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JEL Classification: O13, N53, Q15

Keywords: Denmark, enclosures, Land Inequality



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# Winners and Losers from Enclosure: Evidence from Danish Land Inequality 1682-1895*

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March 2020

**Abstract**

There is a vast literature on the effects of land inequality and agrarian reforms, but little on the origins of this inequality. We exploit a new and unique parish-level database of land inequality in Denmark, from 1682 to 1895, during which period there was comprehensive land reform and enclosure. We demonstrate that inequality increased after land reform in areas with more productive land, measured using contemporary tax assessments. We instrument for land quality using glacial and postglacial sediment soil types. We propose a mechanism whereby agrarian reforms allowed areas with better soil quality to realize greater productivity gains. Malthusian mechanisms and internal migration then led to greater population increases in more fertile areas, leading to a larger share of smallholders and landless laborers. We present evidence for this mechanism in part from population density revealed by censuses. After the reforms, the geographical pattern of inequality remained strikingly constant, although population and inequality continued to grow throughout the nineteenth century.

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# 1 Introduction

The role of agriculture for growth, and the role of institutional reforms in agriculture in particular, are the subject of a large literature. Within this, the role of land reform and enclosures occupies a central place. We take up the example of Denmark which from the late 1700s went through a dramatic period of agrarian reform. Common lands and serfdom were abolished, and new methods were introduced (see also Lampe and Sharp (2019a); Schmidt et al. (2018) and Jensen, Lampe, Sharp, and Skovsgaard (2018); Jensen, Radu, Severgnini, and Sharp (2018)). Such agrarian reform has often been considered to be central to the increases in agricultural productivity, often termed an 'agricultural revolution', which both preceded and made possible later industrialization. Much of the potential gains from reform would be through their facilitation of the use of new agricultural techniques. One striking example of this was the adoption of clover, which has been found to have accounted for about eight percent of the growth in the population of market towns in Denmark between 1672 and 1901. Clover meant an increase in the number of cows it was possible to support on the land, as well as in grain yields and human capital (Schmidt et al., 2018). On the other hand, reform also created losers as common land was abolished, a point emphasized by Kjærgaard (1994, p. 251), who argues that the praise heaped on the agrarian reforms have meant that "no attention has… been paid to freehold tenure and enclosure as mechanisms for economical expropriation. The damage this inflicted upon the lower rural class has not been taken into consideration." In the present work, we demonstrate that land reform in Denmark had both positive and negative effects, although our focus is on the latter.

Thus, in contrast to much other work, we attempt to explain the origins of land inequality, rather than its consequences.[1] Using unique data for Denmark which cover two centuries of land inequality[2] over a period of land reform, we demonstrate that this caused inequality to increase more in areas with better quality land. As soil quality is potentially endogenous to land management and due to omitted variable bias, we identify this using a novel instrument based on the way Danish soil was formed during the last ice age, and present evidence for a mechanism through differential rates of population increase. The most famous hypothesis for the origins of land inequality was postulated by Engerman and Sokoloff (1997) who argue that factor endowments of soil and climate as well as the presence of native populations, predisposed colonies towards paths of development associated with different degrees of inequality in terms of wealth, human capital and political power. Thus, for example, the type of soil determines which crops are grown, and areas with soil suited for crops on large scale plantations developed higher inequality, which in turn hindered economic growth. Easterly

[1] There exists a substantial literature on the consequences of land inequality. On the effect on redistributive policies, see Alesina and Rodrik (1994); Persson and Tabellini (1994, 1996). On the effect on schooling and human capital, see Deininger and Squire (1998); Erickson and Vollrath (2004); Easterly (2007); Galor et al. (2009); Kourtellos et al. (2013); Gray and Clark (2014); Cinnirella and Hornung (2016); Goñi (2016); Oto-Peralías and Romero-Ávila (2016); Ashraf et al. (2017); Baten and Hippe (2018). On the effect on agricultural efficiency, see Vollrath (2007); Martinelli (2014). For the effect on financial development, see Vollrath and Erickson (2007). Finally, for the effect on population and economic growth, see Vollrath (2012).

[2] This is, to our knowledge, the longest available panel on land inequality (see Schubring, 1939).

(2007) provides confirming evidence, although Nunn (2014) discusses how work examining this hypothesis has found rather opposing results (see Dell, 2010; Acemoglu et al., 2008; Nunn, 2008). In contrast to Engerman and Sokoloff, we explain land inequality based on soil quality within an otherwise relatively small and homogeneous country, the Kingdom of Denmark. We propose that agrarian reform is behind the increases in land inequality we observe in areas with better quality soil, as these exploited new opportunities for realizing productivity gains, and population responded through increased fertility (the Malthusian preventive check). Thus, although reform meant that agriculture was largely freed from the constraints of communal agriculture based around the village commons, it also led to increased numbers of people with little or no land.

The introduction of improved private property rights to land was central to the process of agrarian reform, and is the subject of a large literature in development economics more generally (Acemoglu and Robinson, 2012). In many countries, including Denmark before reform, village communities would collectively use grazing land, known as commons, but these were gradually replaced by private property rights between the sixteenth and twentieth centuries (Allen, 1992; Brakensiek, 1991, 1994; Neeson, 1993; Overton, 1996a,b; Whittle, 1998, 2000; Campbell, 2005; Kopsidis, 2006; Olsson and Svensson, 2010). Hardin (1968) suggested that the main benefit of the shift to private property rights was through avoiding the tragedy of the commons, although others have suggested that common land existed to avoid overuse (Neeson, 1993), and besides, in the English case common rights were often traded by the largest farmers in the village (Shaw-Taylor, 2001a,b). Recent research on Spain has demonstrated that common lands there were relatively well managed, and that their dismantling in the nineteenth century did not increase productivity but rather made many rural households worse off, as well as destroying social capital (Beltrán Tapia, 2010). Others have suggested that the main benefit of the expansion of the private ownership of land was to reduce the transaction costs involved in introducing more advanced agricultural techniques (Slicher van Bath, 1963, 1977; Overton, 1996a,b). In terms of arable farming, the main innovation was 'enclosure'. In traditional open-field agriculture villagers cultivated land distributed in scattered strips around the village, but the village as a whole determined how the land was to be managed. The consolidation of these landholdings through enclosure served to reduce the time it took moving from one strip to another, reduced the transaction costs of introducing new agricultural techniques, and increased incentives to invest in the land (Overton, 1996a,b; Brakensiek, 1991, 1994). The extent to which changes in property rights affected growth have however been hotly debated, although a consensus seems to have emerged that they did play some role (McCloskey, 1972; Allen, 1992; Brakensiek, 1991, 1994; Overton, 1996a,b; Kopsidis, 2006; Fertig, 2007). Nevertheless, this certainly took some time, and required in addition at least three other factors: improvements in contracting institutions in the labor market, the credit market, and the output market. Regarding the labor market, many barriers existed, such as serfdom, barriers to migration, wage ceilings favoring employers, and limits on women's work (DeVries, 1976; Harnisch, 1989a,b; Klein, 2013; Ogilvie, 2004a,b, 1996, 2013). Regarding credit markets, modernizing agriculture, through for example enclosure, required capital (Habakkuk, 1994; Holderness, 1976; Lambrecht, 2009;

Thoen and Soens, 2009; Cruyningen, 2009; Ogilvie et al., 2012). Finally, regarding output markets, farmers needed good contracting institutions in output markets so that they could sell their production and gain capital they could use for example to introduce new techniques (Britnell, 1996; Grantham and Sarget, 1997; Bolton, 2012).

Land reforms differed greatly between different countries and regions. In the English case, most land was merged with the estate demesnes into large farms owned by landlords and often managed by capitalist tenants who employed landless labor. Former tenants thus became either agricultural laborers or were forced to leave the countryside, see Allen (1992). In Prussia, peasants were converted into independent farmers, but they received only half of the land and had to pay considerable compensation to the landlords for their loss of boon work and related duties (Federico, 2005; Kopsidis, 2006; Fertig, 2007). In the Russian case, peasants received the largest parts of their holdings after emancipation in 1861 but had to cultivate holdings as a commune (mir), until the 1906 Stolypin reforms, which were modeled on the Danish precedent (Federico, 2005; Chernina et al., 2014; Dower and Markevich, 2019; Korchmina and Sharp, 2019). Finally, in Ireland, the Landlord and Tenant Act of 1870 reduced landlords to rent receivers, where the rents were capped, and with the Irish Land Law Act of 1881 the government facilitated the purchase of full property rights by offering advances raised through publicly traded land bonds (Foley-Fisher and McLaughlin, 2016; Federico, 2005, p. 151). The abolition of institutions like the commons and serfdom and the transition to modern agriculture, along with the conversion of dependent peasants into free farmers, is at the heart of the 'market turn' that accompanied the rise of capitalism (cf. Bryer, 2000) and the integration of markets beyond the local level, increasing the viability of urban agglomerations (Wrigley, 1967). The poster case is the dissolution of feudalism in England in the Middle Ages and the accompanying and subsequent process of enclosures, dissolution of common lands and the creation of modern, market-based tenancy agreements and land markets. Thus, from at least the birth of economics as a discipline, extensive discussions have taken place on the economic efficiency and social consequences of these transformations (see Allen, 1992; Polanyi, 1944). Indeed, in many countries – also in England – this process led to an astonishing concentration of land in the hands of a few landowners (who managed to use the political process in their favor), who are then blamed for using extensive, inefficient, but profit-yielding cultivation, monopsonistic behavior on labor markets and the creation of institutional arrangements that prevented markets or governments from changing the existing property distribution. Therefore, it is no surprise that the question of land reform is not just central to the economic history literature on the birth of capitalism, but was also present at the birth of development economics as a field and has accompanied it ever since (cf. Jones, 2018; Albertus, 2015; Binswanger-Mkhize et al., 2009).

The present work also links to the literature on geography and economic outcomes (see for example Fernihough and O'Rourke, 2014) as well as the impact of inequality on various measures. Thus, for example, Vollrath (2007) finds a negative relationship between land inequality (measured by the Gini coefficient of farm sizes) and productivity (output per hectare) across countries, although other studies (Bhalla, 1988; Bhalla and Roy, 1988) demonstrate that this disappears when controlling for soil quality. Galor et al. (2009) find a negative relation between land inequality and investment in public schooling, although Vollrath (2013) finds that in the case of the United States this is only present in the north and not the south.

Despite the potential for using our unique data to investigate the impact of land inequality, we choose for now to focus on the determinants of land inequality, and the role of agrarian reforms for this, although we will return to the debate on effects in the conclusion. Thus, the remainder of this paper proceeds as follows. The next section discusses the historical background to the Danish case. Section 3 presents our data, Section 4 explains our empirical methodology, and Section 5 gives our results. Section 6 concludes.

## 2 Historical Background

To understand the distribution of soil qualities around Denmark, it is necessary to go back to the last ice age. Denmark was only partly covered in ice during the Weichselian glaciation approximately 18,000 years ago. As the ice retreated, the land in the ice-free parts of the country was eroded, leaving behind dry and sandy soil. The parts covered by ice, on the other hand, were left with markedly different soil with greater shares of clay and are much more suited to arable production. This phenomenon was first described by the Danish geologist Niels Viggo Ussing (Ussing, 1903, 1907) and provides us with the exogenous variation in the quality of soil within the country we exploit below.

As for the distribution of land, as with much else in economic history, our story starts with the Black Death.[3] As a consequence of a fall in population after 1340 and unfortunate changes in the taxation of free peasants around the same time, ca. 60,000 subordinate farms emerged in the fourteenth and fifteenth centuries, and the free peasantry basically disappeared (Arup, 1933; Porskrog Rasmussen, 2003, p. 8). These farms remained more or less constant until the beginning of our period. By this point, the land use studies by Frandsen (1977, 1983) have found that in 1662, admittedly a time of crisis, only twenty to thirty percent of the land classified as arable in 1688 was cultivated. The remainder was used extensively, with the outfields in particular being used only for animal husbandry, with the unfortunate result that an important share of dung which might otherwise have been used as fertilizer was unlikely to be recovered and applied to the cultivated fields (cf. Skrubbeltrang, 1978, pp. 276-7).

Although our focus here is on access to the land rather than formal property rights, as we discuss more below, it is nevertheless important to emphasize that before the land reforms, about 98-99 percent of land was owned by estate owners, among them the crown, the church, schools and universities, as well as private owners from the nobility and (from

[3] This part draws on the material used for chapter 3 in Lampe and Sharp (2019b).

1660) the bourgeoisie. Just 1-2 percent of the land was in the hands of freeholders. Estate owners directly controlled their main farms (the demesnes) which made up 8.5 percent of all land,[4] and they rented out the land belonging to middle-sized farms and smallholders, for whom property rights were divided, as in much of rural Europe, between tenants and the estate. This, however, changed dramatically during the period of reform from the late eighteenth century, and by 1834 50 percent of the land was held by farmers and smallholders in freehold property (*selveje*) or inheritable tenancy (*arvefæste*), while still almost 10 percent belonged to the traditional estate in the form of demesnes, and 40 percent was rented out as 'tenancy for life' (*fæste*). During these reforms, arable land began to be used in more intensive crop rotations and some of the former pastureland and woods were reconverted into arable land, involving substantial investments in work and money by peasants, to make way for more intensive techniques and more and more efficiently used livestock (Dombernowsky (1988), Kjærgaard (1994, pp. 25-27 and ch. 3), Skrubbeltrang (1978, pp. 98-100, 242-4, 406-7), Lampe and Sharp (2019b)).

Between 1600 and 1670 the population of Denmark fluctuated around 500-600,000 inhabitants (Johansen (2002, pp. 13,22-23,44), Kjærgaard (1994, p. 12), and Lassen (1965, pp. 11,530)). From then, it grew steadily to between 625,000 and 700,000 by 1710, but was decimated again due to wars and epidemics in the following decade (Johansen (2002, pp. 44,61-63) and Dombernowsky (1988, p. 275)). This, and the resulting tenantless farms, are said to have motivated the re-introduction of serfdom/adscription for men in Denmark in 1733, which under the motivation of guaranteed military recruitment through manorial conscription rolls allowed large landowners to force dependent young men to take over vacant farms in exchange for military service waivers (Skrubbeltrang (1978, p. 188), Olsen (1957, pp. 310-1,344-50), Løgstrup (1984, pp. 305-9) and Jensen, Radu, Severgnini, and Sharp (2018)). Population growth resumed from the 1720s and was 635,000 by the time of the census of 1769. After growing at a pace of 0.3 to 0.4 percent between 1650 and 1780, population started to grow at much higher (and steady) rates above 1 percent per year from the 1780s throughout the nineteenth century, so that Denmark had 2 million inhabitants by 1880 and 2.75 million in 1911 (Johansen (2002, pp. 125,173), Skrubbeltrang (1978, pp. 391-93), Kjærgaard (1994, p. 13), and Lassen (1965)). We attribute the break in the pattern of population and the transition to higher growth rates to the land reforms and enclosures that took place between 1784 and the first decade of the nineteenth century, although as we will show, this growth differed markedly across the country. It should be noted in this context that Kjærgaard (1994) has disputed the role of the agrarian reforms for the population increase, seeing them almost exclusively as the end result of a long-running political struggle by which power was increasingly centralized under the monarch. He argues that the population growth owes more to the aforementioned introduction of clover and other innovations, although his work remains controversial (see the debate in *Fortid og Nutid*, 1992, pp. 16-57) and widespread use of clover seems to date to after 1775 in his own maps (cf. Schmidt et al., 2018, p. 389, FN7).

[4] Own calculation, in terms of *hartkorn* (see below)

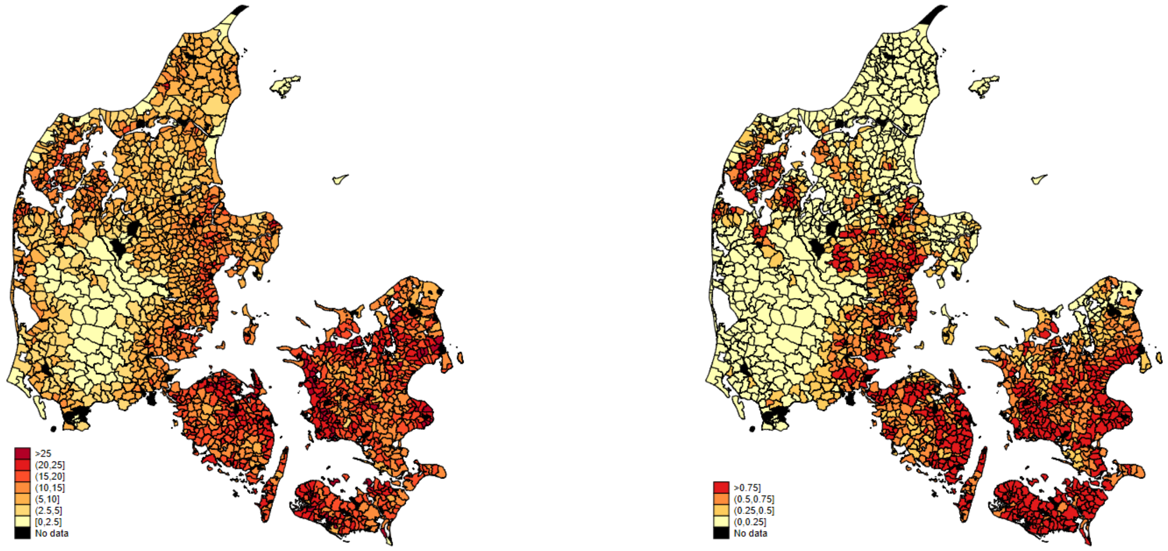
The history of the reforms is rather convoluted and in practice took many decades to complete, with a defining moment being the arrival of a new class of 'enlightened landowners' and the introduction of the Holstein System of agriculture to Denmark from the late 1760s to the end of the eighteenth century: for a detailed survey see Kjærgaard (1994) and Lampe and Sharp (2019b). The central piece of enlightened absolutist reform, at least as far as our story is concerned, was formed by the agrarian reforms that were gradually enacted between 1784 and 1807, with some of the measures breathing new life into earlier decrees and ordinances. Apart from the end of adscription in 1788, which freed the movement of the male rural population, abolished the possibility of forced tenancies and transferred conscription/reserve rolls to local government officials, who had no personal interest in binding workers to the countryside and forcing them to accept tenancies, most of the measures aimed at dismantling the communal cultivating system with its open fields and grazing rights shared between farmers and cotters of one or several villages (see Skrubbeltrang (1978, pp. 135-40, 276-77) for an overview of the old system). Dismantling this system consisted of several interrelated measures: a) consolidating shared grazing rights between villages, b) enclosing the lands of each of the individual tenant farms, c) releasing these farms of rights, especially regarding grazing, that other farmers and smallholding and non-landholding peasants (cotters) might enjoy under village bylaws, d) reorganizing the distribution of farmsteads according to the newly enclosed village, e) updating the old tenancy remuneration system consisting of a flexible entry fee, a nominally constant in-kind rent (*landgilde*) and nominally limitless labor services (*hoveri*) to a more liberal, capitalistically oriented system and/or convert tenants (leaseholders) into freeholders, i.e. privatization of tenant farms.

Of course, in each of these steps, rights instead of being granted (preferentially) to the tenant peasants could also be assigned to the formal owner of the soil (the estate owner) or to a larger part of the peasant population (including cotters and landless laborers and servants). In this sense, the Danish version of land reform, that converted the ca. 60,000 subordinate farms that had existed since the Middle Ages into a virtually identical number of tenant farms (of which a large share subsequently became freehold or at least inheritable tenant farms), was different from the path followed in Britain, where most land was merged with the estate demesnes into large farms operated by capitalist tenants employing landless labor (and shepherds) or a totally egalitarian solution, by which the equally large group of non-tenants (cotters and servants) would have received an equal share and not just small plots of land in compensation for their former communal rights. The Danish land reforms basically cemented the existing property structure at the expense of the rights (but not the main farm lands) of estate owners and the social and economic position of smallholders and landless agricultural laborers. The main beneficiaries were the tenant-owners of the 60,000 medium sized family farms. Contrary to prior centuries, they managed to establish themselves as a stable rural middle class, both thanks to secure and inheritable property rights and because the rural lower classes were rapidly growing as population increased, mortality decreased and access to tenant farms – whose desertedness only fifty years before was a reason behind the introduction of adscription – became more and more difficult. By 1810, more than 40,000 of the ca. 60,000 former tenant farms had been converted to 'full' freehold property (Dombernowsky, 1988, p. 359), while in the land survey of the 1680s (on which more in the following section) this had been a real exception, accounting for maybe one or two percent of the land corresponding to maybe 2,000 or 2,500 farms (Munck, 1977, pp. 39-42).

The end result was however that the reforms had by the early nineteenth century established modern property rights, allowed for individual cultivation (e.g. of clover) and the use of more capital-intensive technologies (e.g. animal husbandry, which allowed for higher yields by providing additional fertilizer in a world of organic farming). This made it possible to overcome prior institutional (common cultivation of open fields, insecure tenancy leading to underinvestment) and technological constraints on land use, and hence enabled higher agricultural yields and, in consequence, population growth. While the land-labor ratio deteriorated with the growth of population and labor force especially from the 1780s, the size distribution of farms remained rather constant over the land reforms and a rural proletariat of smallholders (cotters, see Møller (2016)), landless workers and servants grew alongside the more and more established class of tenants and, increasingly, owners of middle sized farms, who could rely on the rural lower classes for more intensive agricultural production (cf. Kjærgaard, 1994, ch. 6). By this, not only a link between better soils and higher agricultural productivity growth was established, but also one between land quality and farm size inequality – a classical efficiency-equity trade-off.

# 3 Data

We make use of the Danish land registers which give extremely detailed information on the number and sizes of farms per parish. A little historical background is warranted here to help understand the data we use to calculate our parish-level inequality measure. In the wake of defeat by Sweden and the loss of the eastern provinces of the kingdom (Scania), absolute monarchy was introduced to Denmark in 1660. This was followed by the creation of a nationally uniform tax system that abolished several individual and regionally idiosyncratic taxes and introduced as a main source of revenue a tax on the productive capacity of agricultural land, which was adopted, together with sales of crown estates, in order to consolidate government finances, although taxes had to be raised with the help of private estate owners (cf. Horstbøll and Østergård, 1990, p. 160). The basic idea of the new tax, based on a Swedish model and initially adopted in 1662, was to establish a land register, assess the productive capacity of the land in a unified system and tax each unit equally. A first register was established in 1662 with modifications in 1664. From this point, the *tønde hartkorn* (literally: barrel of hard grain), a measure of relative productive capacity, not of actual production, became the basis upon which for example tithes were levied (Skrubbeltrang, 1978, pp. 104-6). The 1664 classification, however, had been adopted rather ad hoc based on reports of crown and private estates on their annual receipts. To improve on this, from 1681 a true land survey was undertaken in all parts of the kingdom. The territory was




(a) Total hartkorn

(b) Boulder clay

Figure 1: Map of total *tønder hartkorn* by parish area (1682) and share of parish area classified as boulder clay.

divided into seven districts with three men responsible for each district, who relied in turn on assistance by the county governors, estate owners, priests, county and military regiment clerks and the district and manorial judges as well as common peasants. Local foresters surveyed the woods. The categorization of land into categories was done publicly, and all types of productive assets (including for example mills) were reduced to *tønder hartkorn* equivalents, and the results were laid down for each farm in each village in detailed books (see Skrubbeltrang, 1978, pp. 107-112). A new survey of productive capacity/*tønder hartkorn* was taken in 1844 and conversion tables are provided in the published statistics.

The land distribution statistics report the number of farms in different size/*tønder hartkorn* categories and the corresponding total number of *tønder hartkorn*.[5] We thus know the number of farms in each parish as well as their distribution in terms of productive capacity. We digitize this data for the years 1682, 1834, 1850, 1860, 1873, 1885 and 1895. The data for the year 1682 is digitized from Pedersen (1928)[6] and for the year 1834 from *Commissionen for det statistiske Tabelværk i Danmark (1837)*. The remaining years are digitized from *Statistiske Bureau (1852, 1864, 1877, 1888, 1896)*. This gives a panel of farm value distribution in Denmark over a very long time period, covering the extensive land reforms in the late 1700s and early 1800s. Figure 1 shows the distribution of total *hartkorn* by area for the year 1682 in the left panel.

We combine this data with population figures on the parish level from the Danish censuses for the years 1769, 1787, 1801, 1834, 1850, 1860, 1870, 1880 and 1890 (Danish National Archives, 1787, 1801, 1834, 1850; Statistiske Bureau, 1911). We thus do not have population

[5] See table A2 in the appendix for the classification schemes in the different years.

[6] Note that the title of the publication states 1688, but the data was collected in 1682. We therefore refer to this data as 1682.

in 1682, the year of our earliest land distribution measure, as the first census was conducted in 1769. However, 1769 is still early enough for us to be able to investigate population before and after the land reforms.

In order to measure the topographical characteristics of the land we use information on soil types from the *Surface Geology Map of Denmark* (Pedersen et al., 2019) which gives a classification of glacial and postglacial sediment types. This means that soil is classified at one metre depth, i.e. below the impact area of the plough and other forms of cultivation. The *Surface Geology Map of Denmark* is based on a digitized version of the 1989 Danish Geological Survey, supplemented with categorization of drilling samples from the GEUS (Jupiter) database and other information in missing areas. It is extremely detailed, such that we have a lot of variation in the soil types even at the parish level. 11 different quarternary sediment types are identified – we use the category 'boulder clay'[7] and calculate the share of the parish classified into this category, as this type of soil seems to have been especially suited for growing barley (Frandsen, 1988). Figure 1 shows the distribution of boulder clay (as a share of parish area) in the right panel.

In addition, we calculate several geographical variables on the parish level. These include parish area, distance to Copenhagen, distance to the coast as well as the longitude and the latitude of the parish centroid. Here, we use a shapefile of historical parish borders available from the Digital atlas over Denmark's historical administrative geography (*Digitalt atlas over Danmarks historisk-administrative geografi*, downloadable at: digdag.dk).

Our data on land inequality in Denmark cover a period of more than 200 years. Naturally, changes in the administrative units occurred, where only changes in parish borders are relevant for us as all our data is on the parish level. We therefore use the parish borders of 1682 and aggregate parishes in subsequent years to the original unit whenever parishes were split or aggregate parishes in the earlier years if they were consolidated later on. We drop the island of Bornholm, as it is not included in the reports in all years. We also drop the area of Southern Jutland which was taken by Prussia during the Second Schleswig war of 1864, as this area is not reported consistently over the whole period for obvious reasons. Additionally, market towns usually consisted of (at least) one parish for the town and one parish for the countryside. Our analysis only includes the countryside where the measure of *tønder hartkorn* is applied to the land belonging to farms. Sometimes, however, market town and countryside parishes are reported together in some years and not in others. In these cases, we drop the countryside parish of the market town in all years. In the end, we have data on 1,605 consistently reported parishes with stable borders across all years.

A brief explanation is needed to understand the nature of the measure of land inequality we use here. It is necessary to differentiate between ownership and 'operational unit inequality', since many of the units we consider were not owners, but were for example tenant

[7] In the map this category is called 'Till, clayey and fine-sandy' soil, we refer to it as 'boulder clay' translated from the Danish classification 'moræneler'.

farmers. Thus, what we are looking at is not really ownership or wealth inequality, but more like income inequality because we are not looking at who actually owns the land, but rather who had access to its productive potential: operational land inequality. Nevertheless, we will refer to this as land inequality below.

# 4 Methodology

We measure land inequality with the Theil index, as this inequality measure exhibits several analytically desirable properties. First, it satisfies the strong principle of transfers, meaning that a redistribution from one individual to a poorer one will lead to a decline in the Theil index proportional to the absolute distances between the individuals' incomes. This is especially important in our context, as our main results concerns the changes in the Theil index. Second, the Theil index ranks distributions unambiguously. Thus, two places with identical Theil indices will also have identical income distributions.[8] This is not the case with the much more popular Gini index, for example, where crossing Lorenz curves leading to identical Gini indices are a possibility.[9] See also Cowell (2011).

The Theil index $T_p$ is calculated as follows:

$$T_p = \frac{1}{N_p} \times \sum_{i=1}^{N_p} \left[ N_{ip} \times \frac{x_{ip}}{\mu_p} \times ln\left(\frac{x_{ip}}{\mu_p}\right)\right] \tag{1}$$

for parish $p$ and size category of farms $i$. $N_p$ is the total number of farms in parish $p$ , $N_{ip}$ is the number of farms in size category $i$ in parish $p$, $x_{ip}$ is the average number of *tønder hartkorn* in size category $i$ (i.e. total *hartkorn* in category $i$ divided by number of farms in category $i$), and $\mu_p$ is the total average *tønder hartkorn* in parish $p$ (i.e. total parish *hartkorn* divided by total number of farms). If all farms are of equal size, i.e. everyone owns the same amount, the Theil index is equal to zero. Maximum inequality, i.e. if all the land belongs to one farm and other houses in the parish have zero land, is given by $\ln(N_p)$. Figure 2 shows the Theil index and the Gini coefficient for the whole of Denmark for the years 1682-1895. We see a pronounced increase in inequality over the whole period, with the largest increase over the period 1682 to 1850. In 1682, the Gini coefficient is 0.32, which roughly corresponds to (income) inequality levels in Germany or France and is only slightly higher than Denmark today. By 1850, however, the Gini coefficient increased to 0.67,[10] which is higher than South

[8]The Theil index also has the advantage of being decomposable into different elements contributing to total inequality. In our case, however, we have no variation in *hartkorn* within the size categories of farms, making it impossible to decompose along this line. Also, we are investigating the change in inequality over time rather than the cross-section and its determinants.

[9]The Gini index is mainly popular for its intuitive interpretation in relation to the Lorenz curve. We find the Theil index preferable due to the mentioned reasons but also present results using the Gini index.

[10]See also Soltow (1979) and Meyer (1997) for other historical estimates of inequality in Denmark. Soltow finds extremely large estimates of wealth inequality in Denmark in 1789, with a Gini coefficient of 0.93. He uses tax returns which consider many sources of wealth, but the reason for his finding seems to be his allocation of land to the few hundred landowners, at a time when most land was effectively held by tenants.

Africa today - currently the country with the highest measured Gini coefficient at 0.63.[11]

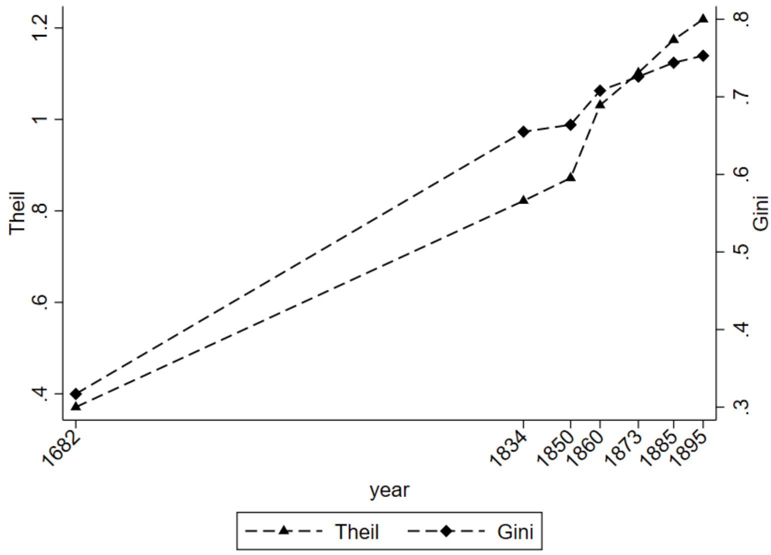
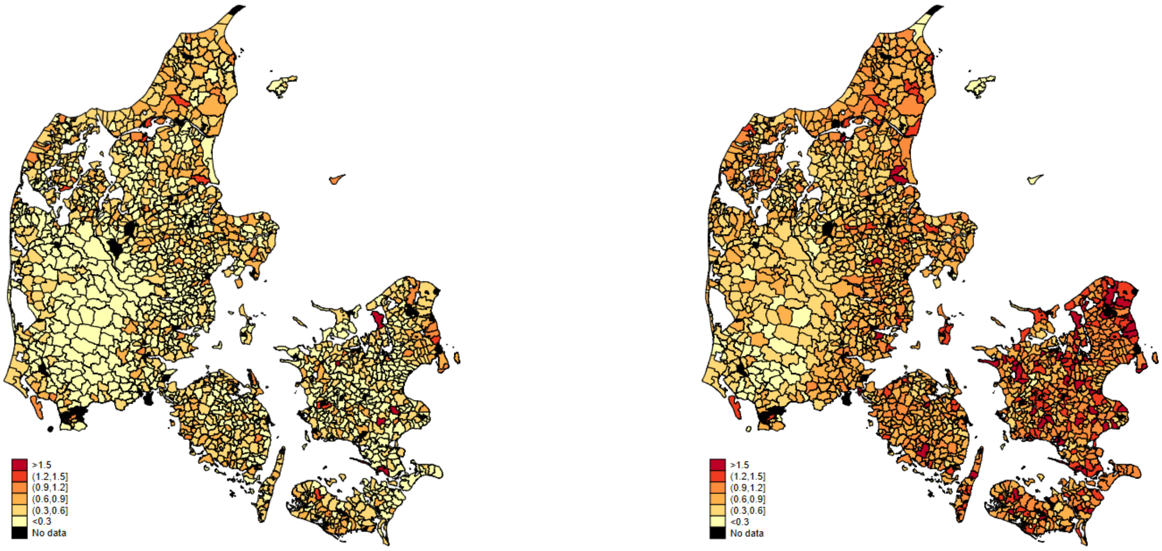



Figure 2: Theil index and Gini coefficient for Denmark, 1682 to 1895.

Figure 3 shows the distribution of land inequality, measured by the Theil index, in Denmark for the years 1682 and 1834, i.e. before and after the land reforms. A clear pattern of increasing inequality emerges, especially pronounced on Zealand and possibly also Funen. We therefore also include regional fixed effects in all regressions. Maps for the later years can be found in figure A1 in the appendix. We also note a striking resemblance of the pattern in 1834 with the distribution of *hartkorn* shown in figure 1a.

His approach thus differs fundamentally to ours. Meyer focuses on Copenhagen only at the turn of the nineteenth century, finding some equalization in the income distribution between 1789 and 1814.

[11]Reference Gini coefficients are taken from: World Bank, Development Indicators, Table 1.3. Downloadable at: wdi.worldbank.org/table/1.3. See also Deininger and Squire (1996, 1998) and Frankema (2010).




(a) 1682

(b) 1834

Figure 3: Theil index of land inequality in Denmark, 1682 and 1834.

We then estimate the following model:

First-stage estimation:

$$\ln(TotalHK)_p = \alpha + \beta \times BoulderClay_p + \lambda_r + X_p'\gamma + \epsilon_p \tag{2}$$

Second-stage estimation:

$$\Delta Theil_p = \alpha + \beta \times \ln(TotalHK)_p + \lambda_r + X_p'\gamma + \epsilon_p \tag{3}$$

where $\ln(TotalHK)_p$ is the natural logarithm of the total value of the land (measured in *tønder hartkorn*) of parish $p$, $BoulderClay_p$ is the share of parish area classified as boulder clay, $\lambda_r$ represent regional fixed effects (defined as: Greater Copenhagen, Zealand, Funen, and Jutland) and $X_p'\gamma$ other geographical characteristics of parish $p$, including the natural logarithm of the parish area, the distance to Copenhagen, distance to the coast and the latitude and longitude of the parish. $\Delta Theil_p$ is the change in the Theil index for parish $p$ from 1682 to 1834.[12]

Sometimes, the land belonging to one farm spans over more than one parish, say parishes A and B. In these cases, the reports allocate the share of the farm's *tønder hartkorn* belonging to the land in parish B to parish B. The farm itself, however, will only be included in parish A, where the actual building is placed. This is problematic, as parish B will then report 'too much' *hartkorn* for its number of farms. Since we do not know the identity and parish

[12] We use absolute differences here because equal increases in the Theil reflect equal increases in inequality.

affiliation of the farm in question, we add one farm to parish B in this case. If the amount of *tønder hartkorn* allocated to this one additional farm in parish B exceeds the upper boundary of the size category it is placed in, however, such that the average *tønder hartkorn* still exceeds its limits after adding one farm, we allocate the (closest integer) number of farms needed to reach the average of the category. For example, if in parish B there are 3 farms in the category *farms 12-8 tønder hartkorn* with a total of 42 *tønder hartkorn*, the average amount of *tønder hartkorn* for each farm is 14, which is above the upper limit of the size category, i.e. above 12. In this case, we add one extra farm, such that the average amount of *tønder hartkorn* is 10.5 and thereby within the size limits. If the total *tønder hartkorn* was 57, however, adding one farm would still leave the average per farm at 14.25 which is above the size limit. In this case, we would then add 2 farms, such that the average per farm is 11.4 and thus within the size limits of the category. Moreover, in 1850 four parishes have a positive value of *hartkorn* for landless houses but no number of houses. In lack of a reference point for 1850, we replace the number of landless houses with one, which is in line with the average value of *hartkorn* of landless houses in these parishes in other years. We calculate the Theil index both for the distribution with and without these corrections. The correlation between the corrected and the uncorrected Theil index is 0.98-0.99 for the years 1682-1885 and 0.95 in 1895.

For the main results we use the maximum amount of information available in every year, i.e. we use the categories as they are given in each year. To check whether differences in the Theil index across years are only due to differences in the size categories, however, we aggregate categories in 1834 to the same (broader) categories of 1682 and in 1860 and 1873 to the categories of 1885/95. For the year 1834, the correlation between the Theil index using the aggregated categories and the original categories is 0.98 and table 1 (column 4) shows that our results do not depend on the definition of categories. For 1860 and 1873 the correlation is 0.99.

We include landless houses into the calculation of the Theil index. Although they in general do not have a *hartkorn* value (with the exception of 9 parishes in 1850 which assign a small value), they are counted in the total number of farms. Excluding them, and thus calculating inequality between farms and houses with land only, would generally result in a lower value of the Theil index. Summary statistics for the variables used can be found in table A1 in the appendix.

## 5 Results

Estimation results of equations 2 and 3 can be found in table 1. The instrument is very strong in the first stage, which is not very surprising as both boulder clay and total *hartkorn* represent a measure of soil quality (where boulder clay is exogenously determined by the extent of the glacial cover and the total *hartkorn* was subjectively determined by an individual assessment of the value and productivity of the land). Thus, higher shares of boulder clay imply higher quality of land in terms of total *hartkorn* assessment. Column (3) shows the second stage estimation for the change in the Theil index from 1682 to 1834. There is a strong positive relation between soil quality and inequality. A one standard deviation increase in total *hartkorn* above the mean leads to an increase of 0.3 standard deviations in the change in the Theil, or a 25 percent increase above the mean change in inequality. Alternatively, moving from the 5th to 95th percentile in soil quality implies a 3.5 standard deviations increase in the change in Theil, representing an increase of almost three times the mean change in inequality. Column (4) repeats the second stage estimation using the same size categories as in 1682 in the calculation of the Theil index in 1834. This is to show that the increase in the Theil index is not due to different size classifications of farms. Finally, column (5) uses the Gini coefficient instead of the Theil index, and similar results are apparent.[13] We are therefore confident that our results do not rest on the chosen inequality metric, such that areas with higher soil quality saw greater increases in inequality throughout the period of reforms.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | OLS | 1st stage | 2nd stage | 2nd stage | 2nd stage |
| | $\Delta Theil$ | $ln(TotalFarmHK)$ | $\Delta Theil$ | $\Delta aggTheil$ | $\Delta Gini$ |
| ln(TotalHK) | 0.042* | | 0.164*** | 0.126*** | 0.101*** |
| | (0.022) | | (0.041) | (0.041) | (0.022) |
| boulder clay | | 0.750*** | | | |
| | | (0.045) | | | |
| Region FE | Y | Y | Y | Y | Y |
| Geography | Y | Y | Y | Y | Y |
| Observations | 1,605 | 1,605 | 1,605 | 1,605 | 1,605 |
| R-Square | 0.29 | 0.59 | 0.26 | 0.27 | 0.17 |
| KP F-statistic | | | 280.11 | 280.11 | 280.11 |

Geography controls include the natural logarithm of the parish area, the distance to Copenhagen, distance to the coast and the latitude and longitude of the parish. Regions are defined as: Greater Copenhagen, Zealand, Funen, and Jutland). Robust standard errors in parentheses.
*** $p < 0.01$ ** $p < 0.05$ * $p < 0.10$

Table 1: IV estimation using total *hartkorn* and the share of parish area classified as boulder clay

Figure 4 shows the estimates of the second stage coefficients in levels for the years 1682 to 1895, the outcome variable in the second stage is thus $ln(Theil)$ in the different years rather than the change in the Theil.[14] As was already to a certain extent apparent from the maps in figures 1 and 3 above, there is no significant relation between soil quality and inequality before the reforms, in 1682. Only from 1834 onwards do we see a strong positive effect of

[13] Table A3 in the appendix also shows level results using the Gini coefficient and again, the results are essentially the same as in figure 4, below.

[14] Note that each plotted beta represents the point estimate from a separate regression. We find this preferable, as it allows to show that there is no significant relation in 1682, which would not be apparent from a difference-in-differences setup.

soil quality on inequality. This pattern seems to stabilize after 1850, where the positive relation between soil quality and inequality remains strong and the estimated coefficient is remarkably stable up to 1895. The land reforms thus appear to be a major determinant of land inequality throughout the nineteenth century.

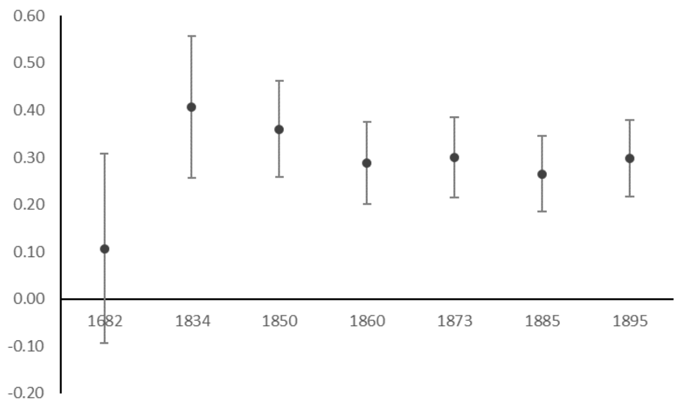



Figure 4: Coefficients from second stage estimations, 1682 to 1895. Dependent variable: $\ln(Theil)$, instrument: *share of boulder clay*, controls included.

## 5.1 Robustness checks

We conduct several robustness checks to verify our results. First, we use a different measure of land value. In the main analysis, we used the value of land measured in total *tønder hartkorn*, which includes all types of crops. One could argue that the relevant measure to look at is how much barley could be produced on the land, as this was the main crop at the time. Barley was most suited for the Danish climate as it has a short growing time, does not easily bend over, and can take more salt in the water than, for example wheat.[15] We therefore, instead of the total value of *hartkorn* of the parish, measure land quality only by the amount of barley paid in tax. We take this measure from digitizing a map presented by Frandsen (1988). Results can be found in the appendix in table A4 and are very similar to our main estimations. There is a strong positive relationship with the change in inequality. As a further robustness check, we present results for the more widely used measure of land suitability published by FAO, instead of the share of the parish area classified as boulder clay, which is of course very specific to the Danish case. These results can be found in appendix table A5 and, again, show little difference to our main results.

Finally, as with any spatial analysis, there is the risk that we are merely capturing spatial correlation over time. We therefore randomize first the outcome variable ($\Delta Theil$), second the main explanatory variable of interest ($\ln(TotalHK)$), and third the instrument (*boulder clay*) in the parish. We then re-estimate the preferred model (columns (3) and (4) in table 2) 10,000 times using the randomized variable instead of the observed variable one at a time. The estimated t-values on the second stage coefficient on $\ln(TotalHK)$ are reported in figure

[15]See http://www.emu.dk/erhverv/miljoe/Miljoetemaer/biodiv/biodiv.html

A2 in the appendix. Clearly, the observed variable outperforms the randomized variable in all three cases. We also present results using Conley standard errors for different cut-off points in table A6 in the appendix. The significance of the estimate is not affected.

### 5.2 Mechanism

As noted above, we propose a Malthusian mechanism for our findings through population growth. Areas with higher soil quality benefited relatively more from the agrarian reforms, meaning that more people could be supported from the land. To investigate this further, we use population data from the censuses taken during our time period and calculate population density on the parish level, defined as total population by parish area. The first stage is as defined in equation 2. The second stage now takes the following form:

$$\Delta ln(pop)_{pt} = \alpha + \beta \times \ln(TotalHK)_p + \lambda_r + X_p' \times \gamma + \epsilon_p \tag{4}$$

where $\Delta ln(pop)_{pt}$ is the change in the natural logarithm of population from year $t-1$ to year $t$ in parish $p$. The rest is as defined before. Estimation results from these separate regressions are shown in figure 5. Population growth shows a small increase during the initial stages of the reforms in areas with higher soil quality. After complete implementation, however, this increase takes off, where the point estimate almost doubles, and thereafter stabilizes. This pattern can also be observed in figure A3 in the appendix, where we provide maps of changes in population densities for the years 1769-1895. From 1769 to 1834 population density increases at a much higher rate, but also much more so in certain areas, resembling very much the pattern of inequality in figure 3.[16] After 1834, population densities grow rather uniformly (apart from the area of Copenhagen), and even start to decline in some areas in the later years, possibly due to emigration from overpopulated areas, which took off from the 1880s (Hvidt, 1971).

[16] In line with a Malthusian explanation, we find a positive relation of population levels with soil quality (measured by total *hartkorn*) throughout the whole period.

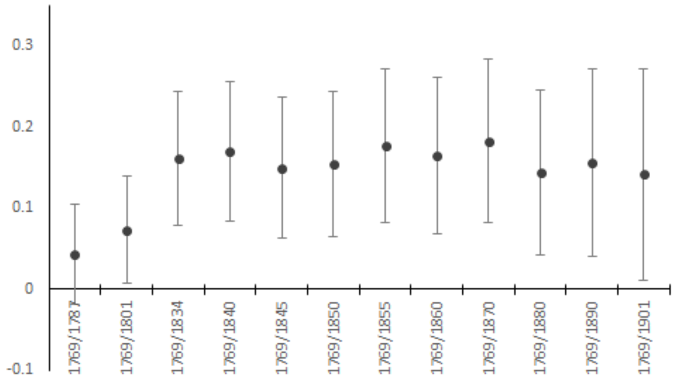
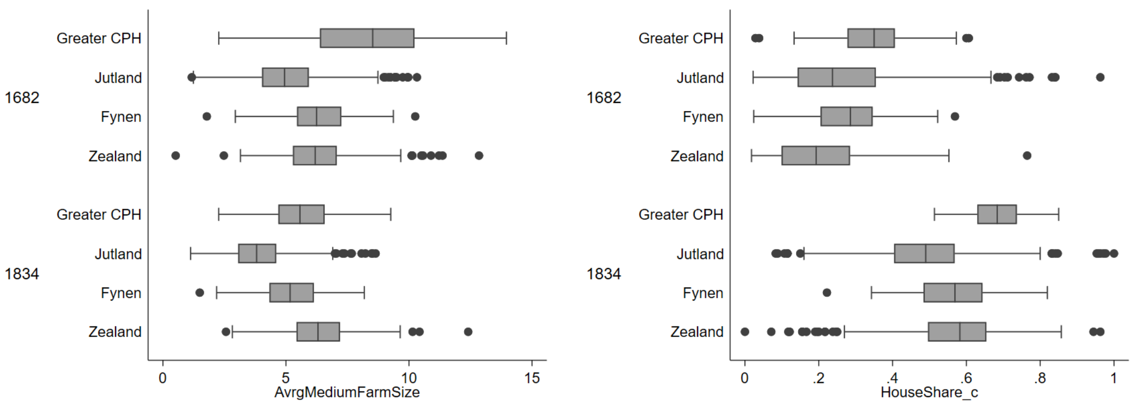



Figure 5: Coefficients from second stage estimations, 1769 to 1901. Dependent variable: $\Delta ln(pop)$, instrument: *share of boulder clay*, controls included.

Figure 6 shows that this increase in land inequality is not just due to a decrease in farm sizes, as the average size of medium sized farms stays rather constant before and after the reforms (left panel). We do, however, see an increase in the number of houses with very little (below one *tønde hartkorn*) or no land attached (right panel). There is thus an increasing share of the population who do not have access to land. This finding is supported by the fact that the Theil index increases relatively more when including landless houses in its calculation. Using the same size categories in both years, the Theil index for Denmark as a whole in 1682 is 0.37 including landless houses and 0.25 excluding them. This figure increases to 0.69 including and to 0.51 excluding landless houses.




(a) Average farm size

(b) Share of 'houses'

Figure 6: Average size of medium sized farms and share of 'houses' in total number of farms, 1682 to 1895.

One issue with our proposed mechanism might be that more productive areas attracted more people after the agrarian reforms, during which adscription and restrictions to labor mobility were eased. Although it seems unlikely that internal migration could be the main cause of changes in relative inequality, we nevertheless proceed to calculate measures of internal migration as well as fertility so that we can investigate their relative contribution to population increases. We calculate fertility measures on the parish level using census data from 1787, 1801, 1834 and 1870. Fertility is defined as the number of children under the age of five per married woman (age 15-54) in the parish. We are thus looking at *recent net fertility* as only children (currently) alive are considered, thus not taking account of child mortality. This measure has become a standard way to measure fertility from census data (see Hacker, 2016; Dribe et al., 2014; Dribe and Scalone, 2014). As for internal migration, it is first possible to calculate this in 1850, since previous censuses do not report the place of birth. In 1850 we are able to locate the birthplace of 88 percent of the census observations to an *amt* in Denmark or to a place outside of Denmark. *Amt* was a larger administrative unit and Denmark was divided into 24 amts in 1850.[17] Migration is then defined as the number of people living in parish $p$ in amt $a$, not being born in amt $a$, divided by the population of parish $p$ with known birthplace. We then estimate the following model:

$$ln(pop)_{p,1870} = \alpha + \beta_1 \times \ln(fertility)_{p,1850} + \beta_2 \times \ln(migration)_{p,1850} + \lambda_r + X_p' \times \gamma + \epsilon_p \quad (5)$$

The results are presented in table 2. Column (1) shows the pooled OLS estimation for all years. Year fixed effects are only included in column 1, since migration is only available in 1850. Column (2) shows the same estimation for 1870 only, i.e. fertility from 1850, to make the result comparable to columns (3) and (4). Column (3) shows the estimation for migration only, and column (4) for including both fertility and migration.

| | (1)<br>ln(pop)<br>1801-1870 | (2)<br>ln(pop)<br>1870 | (3)<br>ln(pop)<br>1870 | (4)<br>ln(pop)<br>1870 |
|---|---|---|---|---|
| L.ln(fertility) | $0.157^{***}$ | $0.196^{***}$ | | $0.192^{***}$ |
| | (0.027) | (0.073) | | (0.073) |
| L.ln(migrated) | | | $0.053^{***}$ | $0.052^{***}$ |
| | | | (0.016) | (0.016) |
| Year FE | Y | N | N | N |
| Region FE | Y | Y | Y | Y |
| Geography | Y | Y | Y | Y |
| Observations | 6,292 | 1,573 | 1,573 | 1,573 |
| R-squared | 0.65 | 0.58 | 0.58 | 0.59 |

Geography controls include the natural logarithm of the parish area, the distance to Copenhagen, distance to the coast and the latitude and longitude of the parish. Regions are defined as: Greater Copenhagen, Zealand, Funen, and Jutland). Robust standard errors in parentheses.
*** $p < 0.01$ ** $p < 0.05$ * $p < 0.10$

Table 2: OLS estimation including possible mechanisms: fertility and migration

[17] We use 18 amts in this paper, as we are excluding the island of Bornholm and Southern Jutland, because these regions are not reported consistently, as mentioned earlier.

Clearly, there is strong positive correlation with fertility and subsequent population growth. This is true for the whole period, as well as the cross-section in 1870. While migration is also positively correlated with population growth, column (4) shows that the elasticity with fertility is around four times the elasticity with migration, while both variables have similar standard deviations (see table A1). Of course, this result has no causal interpretation, but it nevertheless provides some evidence in favor of the Malthusian mechanism.

While we believe that the Malthusian mechanism should have been active in similar settings in other countries as well, it might be that the institutional design of Danish agriculture and the land reforms favored an outcome where increasing population led to more land inequality instead of equally distributed smaller farms. The land reforms built on the idea of keeping the existing family farms, which had been protected from dissolution under Danish absolutism before, intact, and thus provided advantageous conditions to their current tenants. Smallholders and cotters did not enjoy similarly favourable conditions and thus faced greater difficulties in access to land in the transition (Henriksen, 2003). Impartible inheritance of farms to avoid farm division also had a tradition going back at least to 1769, loosened in the immediate reform period, but reinforced at least since the 1830s through all of the nineteenth century.

# 6 Conclusion

We have demonstrated that land inequality in Denmark increased more in areas with better quality soil over the course of agrarian reforms, and that this was the result of greater concentrations of people with little or no land. This highlights that land reform can have negative effects as well as positive. Medium-sized farmers gained from the reforms, which are considered to have been a necessary condition for enabling the rise of the cooperatives, and the massive increases in productivity in agriculture which to a large extent characterizes the Danish development story (see for example Lampe and Sharp, 2019b). Cotters and landless laborers lost, however, and were not to be compensated until further reforms in the twentieth century, by which time many had chosen to leave for the New World or urban settings in Denmark.

Having explained the origin of land inequality, the present work opens the way for many potentially fruitful avenues for future research. In particular, it would be possible to use our data and identification strategy to provide answers to many of the big questions regarding the impact of land inequality on, for example, productivity, conflict, education, and emigration.

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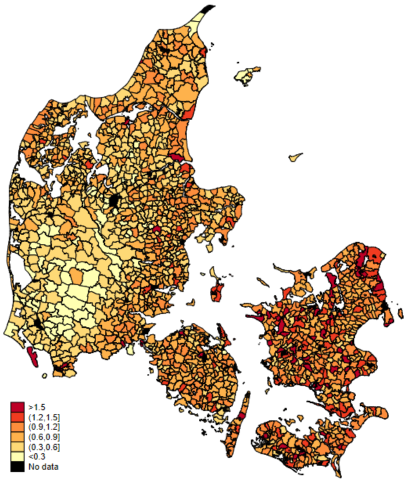
# 7 Appendix

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| TotalHK1682 | 1,605 | 218.5 | 140.8 | 4.3 | 1,089.3 |
| TotalHK1834 | 1,605 | 220.7 | 141.6 | 2.3 | 1,048.4 |
| TotalHK1850 | 1,605 | 221.6 | 140.1 | 7.5 | 1,287.4 |
| TotalHK1860 | 1,605 | 221.1 | 139.4 | 8.7 | 1,287.9 |
| TotalHK1873 | 1,605 | 221.6 | 139.6 | 6.9 | 1,297.9 |
| TotalHK1885 | 1,605 | 221.9 | 139.8 | 7.0 | 1,302.3 |
| TotalHK1895 | 1,605 | 223.3 | 148.8 | 7.0 | 2,297.1 |
| TotalFarmNr1682 | 1,605 | 49.9 | 32.2 | 3 | 262 |
| TotalFarmNr1834 | 1,605 | 94.2 | 65.9 | 8 | 763 |
| TotalFarmNr1850 | 1,605 | 100.8 | 68.9 | 4 | 759 |
| TotalFarmNr1860 | 1,605 | 127.0 | 89.3 | 7 | 1,026 |
| TotalFarmNr1873 | 1,605 | 142.6 | 99.7 | 9 | 1,138 |
| TotalFarmNr1885 | 1,605 | 156.8 | 114.9 | 12 | 1,666 |
| TotalFarmNr1895 | 1,605 | 160.9 | 128.4 | 12 | 2,204 |
| Theil_1682 | 1,605 | 0.35 | 0.25 | 0.02 | 2.08 |
| Theil_1834 | 1,605 | 0.75 | 0.35 | 0.00 | 3.02 |
| Theil_1850 | 1,605 | 0.76 | 0.33 | 0.08 | 2.81 |
| Theil_1860 | 1,605 | 0.90 | 0.32 | 0.11 | 2.51 |
| Theil_1873 | 1,605 | 0.96 | 0.34 | 0.16 | 2.51 |
| Theil_1885 | 1,605 | 1.02 | 0.35 | 0.17 | 3.13 |
| Theil_1895 | 1,605 | 1.05 | 0.37 | 0.19 | 4.54 |
| Gini1682 | 1,605 | 0.28 | 0.15 | 0.02 | 0.88 |
| Gini1834 | 1,605 | 0.58 | 0.12 | 0.00 | 0.93 |
| Gini1850 | 1,605 | 0.59 | 0.11 | 0.19 | 0.94 |
| Gini1860 | 1,605 | 0.65 | 0.09 | 0.18 | 0.92 |
| Gini1873 | 1,605 | 0.67 | 0.09 | 0.29 | 0.93 |
| Gini1885 | 1,605 | 0.69 | 0.09 | 0.30 | 0.95 |
| Gini1895 | 1,605 | 0.70 | 0.09 | 0.32 | 0.97 |
| Population_1769 | 1,605 | 295.0 | 327.9 | 0 | 4,425 |
| Population_1834 | 1,605 | 597.4 | 502.9 | 47 | 7,894 |
| Population_1850 | 1,605 | 686.8 | 583.6 | 42 | 8,932 |
| Population_1860 | 1,605 | 764.8 | 686.4 | 44 | 10,203 |
| Population_1870 | 1,605 | 837.6 | 833.9 | 49 | 16,878 |
| Population_1880 | 1,605 | 890.6 | 1,040.8 | 56 | 26,510 |
| Population_1890 | 1,605 | 930.0 | 1,503.3 | 60 | 46,954 |
| Fertility_1787 | 1,571 | 0.68 | 0.17 | 0.14 | 3.63 |
| Fertility_1801 | 1,571 | 0.41 | 0.11 | 0.06 | 0.90 |
| Fertility_1834 | 1,571 | 0.74 | 0.18 | 0.30 | 4.69 |
| Fertility_1850 | 1,571 | 0.76 | 0.13 | 0.32 | 1.60 |
| Migrated (population share) | 1,571 | 0.11 | 0.10 | 0.00 | 0.82 |
| BarleyLG | 1,605 | 3.5 | 3.1 | 0 | 23 |
| ShareBoulderClay | 1,605 | 0.48 | 0.32 | 0 | 1 |
| AreaSogn | 1,605 | 22.6 | 18.4 | 1.7 | 184.1 |
| Distance to Copenhagen | 1,605 | 165.8 | 75.6 | 2.8 | 295.1 |
| Lat | 1,605 | 6,210 | 76 | 6,056 | 6,396 |
| Long | 1,605 | 579 | 74 | 447 | 730 |
| Distance to coast | 1,605 | 7.9 | 7.3 | 0.02 | 44.6 |

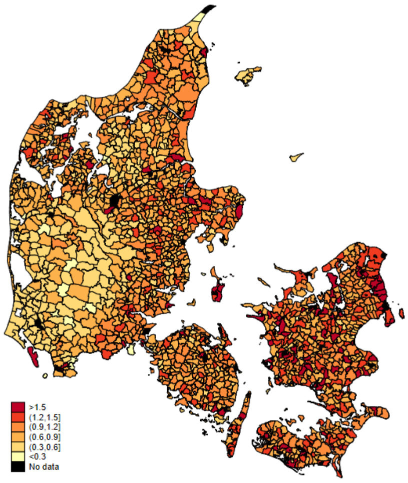
Table A1: Summary statistics

| 1682 | 1834 | 1850 | 1860 | 1873 | 1885 | 1895 |
|---|---|---|---|---|---|---|
| Manors | Complete Manors | | Full property > 30 | Full property > 30 | | |
| | Uncomplete Manors | | Full property 30 - 20 | Full property 30 - 20 | Farms > 20 | Farms > 20 |
| | Unprivileged Manors | Full property > 12 | Full property 20 - 12 | Full property 20 - 12 | Farms 20 - 12 | Farms 20 - 12 |
| Farms | Full property > 8 | Full property 12 - 8 | Full property 12 - 8 | Full property 12 - 8 | Farms 12 - 8 | Farms 12 - 8 |
| | Full property 8 - 4 | Full property 8 - 4 | Full property 8 - 4 | Full property 8 - 4 | Farms 8 - 4 | Farms 8 - 4 |
| | Full property 4 - 2 | Full property 4 - 2 | Full property 4 - 2 | Full property 4 - 2 | Farms 4 - 2 | Farms 4 - 2 |
| | Full property 2 - 1 | Full property 2 - 1 | Full property 2 - 1 | Full property 2 - 1 | Farms 2 - 1 | Farms 2 - 1 |
| | Hereditary >8 | Hereditary 12 - 8 | Hereditary >30 | Hereditary >30 | | |
| | Hereditary 8 - 4 | Hereditary 8 - 4 | Hereditary 30 - 20 | Hereditary 30 - 20 | | |
| | Hereditary 4 - 2 | Hereditary 4 - 2 | Hereditary 20 - 12 | Hereditary 20 - 12 | | |
| | Hereditary 2 - 1 | Hereditary 2 - 1 | Hereditary 12 - 8 | Hereditary 12 - 8 | | |
| | | | Hereditary 8 - 4 | Hereditary 8 - 4 | | |
| | | | Hereditary 4 - 2 | Hereditary 4 - 2 | | |
| | | | Hereditary 2 - 1 | Hereditary 2 - 1 | | |
| | Rented >8 | Rented 12 - 8 | Rented 30 - 20 | Rented 30 - 20 | | |
| | Rented 8 - 4 | Rented 8 - 4 | Rented 20 - 12 | Rented 20 - 12 | | |
| | Rented 4 - 2 | Rented 4 - 2 | Rented 12 - 8 | Rented 12 - 8 | | |
| | Rented 2 - 1 | Rented 2 - 1 | Rented 8 - 4 | Rented 8 - 4 | | |
| | | | Rented 4 - 2 | Rented 4 - 2 | | |
| | | | Rented 2 - 1 | Rented 2 - 1 | | |
| Houses | Full property < 1 | Full property 1 - 0.25 | Full property 1 - 0.25 | Full property 1 - 0.25 | Houses 1 - 0.25 | Houses 1 - 0.25 |
| | | Full property 0.25 - 0.003 | Full property 0.25 - 0.003 | Full property 0.25 - 0.003 | Houses 0.25 - 0.003 | Houses 0.25 - 0.003 |
| | | | Full property 0.003 - 0 | Full property 0.003 - 0 | Houses 0.003 - 0 | Houses 0.003 - 0 |
| | Hereditary < 1 | Other houses 1 - 0.25 | Other houses 1 - 0.25 | Other houses 1 - 0.25 | | |
| | Rented < 1 | Other houses 0.25 - 0.003 | Other houses 0.25 - 0.003 | Other houses 0.25 - 0.003 | | |
| | | | Other houses 0.003 - 0 | Other houses 0.003 - 0 | | |
| Houses without land | Full property without land | Full property without land | Full property without land | Full property without land | Houses without land | Houses without land |
| | Hereditary without land | Other houses without land | Other houses without land | Other houses without land | | |
| | Rented without land | | | | | |

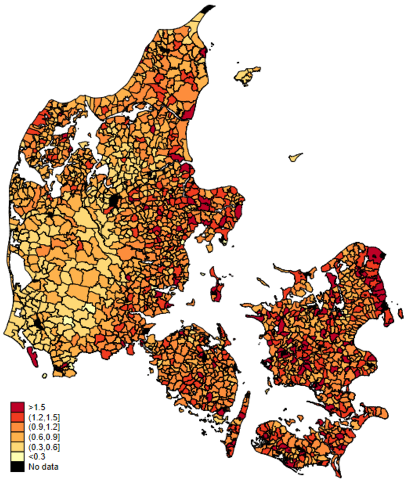
Table A2: Classification scheme of land reports of farms and houses into types and sizes (in *tønder hartkorn*), 1682-1895.



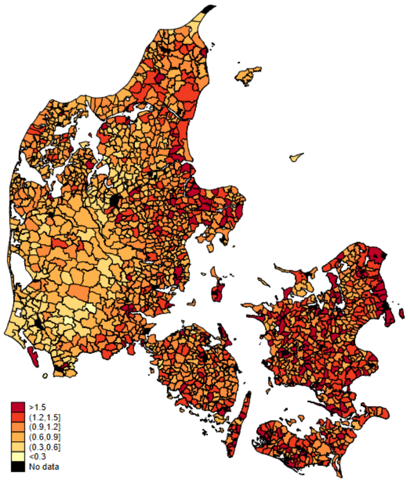

(a) 1850



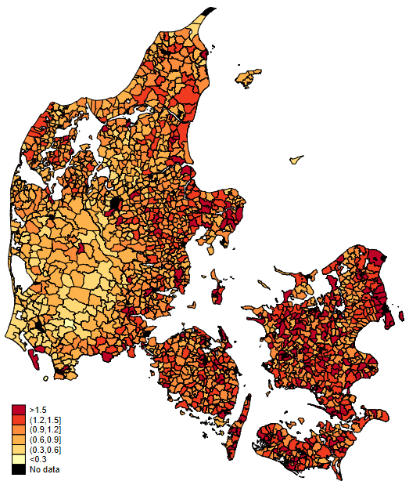

(b) 1860




(c) 1873




(d) 1885




(e) 1895

Figure A1: Theil index of land inequality in Denmark, 1850 to 1895.

| | (1) 2nd stage *Gini* 1682 | (2) 2nd stage *Gini* 1834 |
|---|---|---|
| ln(TotalHK) | -0.006 | 0.094*** |
| | (0.019) | (0.017) |
| Region FE | Y | Y |
| Geography | Y | Y |
| Observations | 1,605 | 1,605 |
| R-Square | 0.14 | 0.26 |
| KP F-statistic | 250.94 | 280.11 |

Geography controls include the natural logarithm of the parish area, the distance to Copenhagen, distance to the coast and the latitude and longitude of the parish. Regions are defined as: Greater Copenhagen, Zealand, Funen, and Jutland). Robust standard errors in parentheses.
*** $p < 0.01$ ** $p < 0.05$ * $p < 0.10$

Table A3: Robustness check: Second stage IV estimates using Gini coefficient

| | (1) OLS $\Delta Theil$ | (2) 1st stage $ln(TotalFarmHK)$ | (3) 2nd stage $\Delta Theil$ | (4) 2nd stage $\Delta aggTheil$ |
|---|---|---|---|---|
| BarleyLG | 0.008*** | | 0.040*** | 0.031*** |
| | (0.003) | | (0.010) | (0.010) |
| boulder clay | | 3.077*** | | |
| | | (0.246) | | |
| Region FE | Y | Y | Y | Y |
| Geography | Y | Y | Y | Y |
| Observations | 1,605 | 1,605 | 1,605 | 1,605 |
| R-Square | 0.29 | 0.38 | 0.23 | 0.25 |
| KP F-statistic | | | 156.30 | 156.30 |

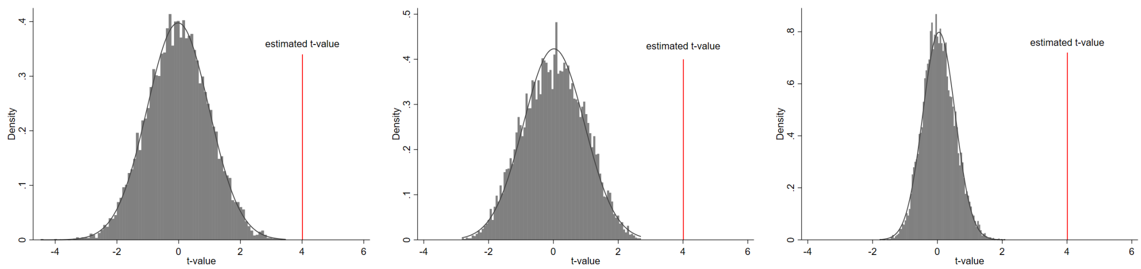
Geography controls include the natural logarithm of the parish area, the distance to Copenhagen, distance to the coast and the latitude and longitude of the parish. Regions are defined as: Greater Copenhagen, Zealand, Funen, and Jutland). Robust standard errors in parentheses.
*** $p < 0.01$ ** $p < 0.05$ * $p < 0.10$

Table A4: IV estimation using barley payments and the share of parish area classified as boulder clay

| | (1) OLS $\Delta Theil$ | (2) 1st stage $ln(TotalFarmHK)$ | (3) 2nd stage $\Delta Theil$ | (4) 2nd stage $\Delta aggTheil$ |
|---|---|---|---|---|
| barleysuit | 0.046** | | 0.208*** | 0.160*** |
| | (0.021) | | (0.051) | (0.051) |
| boulder clay | | 0.591*** | | |
| | | (0.032) | | |
| Region FE | Y | Y | Y | Y |
| Geography | Y | Y | Y | Y |
| Observations | 1,605 | 1,605 | 1,605 | 1,605 |
| R-Square | 0.29 | 0.65 | 0.27 | 0.27 |
| KP F-statistic | | | 338.30 | 338.30 |

Geography controls include the natural logarithm of the parish area, the distance to Copenhagen, distance to the coast and the latitude and longitude of the parish. Regions are defined as: Greater Copenhagen, Zealand, Funen, and Jutland). Robust standard errors in parentheses.
*** $p < 0.01$ ** $p < 0.05$ * $p < 0.10$

Table A5: IV estimation using barley suitability (FAO) and the share of parish area classified as boulder clay



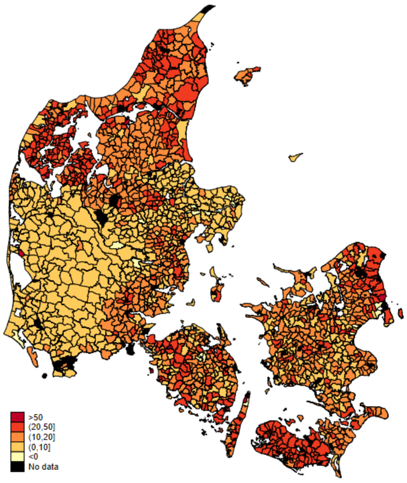

(a) $\ln(Theil)$ randomized (b) $\ln(TotalHK)$ randomized (c) *boulder clay* randomized

Figure A2: T-values of second stage estimation on $\ln(TotalHK)$, randomizing: (a) the outcome variable, (b) explanatory variable, (c) instrument.

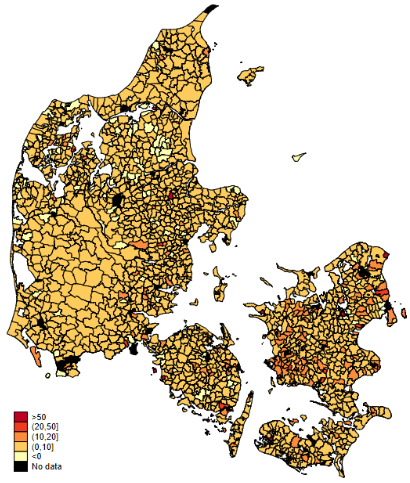
| | (1) $\Delta Theil$ 10km | (2) $\Delta Theil$ 25km | (3) $\Delta Theil$ 50km | (4) $\Delta Theil$ 100km |
|---|---|---|---|---|
| ln_TotalFarmHK_hat | 0.171*** | 0.171*** | 0.171*** | 0.171*** |
| | (0.038) | (0.038) | (0.038) | (0.039) |
| Region FE | Y | Y | Y | Y |
| Geography | Y | Y | Y | Y |
| Observations | 1,605 | 1,605 | 1,605 | 1,605 |

Geography controls include the natural logarithm of the parish area, the distance to Copenhagen, distance to the coast and the latitude and longitude of the parish. Regions are defined as: Greater Copenhagen, Zealand, Funen, and Jutland). Robust standard errors in parentheses.
*** $p < 0.01$ ** $p < 0.05$ * $p < 0.10$

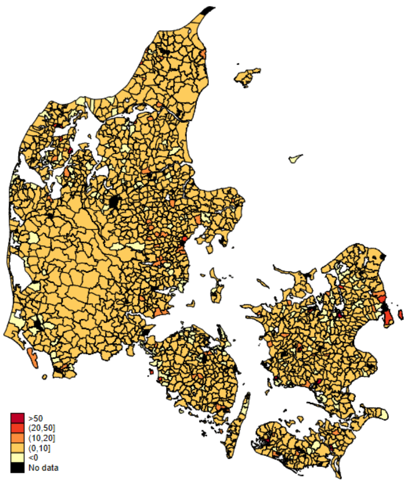
Table A6: Second stage IV estimation using total *hartkorn* and the share of parish area classified as boulder clay using Conley standard errors and different cut-off points



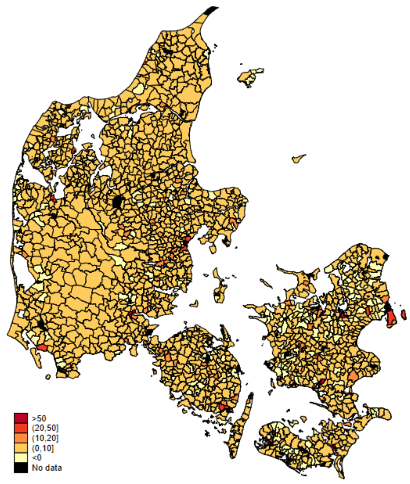

(a) 1769-1834



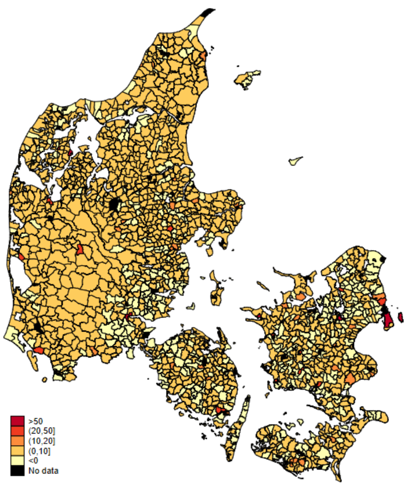

(b) 1834-1850



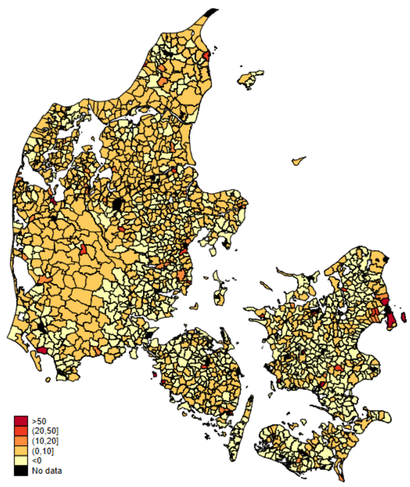

(c) 1850-1860




(d) 1860-1870




(e) 1870-1880




(f) 1880-1890

Figure A3: Change in population density, 1769 to 1890.