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**Abstract**: The frequency at which age data heap at round ages can be used to infer people's ability to count. Földvári, Van Leeuwen and Van Leeuwen-Li (FVV) contend that gender-specific trends in numeracy derived from age heaping in census data are unreliable because women's ages are adapted to those of their male household heads. This paper reassesses this finding by comparing two independently constructed age data sources for the case of rural Ireland in the nineteenth century: prison registers and corresponding census districts, where the former has the unique advantage of being self-reported by newly incarcerated male *and* female prisoners. We find that women are substantially less numerate than a comparison based solely on census data would suggest. We conclude that the FVV bias *is* a concern for the age heaping literature and recommend that female numeracy estimates made for societies where the census is the only available source be used with caution.

**Keywords**: age heaping, numeracy, selection bias, prison registers, Ireland.

**JEL Codes**: I25, N33.

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## 1. Introduction

Age data often display excess frequencies at round or attractive ages, such as even numbers and multiples of five, leading to age heaping. An innovative methodology has been adopted in recent studies which enables researchers to estimate numeracy trends by investigating this systematic misreporting of age statements.[1] One uncertainty regarding the reliability of numeracy estimates from studies of age heaping derives from the high likelihood that family household heads, usually male, report the ages of all family members in their census return. Földvári, Van Leeuwen and Van Leeuwen-Li (henceforth FVV) find that married women tend to heap significantly less than unmarried women in studies based on such data.[2] This suggests that a percentage of women have their ages adapted to that of their spouse and so female heaping patterns merely reflect male numeracy skills.[3]

FVV's solution to the problems associated with using census-derived age heaping estimates is to exclusively use data pertaining to unmarried women. However, a sample based on unmarried women itself presents a problematic selection bias; evidence suggests that women who are successful in the marriage market tend to display superior human capital levels.[4] We contribute to this debate by adopting an alternative approach. We compare male and female numeracy estimates derived from two independently constructed sources spanning the entirety of the nineteenth century for the case of rural Ireland: prison registers and corresponding census districts.[5] Female numeracy estimates derived from Ireland's census data potentially suffer from the 'FVV bias' as census forms were

[1] A'Hearn, Baten and Crayen, 'Quantifying quantitative literacy'; Crayen and Baten, 'Global trends'.

[2] Földvári, Van Leeuwen and Van Leeuwen-Li, 'How did women count?'.

[3] Using age data taken from portrait paintings from the early modern period, De Moor and Zuijderduijn, 'The art of counting', find that married women in upper social classes were more rather than less numerate than their husbands in the case of the Netherlands.

[4] Becker, 'A theory of marriage', p. 813, theorises that 'men differing in physical capital, education or intelligence […] will tend to marry women with like values of these traits'. Evidence suggests that educational investments are responsive to marriage market conditions (Boulier and Rosenzweig, 'Schooling'), and that marriage market outcomes are determined by assortive matching – e.g. wealthier brides marry wealthier grooms (Fafchamps and Quisembing, 'Assets at marriage'). Specifically in relation to the debate in this paper, Stolz, 'Essays on human capital formation', argues that FVV's findings are the result of (upward) selection bias among married women rather than a marriage-related bias of age statement.

[5] The National Archives of Ireland holds the records of 45 prisons (National Archives of Ireland, Dublin, Pris1). Published censuses, available from Parliamentary Papers, provide year-by-year age distributions of the population of Ireland at the county level.

completed by household heads;[6] whereas incarcerated males and females stated their ages independently at the time of their imprisonment,[7] avoiding this problem and permitting us to estimate their 'true' age heaping pattern. Census data on Ireland's female population serves as the potentially biased 'test group'. We then use female inmates and their age statements as the 'control group'. The results presented in this paper allow us to assess whether, and if so, to what degree female numeracy is biased if based on census data alone.

Why do we need to better understand long-run trends in female numeracy? Educational attainment has been shown to be an important driver of economic growth and indicators such as numeracy may help us to understand the mechanisms of this attainment.[8] How does correcting for the FVV bias further the field of Irish economic and social history? Geary and Stark argue that there was considerable growth convergence in Post-Famine Ireland, with per capita GDP growing faster than that of Britain.[9] They argue that the forces underlying Ireland's productivity growth were capital accumulation and growth in total factor productivity (TFP), which they argue was only indirectly influenced by emigration. In order to better understand the sources of this TFP growth, and given the importance of women in Ireland's labour market across the nineteenth century, it is vital that we better measure any secular trend in female educational attainment.

We find strong evidence of an FVV bias in Ireland's census returns. Using the registers of Clonmel Gaol – a sample of 10,222 women and 27,693 men imprisoned over the course of nearly 100 years – we estimate that women's ability to count in County Tipperary is hugely overestimated in the census; one third rather than two thirds of Tipperary's women born in the 1810s had basic numeracy skills. Given women's lower starting point, we conclude that the rate of convergence in human capital attainment between women and men was much more rapid than previously thought. Sections 2 and 3 provide the historical and institutional context necessary to understand the

[6] 'We resolved to adopt the course of sending a form of return to each family, to be filled by its head, as less intrusive than requiring it to be filled by the enumerator from viva voce inquiry. But we, of course, took means to check the returns so obtained, and required from the enumerator a certificate that they were true to the best of his belief', *Report of the commissioners*, p. v.

[7] 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', *Copy of rules and regulations*.

[8] Crafts, 'Exogenous or endogenous growth?', points towards an increased emphasis on the role of human capital formation in modern theories of economic growth. Lindert, 'The rise of social spending' and *Growing public*, finds a positive relationship between social spending and growth, and also between primary education and growth, over the period 1870-1930.

[9] Geary and Stark, 'Examining Ireland's Post-Famine economic growth performance', pp. 931-932.

arguments of this paper. Section 4 introduces the methodology and discusses how we adjust for biases associated with using prison data. Section 5 presents our results and interprets them in light of the historical and institutional context. Section 6 concludes.

## 2. Education in Ireland

Nineteenth-century Ireland was an impoverished sophisticate: despite its poverty there was a demand for education from its peasantry.[10] Basic literacy was already common across Ireland in the early nineteenth century.[11] 'Hedge schools' were found in almost every parish in the country prior to the introduction of state-funded education. These 'schools' were reported to have had a wide and varied curriculum; parental demand led to arithmetic being taught alongside scripture.[12] By 1824 there were 9,000 such schools.[13] Then, in 1831, Ireland became the first polity of the United Kingdom to receive state-funded primary education.[14] The new national schools that were established were promoted to teach numeracy alongside literacy.[15] Clarke illustrates how bookkeeping was a sought after subject taught in hedge schools and national schools alike.[16]

How well did girls do relative to boys from Ireland's educational settlement? Ó Gráda describes FitzGerald's calculations from Ireland's 1821 census that 35 per cent of boys and girls of school-going age (between the age of six and 13) attended schools – 44 per cent of boys and 26 per cent of girls.[17] Attendance improved substantially across the century, especially following the Great Famine; by the 1880s, if there was a gender difference, then it was reversed.[18] By the time attendance was made compulsory in 1892, few, if any, children had not spent at least some time at school.[19]

[10] Akenson, *Irish education experiment*, p. 17.

[11] Ó Gráda, 'School attendance', p. 2.

[12] McManus, *The Irish hedge school*, p. 60.

[13] Ibid., p. 20, 31.

[14] The precociousness of the Irish state financed system is evident in the 1870s when central funding for schools in Ireland was 85% of total funds compared to 35.5% in England and Wales (Lindert, *Growing public*, vol 1, table 5.6, pp. 116-117).

[15] Coolahan, *Irish education*.

[16] Clarke, 'The teaching', p. 23.

[17] Ó Gráda, 'School attendance', p. 7.

[18] Fitzpatrick, '"A share of the honeycomb"', p. 219.

[19] Logan, 'Sufficient for their needs'.

While we know a great deal about trends in school attendance in Ireland across the century, we know relatively little about educational attainment and cognitive ability, especially numeracy.[20] This paper begins to address this gap in our understanding. We measure the numerical ability of cohorts of people that were exposed to Ireland's increasingly more sophisticated education system by analysing self-reported ages of women and men entering the prison system in Clonmel, a garrison town located in Country Tipperary, in the south of the island. Tipperary was predominantly agricultural prior to the 1820s; Clonmel had proto-industrial sectors. Tipperary had some of the finest agricultural land on the island and was an early convert from tillage to pasture. This insulated it somewhat from the catastrophic effects of crop failure: Tipperary features only about midway down Mokyr's league table of Famine-related deaths.[21] Fitzpatrick ranks Tipperary as having above-average female literacy by 1871, partly, he argues, because employing children was considered less profitable there than elsewhere on the island.[22]

In an early application of age heaping, Mokyr and Ó Gráda found that Ireland's emigrants were more likely to heap than the population at large,[23] leading Mokyr to conclude that 'emigrants tended to heap *more*, not less, than those who remained behind'.[24] Fitzpatrick argues that those Irish women who stayed behind on the island – about half of each generation – sought instead to better themselves through education.[25] Overall, he finds that those areas of the island that saw the highest level of emigration saw the most rapid educational improvements of women as they, or their parents, sought to better themselves in preparation for foreign labour markets.[26] Female cohort depletion rates, a measure of emigration favoured in studies of Ireland, suggest that female emigration was lower than that of males in Tipperary until the 1890s (see table 1).[27] Family unit migration was more

[20] Hippe, 'How to measure human capital?', finds that improvements in numeric ability tend to precede improvements in literacy.

[21] Mokyr, *Why Ireland starved*, p. 267. For a recent geographic treatment of Ireland's nineteenth century experience of potato blight, see Crowley, Smith and Murphy, *Atlas*.

[22] Fitzpatrick, '"A share of the honeycomb"', p. 220, 230.

[23] Mokyr and Ó Gráda, 'Emigration and poverty', pp. 375-378.

[24] Mokyr, *Why Ireland starved*, p. 246.

[25] Fitzpatrick, '"A share of the honeycomb"', p. 217.

[26] Ibid., pp. 227-228

[27] The emigration statistics for Ireland do not fully account for emigration (Ó Gráda, 'A note'). We therefore follow Fitzpatrick's methodology of calculating cohort depletion, which is the percentage depletion over an intercensal period of the cohort initially aged 5-24 years in the census of Ireland data for 1821-1891 (Fitzpatrick, 'Emigration', p. 608).

common in the early nineteenth century, after which young males and females migrated independently.[28]

*[Table 1 about here]*

Does Tipperary's experience of migration explain differences in educational attainment found there? In a multivariate analysis of the drivers of Post-Famine Irish migration, Hatton and Williamson find that education was not an important cause.[29] Instead, the factors that account for Irish emigration patterns were poverty, demographic pressures and smallholdings. But while education may not drive migration, Fitzpatrick's argument primarily concerns those that were left behind; migration may drive demand for education. The secular trend in education measures in Tipperary still requires an explanation. We add to this debate by estimating numeracy, a measure of educational attainment that is better than school attendance. We then compare our numeracy estimates with those derived from Tipperary-born inhabitants of England and Wales in order to reassess the findings of Mokyr and Fitzpatrick.

## 3. Prisons and prisoners in Ireland

Irish prison registers are a wealth of information and age data taken from these registers enable us to make the methodological innovation of this paper. A precedent for using Clonmel Gaol's prison registers comes from Ó Gráda's study of Clonmel inmates' heights, which he uses to explore the nutritional status of the Tipperary populace in the 1840s.[30] A short history of prisons and their residents is necessary in order to contextualise this source and its potential biases. The prison system in nineteenth-century Ireland was localised and operated within a socio-political context that varied considerably from England.[31] The numbers, uses and forms of prisons fluctuated greatly over the course of the century and was particularly affected by legislative change and major societal tumults. In 1822 there were 178 prisons in Ireland, the majority being 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.[32] In the early nineteenth century the majority of prison buildings were not custom-built; only five purpose-built

[28] Fitzpatrick, 'Emigration', pp. 574-575.

[29] Hatton and Williamson, 'After the famine', p. 595.

[30] Ó Gráda, 'Heights in Tipperary in the 1840s'.

[31] McConville, *Irish political prisoners*, p. 1.

[32] O'Donnell, *Clonmel*, p. 31.

prisons existed in 1823.[33] This meant there was no facility for implementing increasingly more popular reformist ideas, such as segregation and classification.

Major legislative changes affected the administration and provision of prisons in Ireland. A more uniform prison administration was introduced by new laws in 1810 and 1826.[34] However, the most radical change in prison administration occurred in 1877 when the General Prisons Board was set up to centralise the control of all prisons. Following the mass-centralisation and professionalization of the prison system, only 23 of the 137 prisons in existence in Ireland in 1877 were still open in 1924.[35] Clonmel Gaol, which housed criminals from across County Tipperary, continued to function throughout this latter period of reform.

As well as administrative changes, prisons were greatly affected by the huge upheavals in the mid-century due primarily to the social, economic and political turmoil engendered in the Great Famine (1845-1852). On its broadest level the Famine resulted in prisons throughout the country being their most overcrowded and unmanageable. This was due to increased rates of petty crimes resulting from desperation and starvation, the deliberate committing of crimes in the widespread belief that larger food rations were provided in prisons compared to workhouses, and the introduction of the Vagrancy Act (Ireland) 1847.[36] This law was introduced not only to outlaw begging, but to specifically target the behaviours of, what were considered, the growing threat of recidivist criminals. A more long-term impact of the Famine was a greater demand for land and general legal reforms, as well as a rise in more aggressive nationalist politics. Clonmel Gaol held a number of political prisoners, including initially the leaders of the failed Young Irelanders rebellion in 1848. Tipperary had a long tradition of Whiteboyism, rural violence aimed at socio-political grievances, with Whiteboys derived from varied social backgrounds.[37] It had the highest homicide rates in the country during the 1830s and 1840s.[38] The ending of transportation of convicts to Australia from Ireland in 1853 led to reviews of conditions and forms of imprisonment, which resulted in the creation of the Irish Convict System, introduced to all prisons following legislation in 1877.[39]

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[33] McDowell, *The Irish administration.* pp. 145-151.

[34] Ibid., p. 31.

[35] O'Donnell, *Clonmel*, p. 33.

[36] The Law Reform Commission, *Report on vagrancy*, p. 6.

[37] Beames, 'Rural conflict', p. 75, 86.

[38] Decade average homicide rates in Tipperary were 8.38 per 100,000 capita for the 1830s, and 6.1 per 100,000 capita for the 1840s. This compares to the national average of 2.81 and 1.88 homicides (McMahon, *Homicide*, tables 1.1 and 1.2).

[39] Carroll-Burke, *Colonial discipline*, p. 95.

The surviving prison registers that are accessible via the National Archives of Ireland, and used in our study, do not cover the full period of the most recent prisons' existences. While the prison situated on Richmond Street in Clonmel dates from the late eighteenth century, the prison registers date from 1840 to 1924.[40] These provide sufficient sufficient data to track numeracy for birth cohorts from before, during and after the Great Famine. Moreover, our data encompass all the major judicial and penal reforms of the nineteenth century.

## 4. Age heaping and prisoner selection

Age heaping takes advantage of a specific phenomenon that exists in poorly educated societies: the act of rounding. When asked about their age, individuals who do not know it, are unable to calculate it by subtracting their year of birth from the current calendar year, or live in a society which deems such information not to be very useful, tend to round it to the nearest number ending zero or five.[41] Figure 1 is a histogram of the years of birth of Clonmel Gaol's prisoners implied from their age statements recorded in the prison registers. Figure 2 plots the distribution of ages of these prisoners. Age heaping is clearly present in the data, both for women and men.

*[Figures 1 and 2 about here]*

The United Nations uses the Whipple Index (WI) to assess the quality of age data.[42] This is a ratio of the share of people reporting an age ending zero or five to all age statements, and is obtained as follows:

$$WI = \left( \frac{n_{25}+n_{30}+\cdots+n_{65}+n_{70}}{1/5\times\left(n_{23}+n_{24}+n_{25}+\cdots+n_{72}\right)} \right)\times 100 \; if \; WI \geq 100; \; else \; WI = 100 \qquad (1)$$

A value of 500 indicates that all age statements end in zero or five; a value of 100 indicates no heaping. A'Hearn, Baten and Crayen, on the suggestion of Clark, modify WI to range between zero and 100, where zero indicates that everyone rounds, and 100 that no one does so.[43] This

[40] O'Donnell, *Clonmel*, pp. 31-34.

[41] Age heaping patterns may sometimes be the result of intentional misreporting if a society's institutions incentivise such behaviour. One such case is Ireland in the early twentieth century, when exaggerating ages had a clear financial reward with the introduction of the Old Age Pension for those aged 70 and over in 1908 (Budd and Guinnane, 'Intentional age-misreporting').

[42] United Nations, *Demographic yearbook*, p. 5, 133.

[43] A'Hearn, Baten and Crayen, 'Quantifying quantitative literacy'.

modified index, known as the ABCC index, can be interpreted as the share of the population that is numerate, and is given as follows:[44]

$$ABCC = \left(1 - \frac{\left(WI - 100\right)}{400}\right) \times 100, if\ WI \geq 100;\ else\ ABCC = 100 \quad (2)$$

A large body of anthropometric evidence suggests that data based on convicts do not reflect the overall population. The rationale behind this bias is that individuals with low opportunity cost select themselves more easily into crime, and therefore into prison samples. Persico, Postlewaite and Silverman find that taller workers receive a wage premium, with the disparity in wages being similar in magnitude to the race and gender gaps.[45] Similarly, Case and Paxson find that individual height reflects superior intellectual capabilities, and that the latter explain a large portion of the height premium paid in labour markets.[46] In other words: short individuals and individuals with inferior human capital are disadvantaged in official labour markets, while for taller individuals the opposite is true. In this regard, Bodenhorn, Moehling and Price find that individual stature is negatively correlated with age at entry into criminal activity.[47] In summary, prison populations probably yield a downwardly biased height estimate if taken as a benchmark for the overall population.[48]

It is no stretch, therefore, to posit that prison populations' numeracy may be no more representative than their anthropometry; it is unlikely that prison data accurately reflect the age heaping pattern of a county's general population because the upper and middle social classes are underrepresented. Therefore, it is necessary to correct for this bias to assess the 'true', or unbiased, age heaping pattern of the female population. We do so by running a set of logistic regressions in order to investigate correlates of numeracy, which is approximated by the tendency to report a non-rounded age; the dependent variable equals 1 if an individual reports a non-rounded age, or 0 if a multiple of 0 or 5 is reported. We use prisoners' characteristics, summarized in table 2, as explanatory variables: decade of imprisonment, approximate age at conviction, type of offence,[49] and

[44] Given the formula, ABCC values above 100 are technically possible, and should be interpreted as 100% numeracy.

[45] Persico, Postlewaite and Silverman, 'The effect of adolescent experience'.

[46] Case and Paxson, 'Stature and status'.

[47] Bodenhorn, Moehling and Price, 'Short criminals'.

[48] Bodenhorn, Guinnane and Mroz, 'Problems of sample-selection bias'.

[49] Type of offence categorised by adapting official contemporary classification (*Judicial statistics*): (1) offences against the person; (2) offences against property with violence; (3) offences against property without violence; (4) drunkenness; (5) indecency; and (6) begging and prostitution.

information on recidivism serve as control variables, whereas binary variables controlling for the decade of birth indicate numeracy of a certain birth cohort. These controls are necessary since prisoners undergo selection, and this selection may vary over time (see figures 3 and 4).

*[Table 2 about here]*

*[Figures 3 and 4 about here]*

As discussed in section 3, Irish prisoners were likely to be (more) positively selected during the Great Famine since some individuals committed offences in order to gain access to allegedly superior prison nutrition. The results presented in table 3 support this view; individuals convicted during the 1840s were more likely to report a non-rounded age than prisoners of subsequent periods.[50] A dichotomous variable controlling for those aged 23 to 32 helps to control for the phenomenon that this age group is better at reporting a correct age due to their proximity to birth, marriage, and military service.[51] Regression results confirm this finding; Clonmel prisoners of both sexes are more likely to report a non-rounded age when they are younger. Another dichotomous variable identifying recidivists controls for their potential selection and their multiple appearance in the analysis.[52]

*[Tables 3 and 4 about here]*

In a second step we use the odds ratios presented in table 3 to compute marginal effects of each of the birth cohort coefficients and adjust those according to the methodology suggested by Juif and Baten.[53] These adjusted marginal effects, reported in table 4, constitute an estimation of conventional ABCC values. Finally, in order to calculate the magnitude of the FVV bias, we apply a difference-in-difference approach: assuming that male age heaping patterns – both in census and prison data – are actually reported by males themselves, we compare numeracy scores of the male census and prison populations. In a subsequent step we use the estimated magnitude of this bias to

[50] Our results contrast to those of Mokyr, *Why Ireland starved*, pp. 244-246, who notes that age heaping was most noticeable amongst the Famine generation of migrants to the US.

[51] Following Crayen and Baten, 'Global trends'.

[52] Recidivists were identified by matching names and birth years across registers. A recidivist may remain undetected if she gives a different age on subsequent encounters the prison authorities. However, evidence suggests that an effort was made by prison guards to match prisoners to their previous register entries.

[53] A correction of these coefficients is necessary since approximately 20% of all age statements that are allegedly 'rounded' are in fact accurate. To obtain a corrected numeracy coefficient, they suggest that marginal effects are multiplied by the factor 1.25 (Juif and Baten, 'On the human capital of Inca Indios', online appendix).

adjust the numeracy of female prisoners to estimate female numeracy that is biased neither by prison selection nor male household heads. Formula 3 indicates this approach:

$$ABCC_{fct} = ABCC_{fpt} + \left( ABCC_{mct} - ABCC_{mpt} \right) + \Delta_t \quad (3)$$

$ABCC_{fct}$ indicates female numeracy levels calculated from census age statements at time t, a cohort's decade of birth. These ABCC values are compared with the numeric abilities of the corresponding female prison population ($ABCC_{fpt}$). The latter has to be corrected by adding the estimated prison bias, which is estimated by computing the difference between male census and prison populations. $\Delta_t$ indicates the unexplained rest, that is the part of numeric ability of the female census population which may help to shed light on potential biases related to male household heads reporting their spouses' ages – the FVV bias. If female age statements are unaffected by aforementioned biases, $\Delta_t$ is expected to be small. Formula 4 presents the test scheme; table 4 reports our findings.

$$\Delta_t = \left( ABCC_{fct} - ABCC_{fpt} \right) - \left( ABCC_{mct} - ABCC_{mpt} \right) \quad (4)$$

## 5. Results and robustness

Results indicate that the numeric abilities of both males and females from Tipperary whose ages were reported during the 1841 census were increasing between birth cohorts (figure 5). ABCC levels of the corresponding prison population show a similar development: levels during the late eighteenth century were low, but successive increases occurred during the following decades. Differences in ABCC levels between males and females are visible throughout the period under analysis, with males showing superior numeracy than females. For the census populations, the ABCC advantage for males is approximately 13 points in the 1780s and decreases to approximately five to seven points for the period 1790s to 1810s. As for inmates, gender differences are more pronounced. Male prisoners have an ABCC advantage of approximately 40 and 42 in the 1780s and 1790s; this value decreased in subsequent periods, falling from approximately 35, to nine between the 1800s and the 1830s. Table 4 also provides $\Delta_t$, the unexplained difference between female numeric abilities based on census records and prison registers. The result of the computation according to formula 4 suggests that the unexplained part of female numeracy accounts for approximately 27 and 36 ABCC points during the 1780s and 1790s, and approximately 29 and 30 in the 1800s and 1810s. These results confirm the presence of an FVV bias in Ireland's census returns.

*[Figure 5 about here]*

As a robustness check, we run a test similar to the aforementioned procedure using only those individuals convicted for offences related to 'drunkenness', an offence that was criminalized in Ireland only in the mid-1870s.[54] The rationale behind this measure is that this sub-sample of convicts underwent a less strict selection and, hence, reflects numeracy closer to 'true' numeracy.[55] Economically speaking, we address Bodenhorn et al.'s concerns regarding representativeness by only taking into account individuals who are less characterized by low opportunity costs of crime, but instead attracted the authorities' attention by drinking.[56] We assume that this sub-sample of convicts also underwent some sort of selection, but that this selection is less severe compared to the whole prison sample. We therefore expect that the numeracy of drunkards is less downward biased and, hence, closer to representative values, enabling us to estimate $\Delta_t$ values more accurately.

The results of this exercise, reported in table 5, confirm our expectation in terms of selection, and confirm our findings on the size and sign of $\Delta_t$. Generally, the numeracy of drunkards tends to be at least equal to, but often higher than, numeracy in the whole prison sample.[57] If we apply the aforementioned difference-in-difference approach to recalculate $\Delta_t$ values using the numeracy of drunkards instead of numeracy of the whole prison sample, then the $\Delta_t$ values increase from 30 (1800s)[58] and 29 (1810s) to 65 and 42.[59]

*[Table 5 about here]*

The census that underlies our county-level estimates of numeracy was taken in 1841, before the emigration shock that accompanied the Great Famine. Meanwhile, the prison registers that we use to correct these numeracy estimates refer to people incarcerated throughout the nineteenth century, including cohorts where a considerable portion of Ireland's inhabitants had either died or

[54] Prisoners held for drunkenness enter Clonmel Gaol for the first time in the mid-1870s. This coincides with the introduction of the Licensing Acts, 1872 and 1874 (National Crime Council, *Public order offences*, p. 13).

[55] We thank Chris Minns for this suggestion. The logic follows from Riggs, 'Standard of living', p. 94, a paper that argues that the study of Scottish prisoners is representative of the general population because Scotland was a society of heavy drinkers and many were at risk of arrest.

[56] Bodenhorn, Guinnane and Mroz, 'Problems of sample-selection bias'.

[57] An exception seems to be Tipperary birth cohorts of the 1820s to 1850s, where drunken females are less numerate than the average female prison population.

[58] Note that the number of observations is low in this particular case; see table 5 for details.

[59] A similar robustness check was carried out with prisoners incarcerated for political crimes (dissent or treason). The idea is that these prisoners may be more highly educated than the general prison population. We find a value for $\Delta_t$ of 47.9 ABCC points for the 1810s birth cohort, suggesting otherwise.

emigrated.[60] For example, a person born in 1820 who is imprisoned in 1840 may have different characteristics to a prisoner who is also born in 1820 but incarcerated in 1860; the latter is not just older but the Famine epoch may have further selection effects.[61] We partly take this feature into account by controlling for the time of imprisonment in the logistic regressions; respective coefficients are supposed to capture at least some of this effect. However, in case this measure is insufficient, we must consider the impact of this selection problem: Post-Famine prison populations by definition did not include those who decided to leave Ireland. If, as Mokyr suggests, those that left Ireland were *less* numerate than those that stayed behind, then this would mean our estimates of $\Delta_t$ are biased downwards; had Post-Famine census records survived history and therefore been available for use in the calculation of our ABCC trends, then the true value of $\Delta_t$ for cohorts born in the first half of the century would be higher still. Similarly, if, as Fitzpatrick argues, individuals who did not migrate instead had more invested in their human capital, then we would expect that prison populations incarcerated after the Famine would be systematically *more* numerate than prisoners of the same birth cohort incarcerated before the Famine. If anything, these biases are against us; they reinforce our argument and make us more confident in our findings.

In order to investigate further the migration selection problem, we compare the numeracy of Irish emigrants to England and Wales from County Tipperary with census and prison populations in figure 6.[62] Unlike the census data used for Ireland, that used for emigrants refers to a Post-Famine year, namely 1881. In contrast to Mokyr's findings for migrants to the US, our own comparison suggests that emigrants were *more* numerate than those that stayed behind.[63] Numeracy of male migrants from Tipperary to England and Wales was approximately seven ABCC points higher than the corresponding census populations. For female migrants this difference was approximately 19 ABCC points.

*[Figure 6 about here]*

[60] The way in which age data was reported in county-level census reports for the Post-Famine period make it impossible to detect age heaping patterns.

[61] This is also evident in Mokyr and Ó Gráda, 'Emigration and poverty', p. 376, who find that the 1851 census was more heaped than the 1841 census.

[62] ABCC estimates for Irish emigrants to England and Wales are calculated using data from the 1881 census described in Day, 'Leaving home'.

[63] As our estimates for numeracy over-represent the lower socioeconomic orders, our results are an underestimate; we suggest therefore that emigrants were less numerate still than those they left behind.

## 6. Conclusion

FVV argue that there is a problem in census-derived age heaping estimates for women because male household heads report their age on their behalf. If males are generally more numerate, as they argue, this could systematically bias female numeracy estimates upwards. They advocate instead to only measure age heaping patterns of unmarried women, a solution which itself introduces a selection bias. We offer a very different solution: we estimate the influence of this potential bias by comparing ABCC trends based on census and prison registers – the latter of which contains self-reported age statements – from one Irish county during the nineteenth century. The estimated bias for County Tipperary is consistently positive, with deviations between census and prison estimates of female numeracy ranging between 25 and 35 ABCC points. We therefore find independent evidence of the FVV bias and recommend that female age heaping estimates should be used with caution for societies where the census is the only available source.[64]

This paper has provided a long span of numeracy estimates for a rural area of the island of Ireland. We find trends of increasing numeracy that corresponds to the growth in national schooling. This, we believe, lends support to the Geary and Stark view of TFP-driven economic growth in the Post-Famine period.[65] We find little evidence for Mokyr's argument that emigrants were less numerate than those that they left behind.[66] And we cannot easily assess Fitzpatrick's argument that those Irish women who failed to escape the island sought instead to better themselves through education.[67] Lastly, this paper suggests that the time it took to close the education gap between Ireland's women and men is astonishing, given the size of women's initial disadvantage.

[64] Such as in Friesen, Baten and Prayon, 'Women count', who overlook the FVV bias when calculating female numeracy levels for various Asian countries.

[65] Geary and Stark, 'Examining Ireland's Post-Famine economic growth performance', pp. 931-932.

[66] Mokyr, *Why Ireland starved*, pp. 244-46.

[67] Fitzpatrick, '"A share of the honeycomb"', p. 219.

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Table 1. *Cohort depletion (%), by gender, 1841-1891*

| Decade | Tipperary | | Ireland | | Coefficient of variation | |
|---|---|---|---|---|---|---|
| | Females | Males | Females | Males | Females | Males |
| 1841-51 | 38.39 | 43.17 | 37.57 | 41.04 | 28.94 | 21.20 |
| 1851-61 | 46.02 | 44.93 | 34.07 | 36.79 | 29.35 | 22.18 |
| 1861-71 | 34.22 | 38.12 | 29.97 | 35.54 | 27.69 | 19.96 |
| 1871-81 | 25.96 | 28.35 | 25.69 | 29.37 | 26.52 | 22.69 |
| 1881-91 | 31.97 | 31.10 | 31.34 | 31.48 | 27.53 | 23.98 |

*Source:* Census of Ireland, 1841-1891.

Table 2. *Descriptive statistics (proportions), Clonmel prisoners, by gender*

| Variable | Females | Males |
|---|---|---|
| Numerate (=1 if stating a non-rounded age) | 0.42 | 0.62 |
| *Decade of birth* | | |
| 1770s | | <0.01 |
| 1780s | 0.01 | 0.02 |
| 1790s | 0.04 | 0.05 |
| 1800s | 0.10 | 0.08 |
| 1810s | 0.23 | 0.20 |
| 1820s | 0.28 | 0.16 |
| 1830s | 0.19 | 0.10 |
| 1840s | 0.12 | 0.11 |
| 1850s | 0.03 | 0.08 |
| 1860s | <0.01 | 0.12 |
| 1870s | <0.01 | 0.07 |
| 1880s | <0.01 | <0.01 |
| *Decade of imprisonment* | | |
| 1840s | 0.30 | 0.30 |
| 1850s | 0.30 | 0.17 |
| 1860s | 0.20 | 0.10 |
| 1870s | 0.16 | 0.12 |
| 1880s | 0.04 | 0.05 |
| 1890s | <0.01 | 0.16 |
| 1900s | <0.01 | 0.11 |
| *Type of offence* | | |
| Against the person | 0.15 | 0.24 |
| Against property (with violence) | 0.03 | 0.04 |
| Against property (w/o violence) | 0.33 | 0.21 |
| Begging, prostitution, etc. | 0.11 | 0.06 |
| Drunkenness | 0.04 | 0.18 |
| Indecency | 0.33 | 0.37 |
| Recidivist | 0.39 | 0.38 |
| Age group 23-32 | 0.59 | 0.54 |
| *N* | 10,222 | 27,693 |

*Source:* Authors' calculations using all extant prison registers of Clonmel Gaol (1848-1849; 1849-1850; 1850-1851; 1851-1852; 1857-1862; 1862-1870; 1870-1878; 1878-1880; 1883-1893; 1894-1903; 1903-1925) held at the National Archive of Ireland, Dublin (Pris1).

Table 3. *Determinants of numeracy (odds ratios), Clonmel prisoners*

| Variable | Females | Males |
|---|---|---|
| *Decade of birth* | | |
| 1770s | | -0.58 |
| 1780s | -0.06 | -1.17*** |
| 1790s | -0.11 | -1.19*** |
| 1800s | -0.02 | -1.41*** |
| 1810s | 0.22 | -1.29*** |
| 1820s | 1.09* | -0.92*** |
| 1830s | 1.74*** | -0.83*** |
| 1840s | 2.47*** | -0.67** |
| 1850s | 3.67*** | -0.31 |
| 1860s | 5.05*** | -0.24 |
| 1870s | 3.75*** | -0.58** |
| 1880s | reference | reference |
| *Decade of imprisonment* | | |
| 1840s | reference | reference |
| 1850s | -0.79*** | -0.32*** |
| 1860s | -1.79*** | -0.36*** |
| 1870s | -2.61*** | -0.50*** |
| 1880s | -0.94*** | -0.55*** |
| 1890s | -2.30*** | 0.29*** |
| 1900s | -3.30*** | 0.15 |
| *Type of offence* | | |
| Against the person | 0.16** | 0.09*** |
| Against property (with violence) | 0.05 | -0.04 |
| Against property (w/o violence) | reference | reference |
| Begging and prostitution | -0.03 | -0.22*** |
| Drunkenness | 0.12 | 0.04 |
| Indecency | 0.03 | 0.07* |
| Recidivist | -0.05 | 0.04 |
| Age group 23-32 | 0.09 | 0.56*** |
| Constant | -0.47 | 1.11*** |
| *N* | 10,221 | 27,692 |

*Notes:* Numeracy measured by a non-rounded age statement (odds ratios). * = Statistically significant at the 10% level; ** = Statistically significant at the 5% level; *** = Statistically significant at the 1% level.

Table 4. *Numeracy trends (ABCC), Clonmel prisoners and Tipperary census population, by gender*

| Decade of birth | Females | | Males | | Δ |
|---|---|---|---|---|---|
| | Clonmel Gaol | Tipperary 1841 census | Clonmel Gaol | Tipperary 1841 census | |
| 1770 | 28.8 (13) | 63.1 | 86.3 (78) | 71.1 | |
| 1780 | 28.8 (117) | 46.5 | 68.8 (452) | 59.3 | 27.2 |
| 1790 | 26.3 (426) | 58.6 | 68.8 (1,247) | 65.6 | 35.5 |
| 1800 | 27.5 (995) | 63.2 | 62.5 (2,448) | 68.2 | 29.9 |
| 1810 | 32.5 (2,349) | 72.5 | 66.3 (5,736) | 77.2 | 29.1 |
| 1820 | 53.8 (2,914) | | 76.3 (4,842) | | |
| 1830 | 70.0 (2,001) | | 78.8 (3,529) | | |
| 1840 | 87.5 (1,439) | | 83.8 (4,291) | | |
| 1850 | 108.8 (515) | | 92.5 (3,699) | | |
| 1860 | 120.0 (125) | | 93.8 (4,368) | | |
| 1870 | 110.0 (15) | | 86.3 (2,057) | | |
| 1880 | | | 98.8 (130) | | |

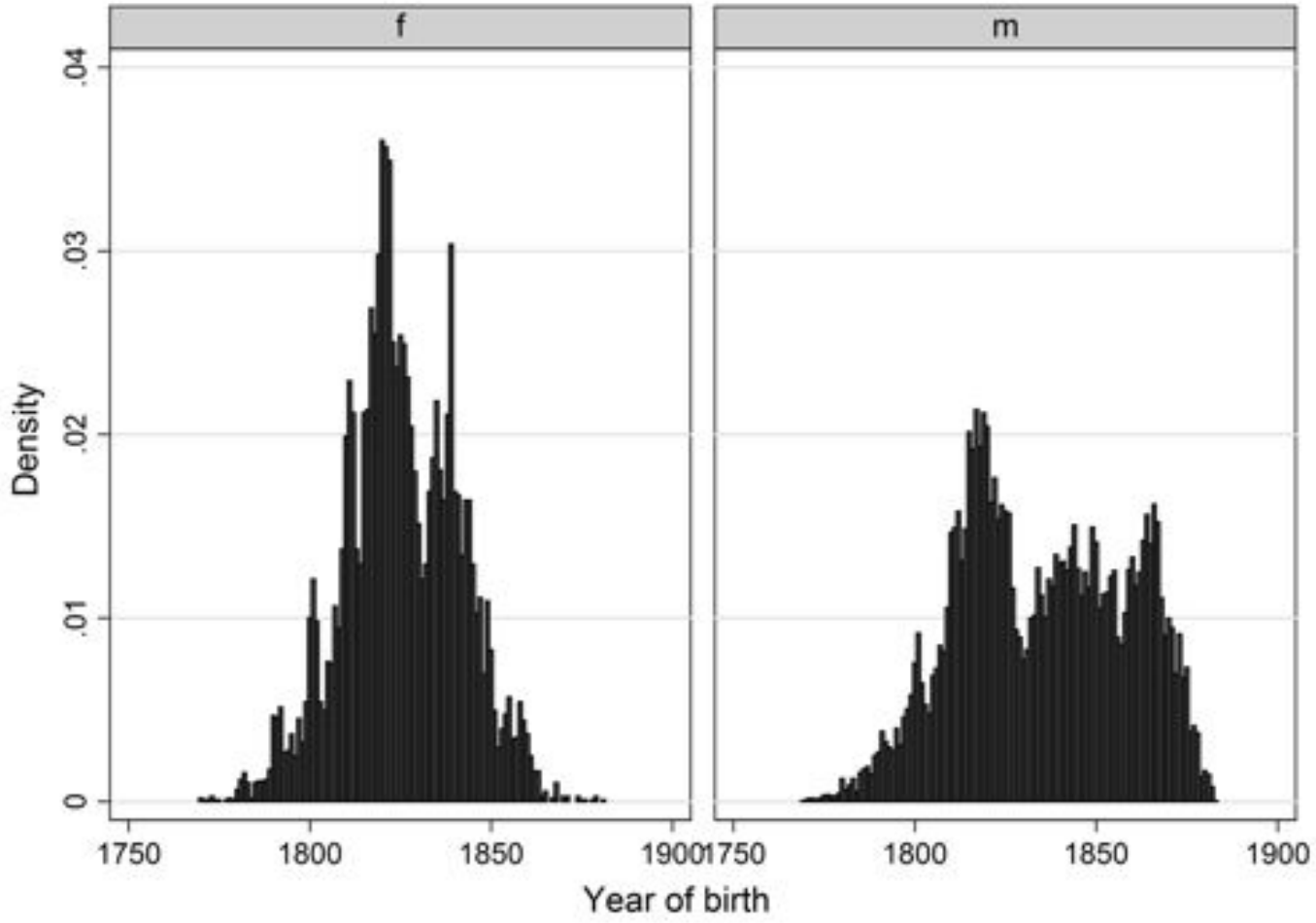
*Notes:* ABCC values can be interpreted as the share of the population that is numerate. The sample size used for calculating ABCC values of prison cohorts is in parentheses. The ABCC value of the census cohort consisting of 23-32 year-olds has been adjusted according Crayen and Baten, 'Global trends'.

Table 5. *Numeracy trends (ABCC), Clonmel prisoners and Tipperary census population, sub-sample of drunkards, by gender*

| Decade of birth | Females | | Males | | Δ |
|---|---|---|---|---|---|
| | Clonmel Gaol | Tipperary 1841 census | Clonmel Gaol | Tipperary 1841 census | |
| 1780 | | 46.5 | | 59.3 | |
| 1790 | | 58.6 | | 65.6 | |
| 1800 | 23.5 (15) | 63.2 | 93.7 (12) | 68.2 | 65.1 |
| 1810 | 48.3 (40) | 72.5 | 94.8 (138) | 77.2 | 41.9 |
| 1820 | 44.3 (83) | | 73.9 (399) | | |
| 1830 | 55.4 (172) | | 90.5 (1014) | | |
| 1840 | 65.4 (179) | | 91.1 (1610) | | |
| 1850 | 72.5 (104) | | 97.2 (1579) | | |
| 1860 | 100.0 (27) | | 97.1 (1,938) | | |
| 1870 | | | 88.8 (932) | | |
| 1880 | | | 99.0 (51) | | |

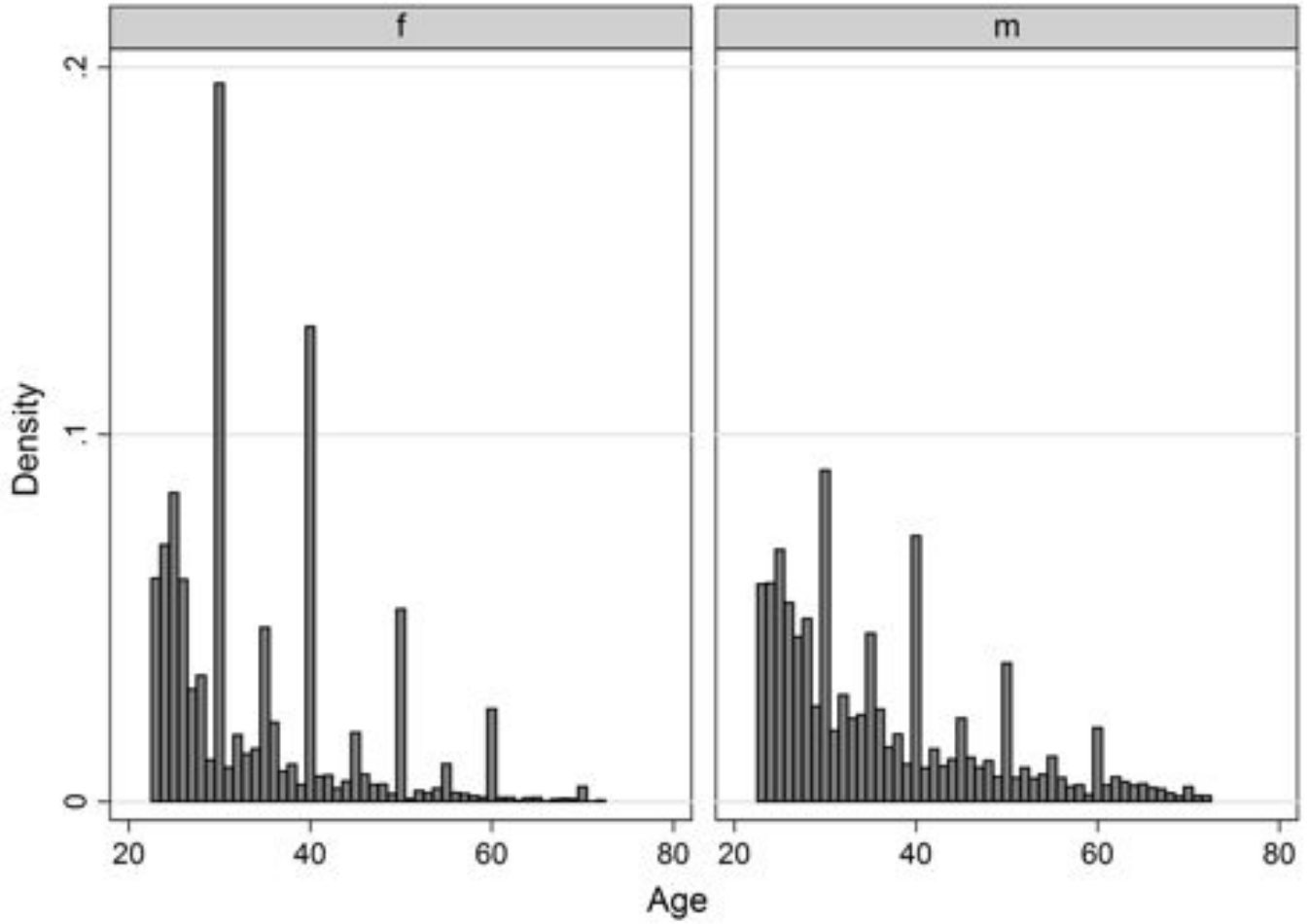
*Notes:* See table 4.

Figure 1. *Approximate year of birth of Clonmel prisoners, by gender*



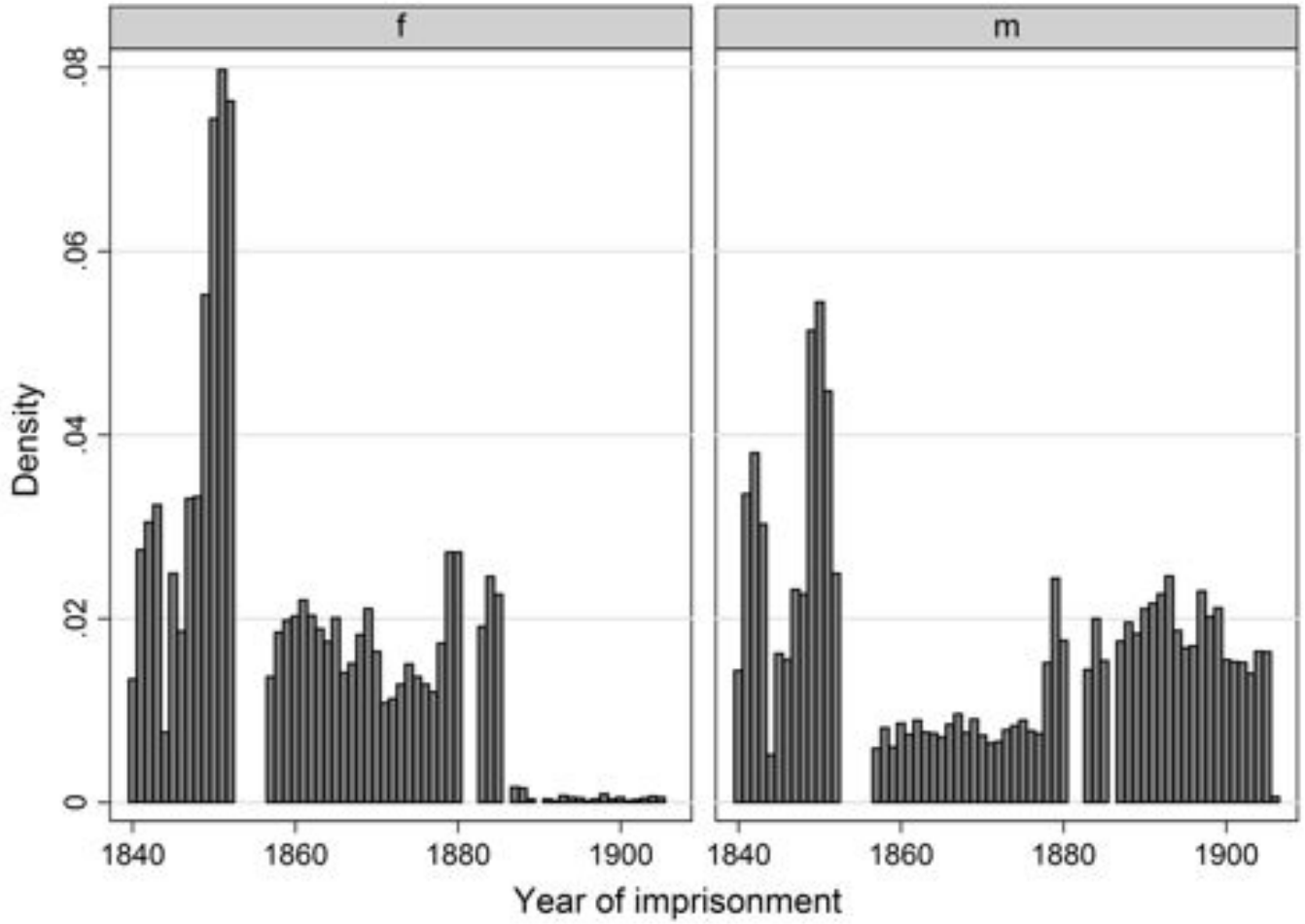

*Notes*: f = females; m = males.

Figure 2. *Age distribution of Clonmel prisoners, by gender*



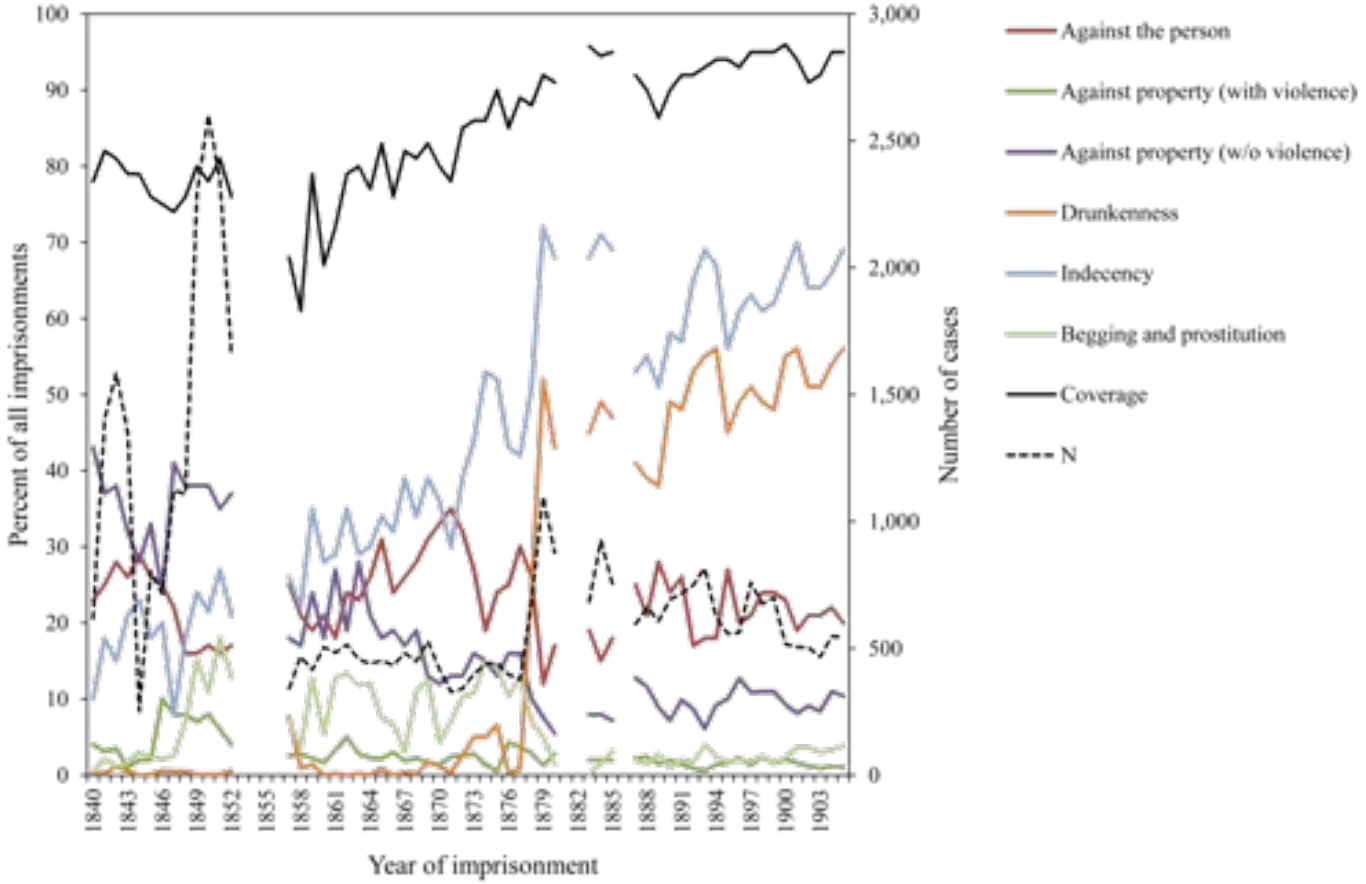

*Notes*: f = females; m = males.

Figure 3. *Year of imprisonment of Clonmel prisoners, by gender*



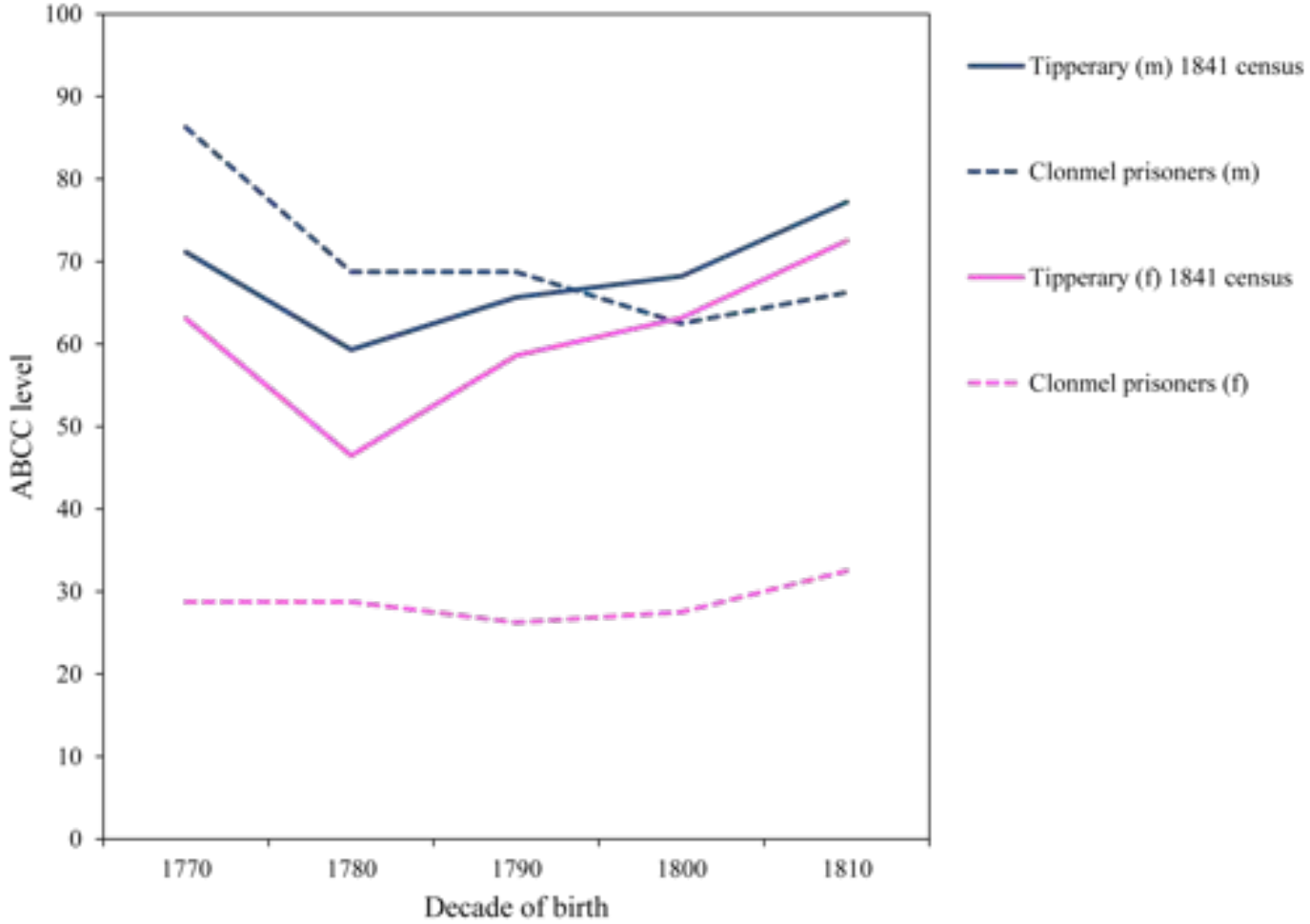

*Notes*: f = females; m = males.

Figure 4. *Offence by year of imprisonment, females and males pooled*




*Notes:* The category 'Coverage' refers to the proportion of all prisoners that are covered by our prisoner classification.

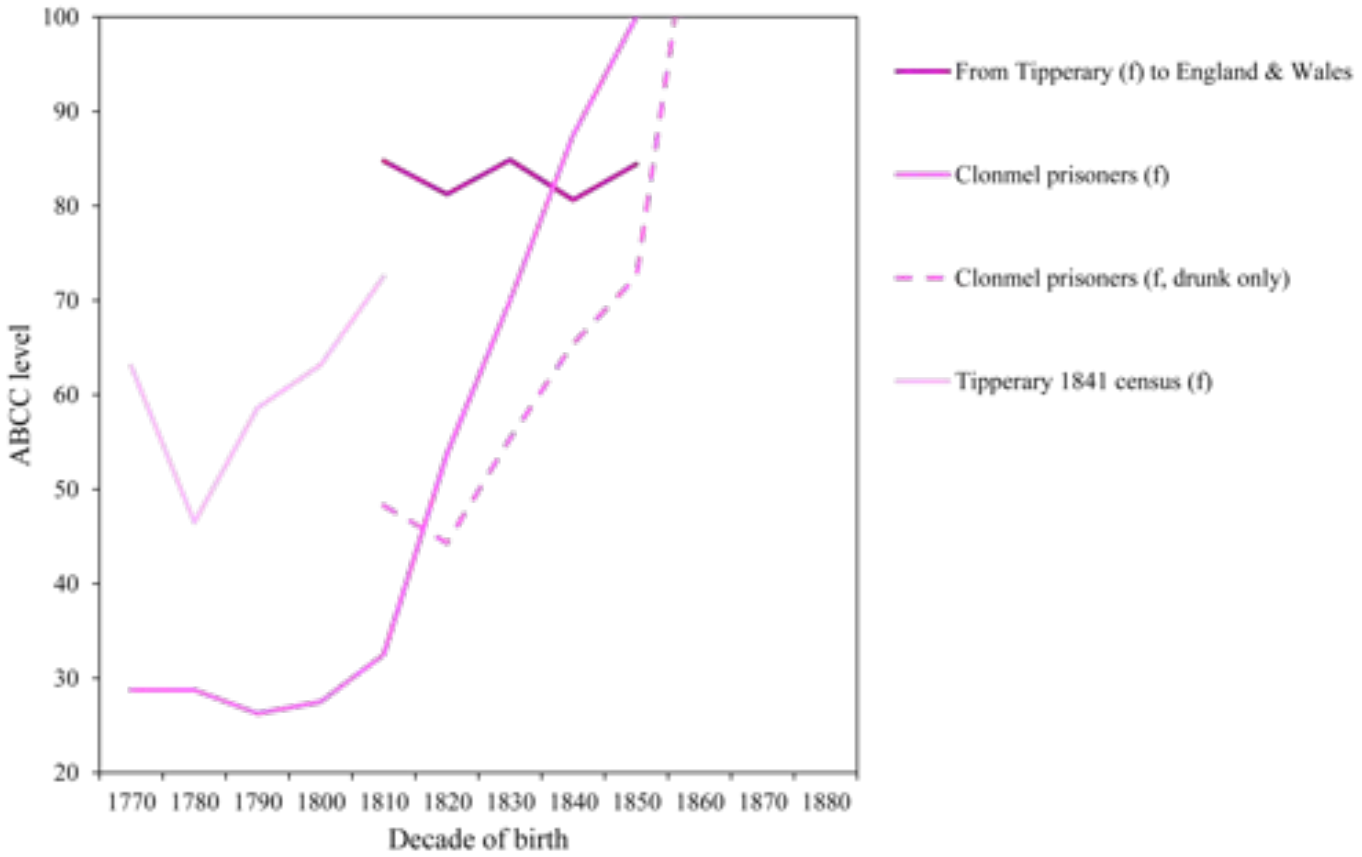
Figure 5. *Numeracy trends (ABCC), by gender, 1770s-1810s*



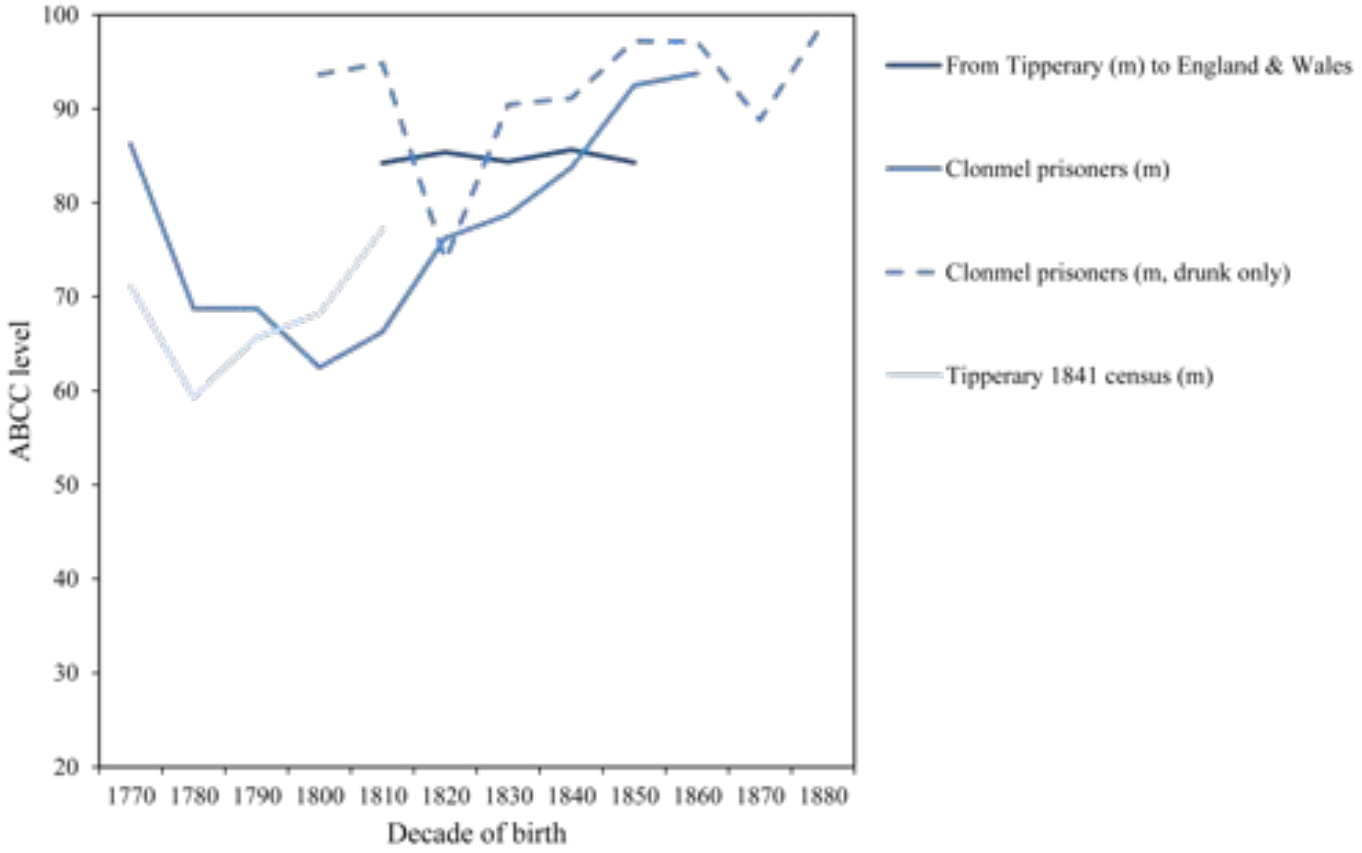

*Notes*: f = females; m = males.

Figure 6. *Numeracy trends (ABCC), emigrants and non-emigrants, 1770s-1880s*

(a) *Females*



(b) *Males*


100
90
80
70
60
50
40
30
20
ABCC level
1770 1780 1790 1800 1810 1820 1830 1840 1850 1860 1870 1880
Decade of birth
From Tipperary (m) to England & Wales
Clonmel prisoners (m)
Clonmel prisoners (m, drunk only)
Tipperary 1841 census (m)