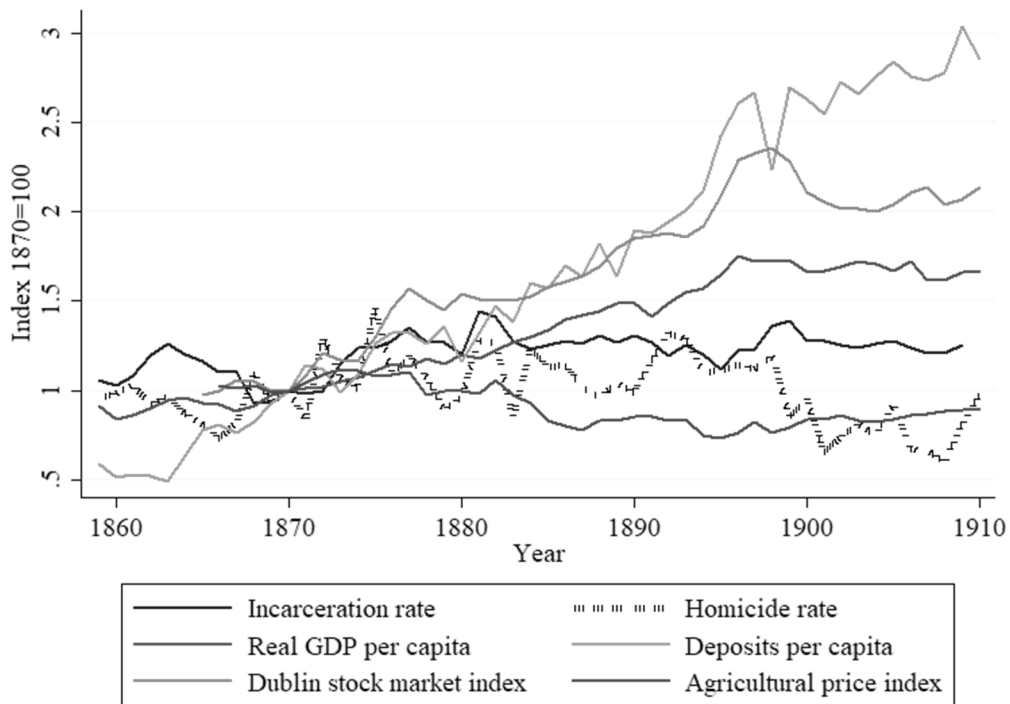
Sources: Authors' calculations, using the annual *Criminal and Judicial Statistics*.

Changing opportunity costs of crime, such as job opportunities and levels of income, may alter the necessity and attractiveness of criminal activity. If such a bias is detected, prison samples may be subject to bias and this bias may change as opportunity cost of crime changes. Consequently, analysing prison (or other sample) data may result in biased study results. We test whether the prison population was responsive to changing economic conditions using a series of macroeconomic indicators and time series analysis. We use the average daily incarceration rate per 100,000 inhabitants and annual homicide rate per 100,000 inhabitants to proxy crime and conviction on the island. The following indicators serve as a proxy of economic opportunity, i.e., the opportunity cost of criminal activity: real GDP per capita (£, 1841 prices); bank deposits per capita (£, real terms); a price index of the Dublin stock market (1964 = 100); and an index of agricultural prices (1856-60 = 100).⁵¹

Indices depicted in Figure A6 illustrate the data we used to perform a set of time series tests, including tests on stationarity, cointegration and correlation analysis. The data we use here refer to the whole range of years of imprisonment, i.e., 1858-1910. Depending on whether we find a cointegrating relationship between these series, we perform vector error-correction models; other tests relied on a simple first-difference approach.

⁵¹ We thank Jason Lennard for providing us with his revised Irish GDP estimates.

Figure A6: Crime and macroeconomic indicators, 1860-1910



Sources: Authors’ calculations, using parliamentary papers cited in text, Kennedy and Solar (2007) for agricultural prices, Grossmann et al. (2014) for stock market data, and Andersson and Lennard (2017) for GDP estimates.

Our results do not suggest that any of these macroeconomic indicators influence homicide or incarceration rates. None of the economic indicators we used have a statistically significant influence on crime. We therefore cannot assume that the size and composition of the prison population in Ireland was responsive to changing economic conditions. Given the view held by most contributors to literature on the economics of crime (see, e.g., Freeman 1999), this is a surprising result. However, following a broader reading of the criminology literature, this is less so: Pratt and Cullen’s (2005) meta study of the determinants of violent crime outlines at least seven competing macro theories commonly tested in this literature. While they note some overlap between these theories, they find that rational choice theory, classically associated with Becker (1968), receives the weakest support across studies. They find that social disorganisation theory, which stresses the role of institutions, receives the strongest backing.

We too argue that any differences in selection into crime across time were much more likely the result of institutions. More specifically, we take the view that the various institutional reforms to the criminal justice system that we discuss in this appendix are key to understanding any changes to selection into crime. We collapse these institutions into three so-called “prison regimes”, which we discuss in more details in Appendix B, and mark with vertical lines in Figure A5. We control for these prison regimes, alongside other political events which potentially saw a change in the attributes of prisoners, in all our regression analyses.

Appendix B: Prison Infrastructure

The institutional records that form the basis of our research hail from two prisons: Kilmainham Gaol, located on the western outskirts of Dublin, and Clonmel Gaol, situated in the heart of Clonmel (see Figure 4). We provide short histories of these prisons and their residents in order to contextualise these records and identify their potential biases.

The prison system in nineteenth-century Ireland operated within a socio-political context that varied considerably from England. The numbers, uses and forms of prisons fluctuated greatly over the course of the century. In 1822 there were 178 prisons in Ireland. Most were dungeons attached to manorial courts or urban debtors jails, with the remainder being local ‘Bridewells’ attached to police stations or courthouses and housing those on remand or serving time for less serious crimes (O’Donnell 2009). The majority of these buildings were not custom-built (McDowell 1964: pp. 145-151). This meant there was no facility for implementing reformist ideas, such as segregation and classification.

A more uniform prison administration was introduced by new laws in 1810 and 1826. Kilmainham and Clonmel were both classified as ‘county goals’ (BPP 1840: Schedule A). The most radical change occurred in 1877, when the General Prisons Board was set up to centralise the control of all prisons. Following this, just 23 of the 137 prisons in existence in Ireland in 1877 were still open by 1924 (McDowell 1964: p. 31). Neither Kilmainham or Clonmel Gaols made the cut and were closed in the early twentieth century.

A leading tourist attraction, Kilmainham Gaol is an iconic building (see photo in Figure B1) located on the outskirts of Dublin, south of the River Liffey. Records suggest that Kilmainham housed a gaol dating back to the twelfth century. Our study utilises records of the “new” Kilmainham Gaol, which officially housed its first prisoner on 12 August 1796 and ceased to take new prisoners in 1910. Our data are derived from the admission registers of this gaol. Our earliest entry is from 28 November 1836 for ‘highway robbery’ and our last entry is from 28 February 1910 for a ‘breach of the traffic act’. In total, there were 98,407 prisoners recorded in our database, from which we draw samples of those born before, during and after the Famine.

Part of the nostalgic appeal of Kilmainham is its association with Ireland’s nationalist past as it was where prominent nationalists were incarcerated and executed. Indeed, the literature on the prison relates almost exclusively to these prisoners (Nolan 1960; Kelly 1988; Cooke 1995; O’Sullivan 2007).⁵² An example is O’Sullivan (2007), where what the author calls ‘civil’ or ‘ordinary’ prisoners receive much less attention in the book to nationalist prisoners. In addition

⁵² Kelly (1988) notes that Kilmainham housed its first political prisoner (Henry Joe McCracken) within months of opening in 1796. Most famously, after its closure as a county gaol in 1910, it was re-opened to execute the leaders of the 1916 Easter Rising and was used to intern suspects in the subsequent revolutionary period.

to these “ordinary decent criminals”, Kilmainham also housed military and navy prisoners following the abolition of corporal punishment (Kelly 1988: p. 74).

Admittedly, in certain periods political prisoners were more predominant, but these were episodic events, such as the Fenian Rising in 1866-67.⁵³ The Inspector General of Ireland’s prison system was acutely aware of the differences between political and other prisoners, and made the distinctions in his reports to parliament (BPP 1867: p. 476). The daily average incarceration rate for 1866 was 100.7 new prisoners; political prisoners averaged 61.7, while prisoners ‘belonging to the county’ averaged 42. In terms of our study, the association of political prisoners with Kilmainham may bias results, however the literature clearly documents the main events: 1803, 1848, 1866-67, 1882, 1916, and 1918-23. In our analysis, we control for the crimes committed by prisoners, and additionally for imprisonment during these events.

Clonmel Gaol provides us with a suitable counterpoint to Kilmainham. The prison housed criminals from across rural County Tipperary and neighbouring counties, and continued to function throughout the nineteenth century, providing us with a long span of anthropometric evidence. Like Kilmainham, it housed political prisoners alongside ordinary decent criminals.⁵⁴ Clonmel had the highest homicide rates in the country during the 1830s and 1840s, but these fell dramatically later in the century (McMahon 2013). Despite this difference, the prison did not house a higher proportion of individuals convicted of indictable crimes than Kilmainham.

While the prison dates from the late eighteenth century (O’Donnell 2009), its registers cover the period 1840 to 1924. These surviving registers provide sufficient data to track birth cohorts from before, during, and after the Famine. Moreover, our data encompass all the major judicial and penal reforms of the period, for which we control. Alongside information on eye colour, hair colour and skin complexion, height was consistently recorded throughout both prisons’ existence. This was because it was used as a means of identifying prisoners in a time where identity cards were non-existent, and fingerprinting was not yet in wide use. With the introduction of a uniform prison administration for the island, a standard set of rules on prisoner admission was also introduced. This makes the data collected across prisons on entry consistent and comparable.⁵⁵

⁵³ These prisoners were originally housed in Richmond prison, but were transferred to Kilmainham after they had escaped from their confines.

⁵⁴ Tipperary had a long tradition of Whiteboyism, rural violence aimed at socio-political grievances (Beames 1978). Clonmel Gaol held these individuals as political prisoners.

⁵⁵ Rule number 10 of the general prison rules of 1888 states that ‘the name, age, religious denomination, height, weight, features, particular marks, and general appearance of a prisoner shall, upon his admission, be noted in a nominal record of prisoners to be kept by the Governor’ (BPP 1888).

Figure B1: Kilmainham Gaol's East Wing, completed in 1857



Source: Glenn Colvin (2014).

Appendix C: Religion, Literacy and Famine Vulnerability

We perform a robustness check by testing for a famine effect among the most vulnerable elements of Irish society: Catholics and illiterates. In the pre-Famine period, most of the Irish population was Roman Catholic and in turn Catholics made up the bulk of poorest in society, those most likely to have been exposed to famine conditions. Historically, Catholics were discriminated following the Reformation, and this only intensified after the Glorious Revolution, from 1688.⁵⁶ This discrimination was felt throughout all levels of Catholic society.⁵⁷

With regards to illiteracy, there is good empirical evidence that literacy and stature are correlated. Short individuals and individuals with inferior human capital are disadvantaged in official labour markets, while for taller individuals the opposite is true.⁵⁸ If illiteracy and human height have a negatively association, and famine exposure and human height are also negatively related, then illiteracy and famine exposure may similarly be negatively related.

⁵⁶ The only battlegrounds of Glorious Revolution, which in practice amounted to a Dutch invasion, were in Ireland.

⁵⁷ Catholics faced discrimination under various Penal Laws, although their enforcement varied. For example, Catholics had restrictions placed on the ownership and inheritance of land, were barred from holding most public offices, and did not have the right to sit in Parliament until the passing of the Catholic Emancipation Act in 1829.

⁵⁸ Case and Paxson (2008b) find that individual height reflects superior intellectual capabilities, and that the latter explain a large portion of the height premium paid in labour markets.

The evidence we review in this study suggests that in severe famines, scarring and selection may have opposite effects and so may even cancel one another out. This may prevent us from detecting the true magnitude of the *in utero* and early-childhood impact of the Great Irish Famine. By using interaction variables that combine information on time of birth as well as religion and illiteracy, we test for a difference in famine exposure between Protestants and Catholics, and between literates and illiterates. If scarring and selection are of a similar magnitude, but in opposite directions, then the height of Protestants and illiterates may reveal a stronger famine effect if their superior social status allowed these strata to attenuate the effects of famine-induced malnutrition and disease. In other words, if reduced famine exposure brought about limited scarring compared to Catholics and illiterates, we may infer that the observed height of Protestants and literates reflects a stronger famine effect.

We use a testing framework that is similar to the one in our main analysis (see Formulas 1 and 2). Formula C1 illustrates our approach:

$$H_{ict} = \alpha + \beta_1(\theta \times F_{it}) + \beta_2(T_t) + \beta_3(X_{ic}) + \varepsilon \quad (\text{C1})$$

where H_{ict} is a function of a vector T , which tests for differences in height between the cohorts born before, during and after the Famine. Again, vector X includes controls for literacy, religion, county-fixed effects, and the type of crime committed. X also contains controls for conviction periods when selection into the prison sample might have differed from normal times. Most importantly, θ is a parameter which can be used to interact famine exposure (F) with either Catholicism or illiteracy.

Results of this exercise are reported in Table C1. When we test for differences by religion, the effects presented in Models 1 to 4 refer to Famine-born Catholic Dubliners. Our hypothesis suggests that more selection (relative to scarring) of this societal group should lead the interaction variable identifying Famine-born Catholics to take on a positive coefficient. Indeed, the corresponding effects shown in Model 1 suggest that there was a general negative famine effect for Dublin-born individuals, leading to a height drop of approximately 2.2 cm. Catholics, however, are characterised by less scarring, and more selection, leading to a somewhat less pronounced height drop of 1.9 cm. Catholics in general are shorter than their Protestant peers – consistent with the literature. And so despite their inferior status in the Irish society, Catholics' height was *less* affected by the Famine compared to Protestants' heights.

Recall that in the general regression setup we did not distinguish between religious groups with the interaction term. Our new results in Table C1 suggest that the weaker famine effect of the Catholic majority and the stronger famine effect of the Protestant community to some extent cancelled one another out, therefore explaining why we did not originally detect a famine effect. This explanation only holds for Dublin- and Leinster-born individuals, however: we ran the same

test on rural-Irish born individuals, but failed to detect such an effect; the baseline variable proxying a general famine effect, nor the interaction terms, reflect a difference in famine effect for Catholics (see Models 3 & 4, as well as Models 9 to 12).

Similarly, we use literacy as the distinctive feature to test for differences in famine effect between literates and illiterates. Again, our hypothesis suggests that illiterate members of society should have experienced more selection, relative to scarring, leading to a somewhat weaker observed famine effect than for literate individuals. The effects for Dublin- and Leinster-born individuals suggest a general negative effect for the Famine-born cohort (Models 5 & 6). While we expected illiterates to be more vulnerable than literates, the interaction effect for Dublin-born individuals suggests that Famine-born illiterates' famine effect is positive, and reflects somewhat *less* exposure to famine conditions compared with literates. Again, we are of the opinion that these height differences among Dublin-born individuals reflect differences in selection, where illiterates experienced more selection than scarring relative to literate individuals. We find ambiguous effects for the rural all-Ireland samples (Models 7 and 8); here we find neither a general famine effect, nor a consistent and economically or statistically significant effect for illiterates.

Appendix D: Weighted Regressions

In our main findings, we use a “targeted” sample in that prisoners constitute the exact individuals which we would expect to have been most affected by famine: the poor and the working classes.⁵⁹ However, this targeting may bias our results: perhaps society's more successful individuals, who survived the Famine but are underrepresented in our prison samples, were most affected by famine conditions in terms of scarring. We attempt to discern whether the overrepresentation of the poor and working classes in the prison population affects our results, and whether a more representative imprisonment of Irishmen would potentially have led to different conclusions.

To achieve this, we compare data from prison populations with data from four census waves – 1871, 1881, 1891 and 1901 – to assess the degree of selection in the prison population across two dimensions: religion and literacy. We find that Catholics and illiterate individuals are overrepresented in our prison population. In Appendix C we found that Catholics and illiterates

⁵⁹ McCrea (2016) conducts a geographic analysis of the prisoners in our dataset that hailed from Dublin at the time of their incarceration. She finds that they overwhelmingly came from poorer parts of the city, such as inner-city slums with poor public health provisioning. She also finds that this did not change much across time: Kilmainham's inmates likely remained poor. It is exactly these individuals who we would expect to have been most affected by famine conditions.

Table C1: Difference-in-differences with interaction effects, 5-year famine window

Panel A: Kilmainham Gaol (males)

Measurement:	Dublin				Dublin			
	Dublin	Leinster	Ireland	Ireland	Dublin	Leinster	Ireland-born	Ireland
Sample origin:			(w/o Dublin) w/o Leinster				(w/o Dublin) w/o Leinster	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Famine-born	-2.22*** (-18.86)	-1.53*** (-3.47)	-0.51 (-1.08)	-0.51 (-0.39)	-0.77*** (-19.25)	-0.58*** (-3.49)	-0.04 (-0.12)	0.73 (1.68)
Catholic	-0.63*** (-6.58)	-0.15 (-0.44)	0.58 (1.55)	0.61 (0.89)	-0.28*** (-3.76)	0.11 (0.40)	0.70* (1.95)	0.59 (1.03)
Illiterate	-0.49*** (-33.53)	-0.66*** (-4.88)	-1.04*** (-4.48)	-1.41 (-1.75)	-0.52*** (-44.43)	-0.73*** (-4.61)	-1.04*** (-4.51)	-1.00 (-1.19)
Famine-born * Catholic	1.86*** (16.14)	1.44*** (5.24)	0.66 (1.43)	0.34 (0.25)				
Famine-born * Illiterate					0.17*** (3.12)	0.43 (1.66)	-0.00 (-0.00)	-2.98*** (-3.21)
Constant	168.61*** (1,795.87)	169.93*** (326.90)	168.83*** (410.99)	169.39*** (213.78)	168.29*** (2,298.54)	169.71*** (365.19)	168.72*** (427.35)	169.35*** (224.48)
Observations	9,504	14,998	7,543	2,049	9,504	14,998	7,543	2,049
R-squared	0.06	0.08	0.06	0.10	0.06	0.08	0.06	0.10

Panel B: Clonmel Gaol (males)

Measurement:	Males (Clonmel)				Males (Clonmel)			
	Tipperary	Munster	Ireland	Ireland	Tipperary	Munster	Ireland	Ireland
Sample origin:			(w/o Dublin) w/o Munster				(w/o Dublin) w/o Munster	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Famine-born	2.03 (0.51)	1.19 (1.34)	0.52 (0.35)	-0.38 (-0.15)	-0.09 (-0.18)	-0.39 (-1.28)	-0.37 (-1.23)	0.72 (0.36)
Catholic	1.54* (1.71)	0.91 (1.41)	0.25 (0.28)	-0.82 (-0.58)	1.39 (1.54)	0.84 (1.52)	0.22 (0.26)	-0.62 (-0.45)
Illiterate	-0.99*** (-4.50)	-0.79** (-3.34)	-0.72*** (-2.85)	0.27 (0.36)	-1.12*** (-4.77)	-0.95*** (-4.73)	-0.87*** (-3.86)	0.37 (0.53)
Famine-born * Catholic	-1.69 (-0.42)	-1.10 (-1.60)	-0.43 (-0.30)	0.90 (0.30)				
Famine-born * Illiterate					0.95 (1.46)	1.08*** (4.26)	1.04*** (3.91)	-0.72 (-0.33)
Constant	169.14*** (170.71)	169.70*** (341.33)	168.05*** (233.47)	167.78*** (114.71)	169.36*** (169.91)	169.86*** (396.92)	168.16*** (249.48)	167.55*** (102.78)
Observations	3,318	4,223	4,589	501	3,318	4,223	4,589	501
R-squared	0.03	0.04	0.04	0.10	0.03	0.04	0.04	0.10

Notes: The dependent variable is final adult height. Interaction effects between Famine-born and Catholic tests the difference in famine exposure between Protestants and Catholics. Interaction effects between Famine-born and illiteracy tests the difference in famine exposure between literate and illiterate individuals. Control variables include age at measurement, time of imprisonment (prison regime dummies), religion, literacy status and the type of offence. Robust t-statistics in parentheses; where relevant, standard errors are corrected for clustering and autocorrelation by clustering at the birth-county level; *** p<0.01, ** p<0.05, * p<0.1.

were less likely to show a famine effect due to their increased vulnerability and their increased exposure to selection relative to scarring. If we use weights to mimic the religious and educational composition of the whole of Irish society, we may also adjust the relative influence of scarring and selection effects, potentially leading to a different study outcome.

In practical terms, then, we use the shares of Catholics and illiterates reported in the census record for Dublin County (including the City of Dublin) and County Tipperary, and compare them with population shares in corresponding prison population. Our methodology follows the rationale of survey research, where usually response rates differ between various population groups and must be reweighted before inferences can be drawn. Table D1 shows the share of illiterate inhabitants of Dublin according to the census data for 1871, 1881, 1891 and 1901. In 1871, for example, 25 per cent of Catholics in Dublin reported to be illiterate, whereas 33 per cent of the corresponding Catholic prison population was illiterate. We find this pattern across all four census records for Catholics, but not for Protestants. Protestants are generally more literate than Catholics, and illiteracy rates in Protestant census and prison populations do not differ substantially.

We use the shares presented in Table D1 to create adjustment weights, which we use in a regression framework. Formula D1 illustrates how we compute a representation rate, θ , which is the illiteracy rate in the prison population (n) and the illiteracy rate in the general population according to the census (N). Adjustment weights are obtained by computing the inverse of θ (formula D2); weights for literate and illiterate individuals are presented in Table D2. Accordingly, adjustment weights to correct for illiteracy are near the value of one for Protestants, reflecting a minimal misrepresentation in the prison population. For Catholics, adjustment weights reflect a stronger misrepresentation compared to the general population.

$$\text{Representation rate:} \quad \theta = \frac{n}{N} \quad (\text{D1})$$

$$\text{Adjustment weight:} \quad \omega = \frac{1}{\theta} \quad (\text{D2})$$

We also found that the relative share of Protestants and Catholics differs between census population and prison population. In 1871, for example, 71 per cent of the population in Dublin was reported to be Catholic, whereas 90 per cent of the prison population reported to be Catholic, suggesting overrepresentation of Catholics. Likewise, Protestants are underrepresented in the prison population where only ten per cent report a Protestant denomination, compared with 29 per cent in the census records (Table D2). We compute adjustment weights using the methodology outlined above. Adjustment weight for Catholics are below one to adjust for overrepresentation in the prison population, whereas weights for Protestants aim at increasing their relative weight.

By contrast, the composition of the Clonmel Gaol population is more representative than that of Kilmainham Gaol (not shown here). Weights for the period 1871 to 1901 aiming to adjust the relative shares of literate and illiterate inmates also suggest that the most overrepresented

Table D1: Illiteracy in Dublin County

Year	Catholics		Protestants	
	Census	Prison	Census	Prison
1901	0.11	0.27	0.11	0.11
1891	0.24	0.34	0.12	0.10
1881	0.27	0.35	0.08	0.12
1871	0.25	0.33	0.16	0.17

Table D2: Religious composition of census and prison population, Dublin

Year	Catholics		Protestants	
	Census	Prison	Census	Prison
1901	0.71	0.93	0.29	0.07
1891	0.70	0.94	0.30	0.06
1881	0.72	0.91	0.28	0.09
1871	0.71	0.90	0.29	0.10

Table D3: Adjustment weights for Kilmainham and Clonmel Gaols

Year	Dublin		Clonmel	
	Catholics	Protestants	Catholics	Protestants
1901	0.76	4.14	0.99	1.17
1891	0.74	5.00	0.98	1.50
1881	0.79	3.11	0.97	2.00
1871	0.79	2.90	0.98	1.40

population group is illiterate Catholics, resulting in a weight below the value of one. Illiterate Protestants and literate population groups in general are fairly close to a weight of one, suggesting over and underrepresentation is only modest. Similarly, we do not find a strong overrepresentation of Catholics in Clonmel Gaol during this period, resulting in adjustment values close to the value of one. The final adjustment weights, combining both literacy and religion, which are computed using aforementioned methodology, are reported in Table D3.

We re-run our basic regressions setup where we test for a change in height between the pre-Famine cohort (born 1840-44) and the Famine-born cohort. We present results for unweighted regression, i.e., where no adjustment weights are used, alongside the corresponding regression model that uses weights, adjusting for over and underrepresentation specified in Table D4. By and large, results of both sets of regressions, for Dublin and Clonmel, are robust to this robustness

Table D4: Weighted regressions, 5-year famine window

Panel A: Kilmainham Gaol (males)

Measurement:	Dublin		Dublin		Dublin		Dublin	
Sample origin:	Dublin		Leinster		Ireland (excl. Dublin)		Ireland (excl. Leinster)	
Weights used:	original	weighted	original	weighted	original	weighted	original	weighted
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1840-44	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>
1845-49	-0.68*** (-22.26)	-0.59*** (-11.19)	-0.36 (-1.63)	-0.49*** (-4.88)	0.08 (0.36)	-0.14 (-0.57)	0.31 (0.70)	0.56 (1.35)
Constant	167.55*** (6,441.97)	167.41*** (5,105.56)	169.17*** (488.89)	169.06*** (964.65)	168.35*** (535.72)	168.32*** (385.47)	168.35*** (221.36)	167.73*** (175.43)
Observations	7,864	7,864	12,219	12,219	6,024	6,024	1,669	1,669
R-squared	0.07	0.06	0.09	0.09	0.08	0.08	0.11	0.11

Panel B: Clonmel Gaol (males)

Measurement:	Clonmel		Clonmel		Clonmel		Clonmel	
Sample origin:	Tipperary		Munster		Ireland (excl. Dublin)		Ireland (excl. Munster)	
Weights used:	original	weighted	original	weighted	original	weighted	original	weighted
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1840-44	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>	<i>reference</i>
1845-49	0.59 (1.58)	0.47 (1.22)	0.44** (2.69)	0.31 (1.83)	0.43* (1.98)	0.24 (0.93)	0.72 (0.39)	0.26 (0.13)
Constant	169.87*** (386.06)	169.82*** (372.83)	169.83*** (1,380.29)	169.56*** (1,224.72)	166.42*** (567.83)	166.05*** (635.09)	165.56*** (96.62)	165.50*** (119.94)
Observations	2,739	2,739	3,476	3,476	3,765	3,765	406	406
R-squared	0.04	0.04	0.04	0.05	0.05	0.05	0.09	0.10

Notes: The dependent variable is final adult height. Original regressions are identical to those reported in Table 3. Weighted regressions use weights taken from Table D3. Control variables include age at measurement, time of imprisonment (prison regime dummies), religion, literacy status, birth-county fixed effects and the type of offence. Robust t-statistics in parentheses; standard errors are corrected for clustering and autocorrelation by clustering at the birth-county level; *** p<0.01, ** p<0.05, * p<0.1.

check. As for inmates of Kilmainham Gaol, no noteworthy changes are detected for Dublin- or rural-born inmates. For the sub-sample of Leinster-born individuals, which includes also the Greater Dublin area, weighted regressions result in lower standard errors and a slightly increase effect size, suggesting a modest famine effect of similar magnitude as in the Dublin-only sub-sample. Weighted regressions for Clonmel, Tipperary, result in somewhat lower coefficients and higher standard errors. Nevertheless, we still do not find evidence of a famine effect for Tipperary-born and rural-born Irish (excl. Munster).

Appendix E: Window Length and Age Heaping

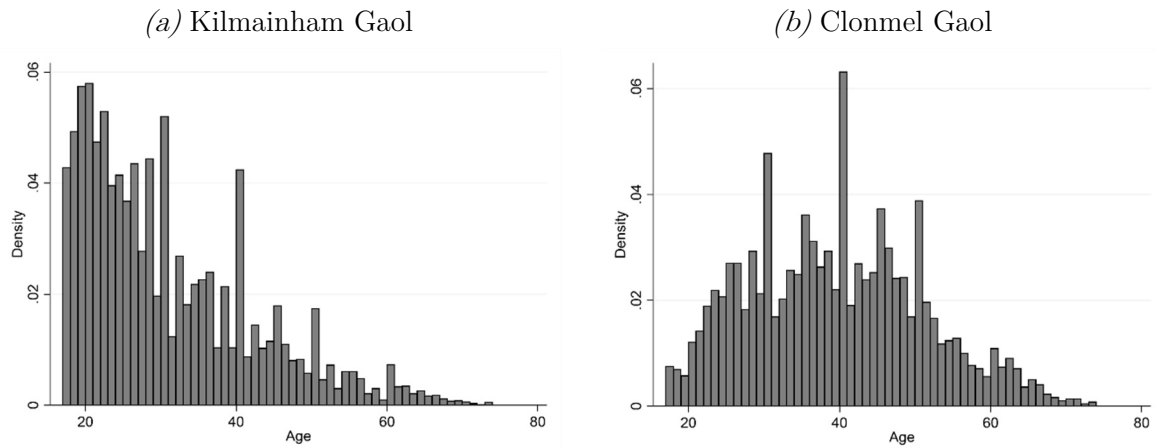
The principal empirical strategy we use in our analysis is to compare the average height of birth cohorts before, during and after the Famine, which we define in either 10-year or 5-year windows. We choose these multi-year windows partly because we cannot be entirely confident about the accuracy of the birth year that newly-incarcerated prisoners provide to prison officials on entry to the prison system. This is due to “age heaping”, a well-documented phenomenon where individuals who are uncertain of their true age round their age statements to multiples of five or ten. In this appendix, we employ an alternative sampling strategy which allows us to be more precise about the year of birth, and so enables us to determine whether our principal results are driven by the choice of cohort window. In short, we remove all individuals from our sample that report a round age, enabling us to report year-on-year height differences. Unfortunately, this alternative empirical strategy raises additional issues of representativeness, which we discuss below.

Age data often display excess frequencies at round or attractive ages, such as even numbers and multiples of five, leading to heaped distributions. A society’s propensity to age heap has been linked directly to its overall level of human capital (Mokyr and Ó Gráda 1982); trends in age heaping reveal trends in human capital accumulation (A’Hearn et al. 2009). Blum et al. (2017) find significant amount of age heaping among Ireland’s prison population, but find that this disappears by the end of the nineteenth century. Figure E1 demonstrates that there is also heaping in the sample of prisoners that we take for our analysis.

Removing all those prisoners who give an age ending either with a five or ten means that we can be more confident about capturing only those individuals who knew precisely in which year they were born. This enables us to compare individuals born in years of the Famine which were severely affected in terms of excess mortality, such as 1847, with other years which were affected to a much lesser extent, such as 1845.⁶⁰ However, removing these individuals from our sample creates two further selection issues: (1) some removed individuals were likely reporting their age accurately, and just happened to have a rounded age at the time of their incarceration; and (2) by removing those prisoners reporting a rounded age, we may be failing to capture those individuals who display low levels of human capital. Both selection issues are likely to work in opposite directions, and it is difficult to determine what the overall selection effect is.

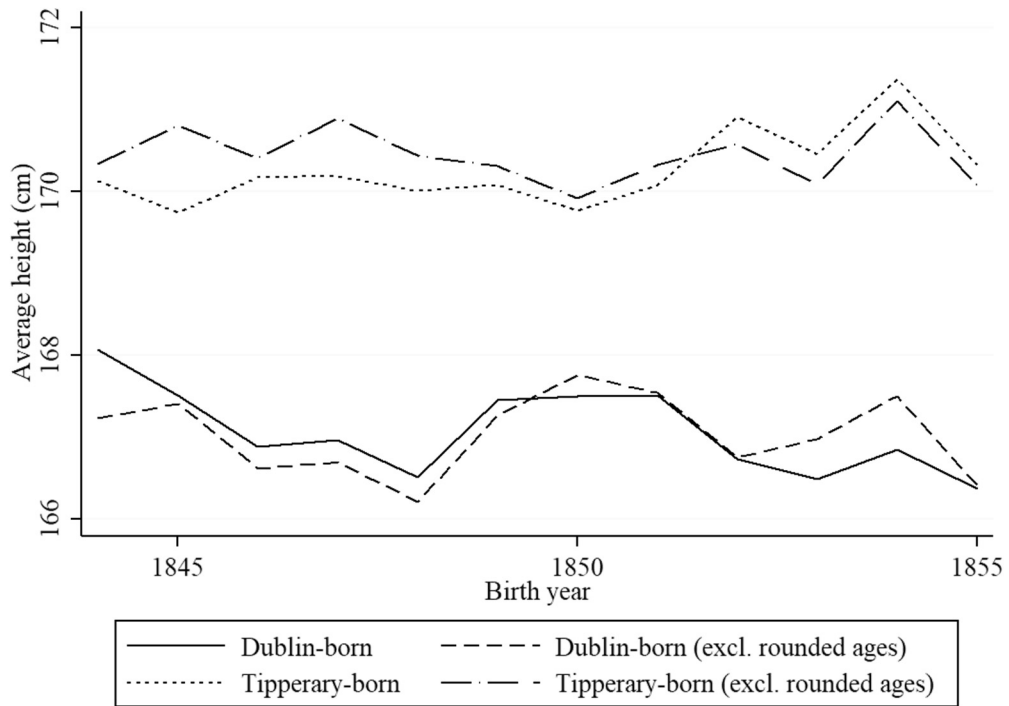
⁶⁰ Precise dating of the Famine is complicated as it has no clear beginning or end date (Ó Gráda 1999, pp. 37-38). If a famine is defined as excess mortality, then the start date could not be before the autumn of 1846, although contemporaries were aware of harvest shortfalls in the autumn of 1845. Dating the end date is equally problematic – compare, e.g., Woodham-Smith (1991) with Edwards and O’Neill (1956) – with end-dates of studies ranging from 1849 to 1852.

Figure E1: Age histograms, male prisoners



Sources: Authors' calculations, using Clonmel and Dublin prison registers.

Figure E2: Height trends in rural and urban Ireland, 1844-55



Sources: Authors' calculations, using Clonmel and Dublin prison registers.

Figure E2 displays the results of our year-on-year analysis graphically.⁶¹ Each height trend was computed from the coefficients of the year of birth and the regression model’s intercept. We plot height trends of all individuals in our samples alongside the subset of individuals who reported non-rounded ages. One of the most striking feature of the figure is the so-called “urban height penalty”, the consequence of poorer diet and sanitation in the city of Dublin. In terms of the aims of our study, and in common with our earlier analysis, we find no significant impact of famine on the heights of those born during the Famine period among Tipperary-born prisoners, but find a difference of approximately 1.0 cm for those born in Dublin. Removing those individuals born in rounded years does not change the height trend or the magnitude of these results.

Appendix F: Adolescent Growth

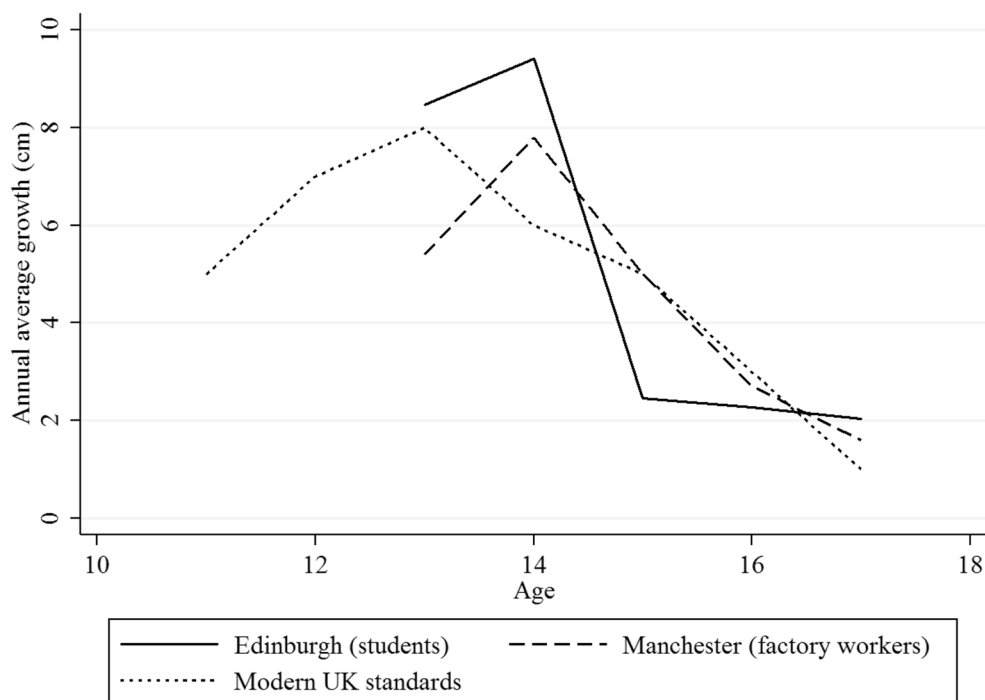
The principal goal of our analysis has been to measure whether there was an *in utero* impact of the Great Irish Famine on terminal adult height. The motivation for this goal has been the FOH scholarship, which establishes that the health and disease environment of a child’s mother from its inception to about age two are the most important determinants of adult stature.

But early infancy is not the only period in which human beings experience rapid growth in stature; teenagers also experience rapid growth. Indeed, as illustrated by the growth velocity curve in Figure F1, the second-most important period of growth is adolescence, historically between 12 and 16 for well-nourished boys (Komlos et al. 2009). Typically, teenage years are presented in the historical anthropometrics literature as a period in which those undernourished in infancy experience catch-up growth (Steckel 1986; Schneider 2017). However, if nutritional and disease environments are impaired during this period, this catch-up may never take place. Moradi (2010) shows that heights of adolescents in sub-Saharan Africa stagnated at the same time as countries experienced negative shocks GDP between the 1950s and 1980s. More pertinent still to our own study, Depauw and Oxley (2016) find evidence that Belgium’s mid-century potato famine impaired adolescent growth using a prison sample from Bruges.

We wish to cross-check our principal findings by ascertaining whether there is a famine shock to adolescent boys, and whether this differed across Ireland. We therefore look at the possibility of growth stunting among those individuals who experienced the Famine during adolescence. We draw new samples of individuals who at the end of the Famine, in 1852, were

⁶¹ In common with the regression analysis in the rest of this paper, we control for various personal characteristics, for literacy level and for offence type and conviction period.

Figure F1: Growth velocity of adolescent boys in the United Kingdom



Sources: Modern growth charts of boys in the UK are taken from RCPCH (2012); historical growth charts are derived from historical samples of students enrolled in the University of Edinburgh (Forbes 1837), and factory workers from Manchester and Stockport (Quetelet 1842).

aged 3-7, 8-12, and 15-17. The first category, aged 3-7, were *born* during the Famine,⁶² while the last, aged 15-17, constitutes the group that was due to undergo its adolescent growth spurt *during* the Famine years.⁶³ The middle category serves as a reference group.

Throughout all our tests, reported in Table F1, the only statistically significant famine effect that we can detect among adolescents is found in Dublin-born individuals imprisoned in Dublin. This cohort is approximately 1.0 cm shorter on average than the reference group in our OLS setting (see Section 6 for methodology). However, this result largely disappears when we use our weighted OLS estimator (see Appendix D for methodology). These findings are consistent with our earlier results in that Dublin-born survivors of the Famine show a famine scarring effect, while survivors born in Tipperary do not show any such signs.

⁶² Of the 3,165 individuals born and incarcerated in Dublin, 37.1% belong to this 3-7 category. And for Tipperary-born individuals incarcerated in Clonmel, this is 51.7%.

⁶³ 27.0% of Dublin-born Dublin prisoners belong to this 15-17 category, and 19.6% of Tipperary-born Clonmel prisoners.

Table F1: Adolescence famine exposure

Panel A: Kilmainham Gaol (males)

Measurement:	Sample origin:	Estimator:	Dublin		Dublin		Dublin		Dublin	
			Dublin		Leinster		Ireland (excl. Dublin)		Ireland (excl. Leinster)	
			OLS	Weighted OLS	OLS	Weighted OLS	OLS	Weighted OLS	OLS	Weighted OLS
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)			
<i>Birth cohort Age in 1845 Age in 1852</i>										
1835-39	6-10	13-17	-1.00*** (-3.07)	-0.51 (-1.33)	-0.45 (-1.24)	-0.24 (-1.53)	-0.04 (-0.15)	-0.07 (-0.32)	-0.54 (-0.91)	-0.10 (-0.17)
1840-44	1-5	8-12	reference	reference	reference	reference	reference	reference	reference	reference
1845-49	unborn	3-7	-0.86*** (-3.13)	-0.96*** (-2.96)	-0.46 (-1.64)	-0.67*** (-3.36)	0.18 (0.69)	-0.05 (-0.19)	0.32 (0.79)	0.59 (1.30)
Constant			167.48*** (418.15)	167.33*** (368.58)	169.83*** (599.50)	169.86*** (1,053.72)	168.91*** (372.11)	169.00*** (311.41)	164.56*** (292.02)	163.78*** (207.72)
Observations			3,165	3,165	5,275	5,275	2,974	2,974	864	864
R-squared			0.06	0.07	0.07	0.08	0.08	0.08	0.14	0.15

Panel B: Clonmel Gaol (males)

Measurement:	Sample origin:	Estimator:	Clonmel		Clonmel		Clonmel		Clonmel	
			Tipperary		Munster		Ireland (excl. Dublin)		Ireland (excl. Munster)	
			OLS	Weighted OLS	OLS	Weighted OLS	OLS	Weighted OLS	OLS	Weighted OLS
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)			
<i>Birth cohort Age in 1845 Age in 1852</i>										
1835-39	6-10	13-17	-0.22 (-0.45)	-0.37 (-0.71)	-0.20 (-0.97)	-0.26 (-0.98)	-0.18 (-0.68)	-0.34 (-1.21)	0.17 (0.07)	-0.21 (-0.10)
1840-44	1-5	8-12	reference	reference	reference	reference	reference	reference	reference	reference
1845-49	unborn	3-7	0.64 (1.46)	0.36 (0.77)	0.33 (1.14)	0.04 (0.14)	0.28 (0.93)	-0.05 (-0.14)	1.00 (0.75)	0.90 (0.41)
Constant			171.00*** (247.45)	171.03*** (228.45)	170.32*** (279.14)	169.61*** (274.07)	166.62*** (276.43)	166.69*** (321.66)	168.21*** (67.56)	165.25*** (75.58)
Observations			969	969	1,264	1,264	1,369	1,369	161	130
R-squared			0.02	0.02	0.03	0.03	0.06	0.07	0.22	0.26

Notes: The dependent variable is final adult height. Control variables include age at measurement, time of imprisonment (prison regime dummies), religion, literacy status, birth-county fixed effects and the type of offence. Robust t-statistics in parentheses; where relevant, standard errors are corrected for clustering and autocorrelation by clustering at the birth-county level; *** p<0.01, ** p<0.05, * p<0.1.

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