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New crops, local soils and urbanization: Clover, potatoes and the growth of Danish market towns, 1672-1901

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New crops, local soils and urbanization:
Clover, potatoes and the growth of Danish market towns,
1672-1901

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Abstract

This research evaluates the impact of the introduction of clover and potatoes on urbanization using a panel of Danish market towns from 1672 to 1901. We find evidence that both clover and potatoes contributed to urbanization using a difference-in-difference type estimation strategy which exploits that the breakthrough of clover and potatoes should have differential local effects because of soil suitability. To take into account the endogeneity of clover adoption, we instrument by suitability for growing alfalfa, which like clover is a legume. Importantly, alfalfa did not have its breakthrough in the period studied. Our IV estimates suggest that clover accounted for about 8 percent of market town population growth between 1672 and 1901, whereas roughly 6 percent can be attributed to potatoes. The analysis also indicates that the potato had its breakthrough later in Denmark than in many other countries as suggested by the historical narrative.

JEL classification: N1, N9, O1, R4, R11

Keywords: clover, potatoes, agricultural productivity, urbanization

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1. Introduction

From 1672 to 1901, average Danish market town populations¹ increased from 1,826 to 15,493 inhabitants corresponding to an increase by a factor of nearly 8.5.² The evolution of urban populations is arguably one of the best proxies for economic development historically (Acemoglu, Johnson and Robinson, 2005b; Cantoni, 2013). Therefore, understanding the causes of this evolution provides insights into the causes of economic growth in periods in which it is difficult to measure growth. In addition, urban populations capture the geographical distribution of economic activity as pointed out by Fernihough and O'Rourke (2014). Further, the historical rise of towns and cities arguably matters for present-day urban agglomerations as suggested by Percoco (2014) who stresses physical geography along with institutions as important sources of path dependence in urbanization through economies of agglomeration. In this paper, we zoom in on the interaction between new crops and physical geography as a source of higher agricultural productivity which cause urbanization. We do so by investigating whether the widespread adoption of two new crops—clover and potatoes—affected market town populations differentially across Denmark because of soil conditions.

There are several reasons why higher agricultural productivity could affect town development.³ First, it is arguably the case that only societies with a certain level of agricultural productivity can sustain urban centers; Acemoglu et al. (2005b).⁴ Second, higher agricultural productivity may spur rural-urban migration if it serves to lower demand for labor in the agricultural sector as stressed by for example Nunn and Qian (2011). Third, Gollin, Parente and Rogerson (2007) propose a model in which agricultural productivity is important for the development of societies in terms of income per capita. They argue that countries initially suffer from the “food problem”—a term due to Schultz (1953)—which refers to the fact that many poor countries devote most of their resources to agricultural production in order to meet subsistence needs due to low productivity. The present research investigates how two potential solutions to the “food problem” used in Denmark⁵ and other North European countries affected urbanization. Finally, historically it was the case that

¹Based on 56 market towns for which data exist for the population over the whole period 1672 to 1901.

²This development runs parallels to what happened elsewhere in Europe (Acemoglu, Robinson and Johnson, 2005a; Van Lottum, 2011; Percoco, 2013).

³Other channels such as the impact on nutrition and health may also be important.

⁴See also Glaser (2014) who stresses agricultural productivity as historically important for the development of cities.

⁵Kjærgaard (2003) observes that Denmark was one “among the many European countries that experienced more or less identical problems.” This suggests that the lessons from Denmark may apply more broadly.

Danish market town dwellers were directly involved in the agriculture just outside their town, and therefore they would experience productivity increases directly.⁶

Clover and potatoes contribute to agricultural productivity via a number of principal advantages. The first advantage of growing clover is that crop yields increase since clover is a nitrogen-fixing plant. In fact, nitrogen governs the yields of crops that have enough water (Kjærgaard, 1995:p.3). As stated by Taylor (2008), clover was “the chief provider of atmospheric nitrogen for cereals.” The second advantage is that clover provides excellent animal fodder, which allows for a larger cattle population and increased production of milk and butter. Fixing nitrogen may also be important for potato adoption as suggested by Kjærgaard (1995). He argues that the slow expansion of potatoes was caused by an absence of “biological opportunity” which was eventually provided by clover. Unlike clover, potatoes do not increase the supply of nitrogen in the soil (Nunn and Qian, 2011), but they do have a number of other advantages. These advantages include that (1) they produce higher yields than many old world crops; (2) they can be used as animal fodder; (3) they are excellent human food since they are superior in nutritional terms, (4) they allow for crop diversification, and (5) they can be planted on land otherwise left fallow (Nunn and Qian, 2011). We discuss these advantages in more detail below.

Both clover and potatoes may have been crucial for economic development. For example, Taylor (1983) proclaims that clover had “a greater influence on civilization than the potato.” Clover is also emphasized by Chorley (1981) for northwest Europe and by Allen (2008) for England. Kjærgaard (1991, 1995, and 2003) highlights the importance of clover for the Danish case and notes that contemporary observers of Danish agriculture also praised clover. One example is the founder of the Royal Danish Agricultural Society, who argued that clover would transform Denmark “into a new Canaan with milk and honey”. Similarly, 19th century agronomist Karl A. Jørgensen proclaimed that clover was “a blessed gift, one of Denmark’s great benefactors” (Kjærgaard, 1995:p.11). Regarding the potato, Langer (1963) associated larger populations with the spread of potato agriculture in Europe, and Adam Smith emphasized that the food produced on a field of potatoes is “much superior to what is produced by a field of wheat” in the *Wealth of Nations*. In line with this, Nunn and Qian

⁶For example, Elkjær (2001) stresses that Danish market town dwellers were simultaneously craftsmen, merchants and farmers as they grew crops on the fields outside their town. She also documents that three of the market towns in Jutland in the western part of Denmark all had clover and potatoes production at the time of the first agricultural census of 1837. For the 18th century, Mikkelsen (1993) demonstrates substantial production in the vicinity of market towns on Zealand in the eastern part of Denmark, but at this point in time neither potato or clover production is reported.

(2011) find that the introduction of the potato can account for about a quarter of population growth from 1700 to 1900. The potato has also been stressed as important by Ax (2008) for the case of Denmark.

The Danish case has at least four features that make it appealing for testing the effects of widespread adoption of clover and potatoes.

First, the Danish data show considerable regional variation in soil suitability for growing potatoes and legumes such as clover. They also show variation in the places which adopted clover early. Suitability measures arguably capture exogenous variation, and we therefore worry less about reverse causality bias regarding potatoes. For clover, we test the effect of adoption using data from Kjærgaard (1991) on the distribution in 1805.⁷ By this year, clover had spread to many places in Denmark. Since these data indicate adoption, reverse causality concerns naturally arises as early adoption may be caused by increased demand from rising urban populations. To address this, we instrument clover adoption by using suitability for growing alfalfa—another legume—which according to the historical narrative had its breakthrough *after* the period studied. This allows us to gauge the relative importance of clover and potatoes, which has not been done in previous literature.

Second, detailed data for clover adoption are not available for other countries, and the Danish data therefore provide a unique opportunity for investigating the role of clover for urbanization. In related research, Allen (2008) carried out simulations, which attributes more than 50 percent of the rise in crop yields in England between 1300 and 1800 to nitrogen fixing legumes such as clover. Yet, Allen (2008) had no measures of local clover adoption and local economic activity needed to evaluate the effect econometrically.⁸ The breakthrough of clover in Denmark has been placed from the early 19th century to the 1830s. In some countries, the breakthrough seems to have happened earlier, whereas in countries such as Denmark and Sweden, this happened later (see Kjærgaard, 1995: p.5).⁹ The relatively late

⁷The adoption of clover spread gradually from 1775 to 1805, according to Kjærgaard (1991), where adoption in 1775 was very limited. We also explore this variation.

⁸Chorley (1981) provides a calculation suggesting that legumes were important in expanding the nitrogen supply from 1750 to 1880. Yet, like Allen (2008), he provides no econometric analysis.

⁹He gives the following years as indication of some adoption for the following places: Andalusia (before 1270), Brescia (1550), Flanders (1563), France (1583), England (1620), Mainz (1645), Fehmarn (1710), Würzburg (1720), Schleswig-Holstein (1725), Berlin (1735), Moravia (1740). For Sweden, Mats Morell indicated in personal communication that clover had early introductions in Sweden in the early 18th century, but that it was only about 100 years later that it had its breakthrough.

breakthrough, combined with Kjærgaard's data, allows us to investigate the effect of clover on urbanization.

Third, some confounding factors can be ruled out. Denmark does (and did) not have coal deposits, and this rules out that proximity to coal confound the results. Fernihough and O'Rourke (2014) demonstrate a relationship between proximity to coal and city growth after 1750. Their maps indicate that the Danish cities in the Bairoch dataset were all far from coal reserves.¹⁰ Falbe-Hansen (1887, pp.7-9) emphasized that agriculture was the most important sector in the Danish economy as late as 1880. He noted that more than 50 percent of the population earned its living from agriculture according to census data from that year. Also, while the potato was introduced in Denmark in the period studied, this was not the case for other new world crops such as maize.¹¹ Finally, Cook (2013) argues that countries with higher shares of lactase persistent population, i.e. the share of the population that can digest milk, benefit more from the potatoes. In the Danish case, lactase persistence is almost 100 percent, Ingram et al. (2009). This suggests that the benefits can be enjoyed in full. Focusing on Denmark also allows us to control for the effect of concurrent institutional changes which are difficult to control for in studies that exploit variations in city size across borders as done by Nunn and Qian (2011).¹² During the period studied the kingdom of Denmark was subject to serfdom from 1733 to 1800, and we can control for this by including common time effects. The common time effects arguably also capture other common institutional changes that were taking place in this period. Further, there were even some (early) institutional differences within Denmark, and we demonstrate that these do not drive our results.

Fourth, the data for Danish market towns have a number of advantages relative to the Bairoch et al. (1988) and de Vries (1984) city population data used by Nunn and Qian (2011) and others in analyses of European cities. The first advantage is that we can evaluate more tightly when potatoes (and clover) had their breakthrough in Denmark. This cannot be done with the

¹⁰We note below that deposits of brown coal were mined on the island of Bornholm. Since we cannot obtain data on this, we opt to leave out this remote island for this and a number of other reasons in our baseline results.

¹¹Thaarup (1820) discusses some attempts to grow maize in Denmark from the late 18th century to the 1810s. While, the experimenters report some success, later sources argue that maize could not be grown for human food in Denmark due to the growing season being too short (Madsen-Mygdal, 1912; Encyclopedia Denmark). The same source discusses some experiments with using maize as a fodder crop, but this use was recent and not widespread around 1912 when Madsen-Mygdal published his handbook. According to FAO soil suitability measures, sweet potatoes cannot be grown successfully in Denmark though this crop reached Europe very early (Nunn and Qian, 2011).

¹²They also consider the effect of potato introduction on the heights of French soldiers, and in this setup they control for country-specific institutions as well as changes to these. We note, however, that the outcome of these regressions is height, and not urbanization.

Bairoch et al. (1988) dataset, which only has data for 10 Danish towns from 1600 to 1850.¹³ By contrast, the Danish data include 56 market towns with data available from 1672. Nunn and Qian (2011) assumed that the potato had its breakthrough from 1750 onwards in Europe as a whole. However, the historical accounts for Denmark and Sweden¹⁴ suggest that this year is too early for these countries. For Denmark, the timing has been argued to be from the 1820-30s onwards. Thus, the Danish data allow us to relax the assumption of a widespread breakthrough from 1750 onwards and investigate whether the historical narrative fits the quantitative evidence. The second advantage is that the data are not selected on the basis of a size criterion. By contrast, the Bairoch et al. data include towns that reached 5,000 inhabitants at some point in the period 1600-1800. In this way, towns that historically reached a certain size are selected into the dataset. This increases the risk of using the wrong counterfactual when carrying out empirical analyses. Using a larger set of market towns, which also include those that did not reach 5,000 inhabitants, but might have similar soil conditions for growing potatoes and clover reduces this risk.¹⁵ The third advantage is that the Danish data have higher frequency which increases over the 19th century. This allows for a tighter assessment of the impact of the potato on the growth trajectory of market towns. The final advantage of the Danish data is that they are actual census data. By contrast, Bairoch et al. (1988) construct data at regular intervals—every 100th and later every 50th year—by interpolating between census years.¹⁶

Based on a difference-in-difference type estimation strategy which exploit that the two crops should have differential local effects because of variation in soil conditions, we find that both clover and potatoes had an effect on urbanization. Our instrumental variables estimates suggest that clover had its effect mainly in the 19th century, whereas the OLS estimates suggest that towns which had adopted clover by 1805 had high populations before adoption. This may plausibly be attributed to endogeneity bias, which is further corroborated when we exploit time variation in the adoption of clover since we find little evidence of an effect

¹³Bairoch et al. (p. x) note that they have included all cities that reached 5,000 inhabitants at least once between 800 and 1800. In the Danish case, only Copenhagen and Ribe have coverage before 1600. Nunn and Qian (2011, p. 640) indicate that they use European cities with at least 1,000 inhabitants, but the Danish cities that they include all come from the Bairoch et al. database. This means that 10 cities which had 1,000 inhabitants in 1672 are missing from the dataset used by Nunn and Qian (2011).

¹⁴Heckscher (1945) argues that widespread adoption happened in Sweden in the early 19th century.

¹⁵As explained below, the Danish part of the Bairoch et al. data for 1700 and 1750 were constructed using data for 1672 and 1769. Yet, for two out of ten towns, data are not included in the Bairoch database for these years.

¹⁶Bairoch et al. (1988, p.2) indicate that they have used either 1) the probable evolution as indicated by other sources or 2) an interpolation using the surrounding periods. The data used for 1700 seem to be based on interpolation between 1672 and 1769, as the sources used give data for these periods, and not for 1700 and 1750.

before 1805. For the potato, the effects also appear in the 19th century around the time that the historical narrative suggests. Moreover, the combined effect from the IV estimation of the two crops corresponds to roughly 14 percent of growth in market town populations from 1672 to 1901 with a little more than half being attributable to clover.

The rest of the paper is organized as follows. Section 2 gives historical background and discusses the advantages of clover and potatoes in more detail. Section 3 describes the empirical strategy and the data. Section 4 presents the results. Section 5 concludes.

2. Historical background

This section provides background on the main advantages of clover and potatoes and their historical breakthrough in Denmark. We need to explain in more detail what benefits arise from these crops in order to understand why they would be adopted and how they might impact agricultural productivity. The timing of breakthroughs informs the empirical analysis on when to expect effects from clover and potatoes.

Advantages of clover

As mentioned above, the first advantage of introducing clover as a crop is that it serves to increase nitrogen supply in the soil. According to Cooke (1967, p.3), nitrogen is in a class of its own, for in most agriculture its supply governs the yields of crops that have enough water. For the historical period under consideration, Kjærsgaard (1995, p.4) concludes that the main way to increase the supply of nitrogen was to increase the cultivation of leguminous crops. In northern Europe, this was done mainly by introducing clover, which is considerably better at fixing nitrogen than many other crops such as peas which were already grown, see Kjærsgaard (1991, p. 111) who shows that clover adds about 3 times as much nitrogen as e.g. peas. Allen (2008, p.186) notes that experimental data posits a proportional relationship between crop yields and nitrogen input, and his simulations suggest that clover contributed more than half of the increase of nitrogen for England.¹⁷ The second advantage is that clover served as fodder for cattle, whereby milk and butter production could be increased. Moreover, as

¹⁷Allen (1992) ran regressions using a dataset of 28-35 Oxford shire villages and found no relationship between the share of land used for leguminous crops such as beans and pulses and yields for wheat and barley. Allen's data do not include clover or yields of clover (which indicate suitability) and are drawn from a very small database. By contrast, when we use data from the agricultural census for Germany of 1886 from the Prussian Economic History Database (Becker et al., 2012) with 518 observations, we do in fact find strong, positive relationships between clover yields and yields of wheat and barley. [Results are available upon request].

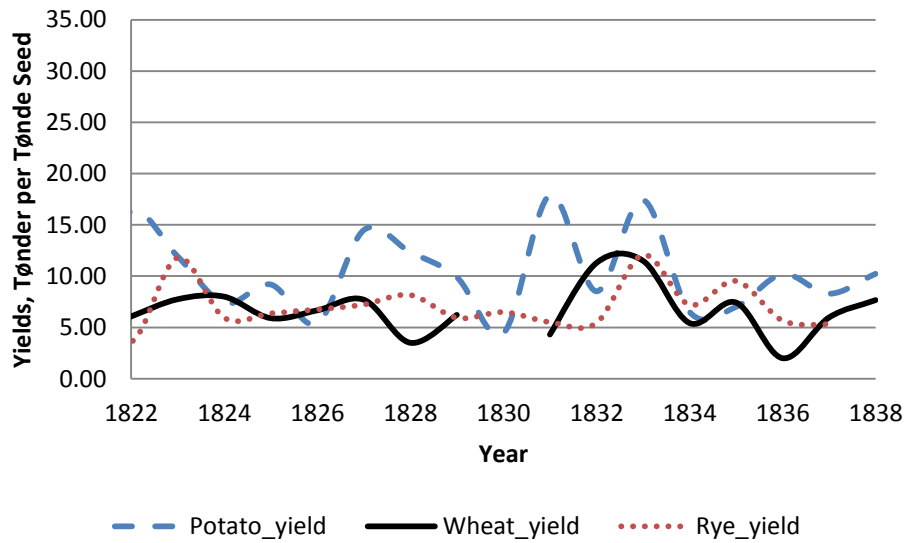
pointed out by Mokyr (2009, p.180), better-fed animals produce more fertilizer.¹⁸ He also points out that the empirical relationship between clover and soil fertility was known at the time. This is corroborated by Marshall (1929, p. 46) who notes that the relationship was known by 18th century writers such as Stephen Switzer and Robert Maxwell, who posited that clover draws nitrogen from the air and “gives it to the land.” Finally, we note that alfalfa has similar advantages but as described below, it did not have its breakthrough in Denmark in the period studied.

Advantages of the potato

The potato has certain advantages compared to other crops. First, they produce higher yields than old world crops. Evidence on this is given in Figure 1 from early 19th century farmer Søren Pedersen from western Zealand, who kept a diary in which he recorded seed and harvest. The yield measure is given per *tønde* of seed. The unit *tønde* corresponds to 100 kilograms (plural: *tønder*). On average, potato yields are higher than the other crops with around 12 *tønder* per *tønde* of seed in comparison to 7.05 for wheat and 6.92 for rye. Second, they can be used as fodder for animals, as also emphasized by contemporary writers (Ax, 2009). Third, they are superior to other staple crops in nutritional terms. This was acknowledged by some writers at the time, e.g. Bendix (1807, p.22), but others did not believe that potatoes were proper food for humans due to their role as fodder crops (Ax, 2009). Fourth, they allow for crop diversification and as noted by Ax (2008), this was one of the main arguments that writers of the time used to promote the potato. Finally, “potatoes could be planted on the land that was otherwise left fallow between the periods of grain cultivation” (Nunn and Qian, 2011: p.601), and in this way one did not need to switch completely away from old staple crops. The case of Søren Pedersen also illustrates this.

¹⁸He also argues that the above mentioned prediction that clover introduction would transform Denmark into a “new Canaan of milk and honey” should be understood literally. Clover contributed both to increased milk production and increased the biological niche for the honeybee.

Figure 1: Yield for Potato, Wheat and Rye of Søren Pedersen, 1811-1838

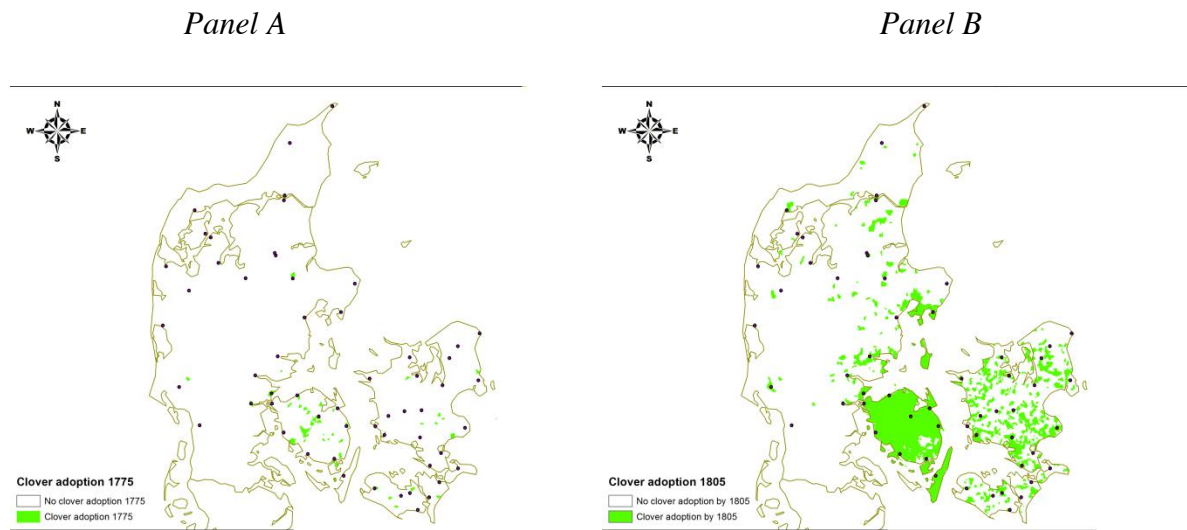


Source: Schousboe (1983).

Breakthrough of clover

According to Falbe-Hansen (1887, p.136), it was only from the 1830s that clover was introduced on many farms in Denmark. Kjærgaard (1991, 1995) provides a short historiography of clover in Denmark. Importantly, he provides maps of its diffusion covering 1775, 1785, 1795, and 1805. Clover seems to have been grown in a single town in 1732, but Kjærgaard (1995, p.6) stresses that it was still regarded as a new crop and only grown experimentally. His maps suggest that only few places had adopted clover by 1775 (see panel A of figure 2) and it was only by 1805 that it had spread to a significant proportion of the country (see panel B of figure 2). The map for 1805 shows limited diffusion in the western part of the country, whereas adoption in the eastern part was much more widespread. It is important to note that Kjærgaard's maps only indicate clover adoption and not the intensity. This would be consistent with a later breakthrough as suggested by Falbe-Hansen (1887).

Figure 2: Clover adoption in Denmark in 1775 and 1805 following Kjærgaard (1991)



Source: Kjærgaard (1991)

Notes: Each town is shown by a dot.

Clover would often be introduced on Danish fields using a crop rotation system known as *koppelwirtschaft* invented in Holstein (Bjørn, 1988:p.35-37).¹⁹ This system would require that the cultivated area was divided into at least seven fields. Clover would be planted on some of the fields along with old world crops and on pastures, and in this way, the advantages of clover could be enjoyed.

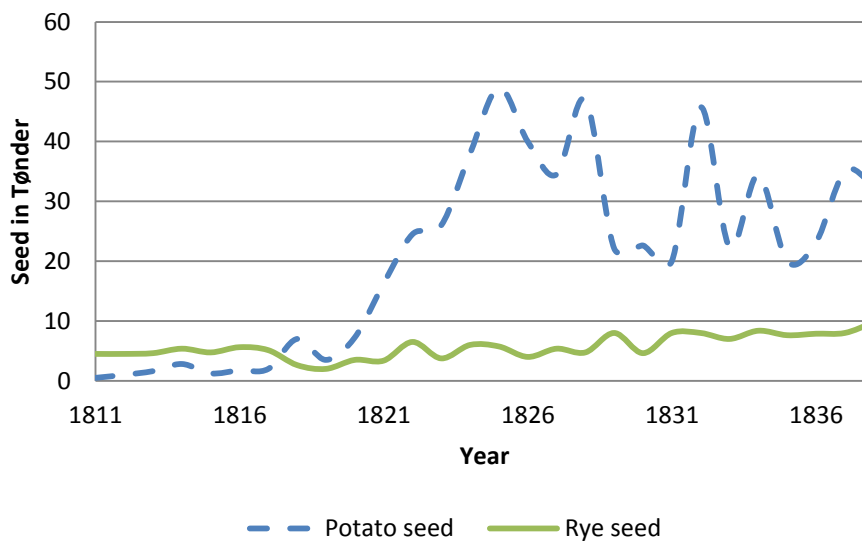
Breakthrough of the potato

German immigrants who were invited by King Frederik V, in the period 1759-62, grew the potatoes on the Jutish heath in western Denmark. Nonetheless, it was not until the 1820s or 1830s that the potato spread widely to all Danish areas and all parts of the population, Ax (2008, p.45). Falbe-Hansen (1887, p. 137) notes that potatoes were mostly grown in people's gardens in the beginning of the 19th century, but it was uncommon as a field crop. Begtrup

¹⁹In England, some places adopted a four-course (or Norfolk) rotation which included: (1) wheat, (2) turnips, (3) barley or oats, and (4) clover. In both *koppelwirtschaft* and the four course rotation system, clover paid an important role, see Birnie (1962, p.14). Turnips were not included in *koppelwirtschaft*, and are only included in official agricultural statistics from the 1870s in Denmark together with other fodder plants. Moreover, turnips do not fix nitrogen from the air, whereas clover does (Allen, 2008:p.197). Thus, it is likely that good turnip yields depend on growing clover, but not the other way around. Timmer (1969) says that the turnip was used as winter fodder, and also stresses the importance of increased hoeing associated with growing turnips.

(1810, p. 86) corroborates this. He notes that in Randers county in western Denmark (Jutland), potatoes were only grown in relatively small quantities in farmers’ gardens. While Begtrup points to a few areas where potato were grown in fields, his descriptions suggest that potatoes were being grown in relatively small quantities around the country (Ax, 2008). Søren Pedersen’s diaries support the views of Falbe-Hansen (1887) and Ax (2008) as potatoes became a more and more important crop on his fields in the 1820s. Figure 3 plots Pedersen’s potato seed over the period 1811-1838. Around 1811, Pedersen only grew them in his garden and his seed was less than one tønne. The breakthrough seems to happen around 1821 where total potato seed exceeds 10 tønner corresponding to 1000 kilograms. Ax (2009) surveys the county descriptions from the period 1826-1844. All counties had potato production in this period, production was expanding, and potatoes were no longer only grown as a garden crop.²⁰

Figure 3: Søren Pedersen’s Potato Seed, 1811-1838



Source: Schousboe (1983).

The late breakthrough of the potato in Denmark—despite being grown in gardens in a few places—is also corroborated by the fact that the harvest reports collected by the government agency “rentekammeret” of the late 18th century do not mention potatoes at all. While not a question that we will resolve, one may wonder why the breakthrough took such a long time. Some authors mention that storage during winter was a challenge (Thaarup, 1820; Bendix,

²⁰Ax (2009) mentions that the islands of Lolland and Falster were exceptions in that they had little potato production. As we explain below, these areas are dominated by heavier, clay soils which according to our sources do not produce the best potatoes for human consumption.

1807). The basic challenge was to protect the potatoes from frost, and Thaarup mentions that at the time of writing relatively simple ways of storing potatoes had been devised. Other authors stress skepticism towards potatoes as food for humans.²¹ Above, we also noted that some authors stress that clover introduction may have mattered for potato introduction, since nitrogen may be needed to enjoy the high yields of potatoes.

Summing up

This section discussed the benefits and breakthrough of the clover and potatoes. The historical narrative suggests that clover and potatoes had their breakthroughs around 1820-30s with a possible earlier breakthrough for clover. In the next section, we discuss what areas were more likely to benefit from adopting these crops and as a consequence are more likely to experience town growth.

3. Empirical strategy and data

This section describes our empirical strategy and the data we use in the analysis. The empirical model is described in subsection 3.1 and data descriptions follow in subsection 3.2

3.1 Empirical model

We estimate models that build on the logic of the difference-in-difference estimator. In practice, we interact measures, which vary within the cross-section of towns, with time dummies. We estimate flexible and non-flexible models using both OLS and IV. We begin by estimating the following flexible specification for the natural logarithm of the populations ($\ln \text{pop}$) of town i , which allows for separate coefficients for each point at time (t):

$$\ln \text{pop}_{it} = \sum_{j=1}^{13} \beta_j^{\text{potato}} \ln(1 + \text{potato}_i) I_t^j + \sum_{j=1}^{13} \beta_j^{\text{clover}} \ln(1 + \text{clover}_{i,1805}) I_t^j + \sum_R \lambda_R I_i^R + \sum_{j=1}^{13} p_j I_t^j + \varepsilon_{it} \quad (1),$$

where β_j^{potato} and β_j^{clover} are the parameters of interest that measure whether there are effects of the breakthrough of the potato and early clover adoption. I_t^j represents time dummies and I_i^R represents market town dummies, i.e. time and town fixed effects. The variable potato_i is the share of land suitable for growing potatoes, while $\text{clover}_{i,1805}$ is the share of land on which clover was grown in 1805 as will be explained below. Note that we log transform the variable in the

²¹Bjørn (1988) attributes the breakthrough of potatoes to the enclosure movement. By 1810, most villages had abandoned the tradition of having common lands in favor of individual plots (Dombornovsky, 1988). This allowed peasants to introduce potatoes on their own fields. While this may be a valid explanation of the timing, it fails to explain why the potato may have had differential effects on town populations across Denmark.

same manner as in Nunn and Qian (2011). We also estimate non-flexible specifications that assume breakthroughs in the 1820-30s:

$$\ln \text{pop}_{it} = \beta^{\text{potato}} \ln(1 + \text{potato}) I^{\text{post}} + \beta_j^{\text{clover}} \ln(1 + \text{clover}_{i,1805}) I^{\text{post}} + \sum_R \lambda_R I_i^R + \sum_{j=1}^{13} p_j I_t^j + \varepsilon_{it} \quad (2),$$

where I^{post} is equal to one after 1830 and zero otherwise. This model allows us to evaluate the effect of clover and potatoes on urban populations. We also estimate versions of the model that combine a flexible specification for clover and non-flexible for potatoes.

We further estimate versions of the models where we replace $\text{clover}_{i,1805}$ by alfalfa_i which denotes the share of soil suitable for growing another legume – alfalfa. As we note below, obtaining better alfalfa and clover yields requires similar soil conditions. The alfalfa suitability measure is arguably plausibly exogenous, and since the historical record shows that alfalfa had its breakthrough in Denmark long after the period studied, we use it as an instrument for $\text{clover}_{i,1805}$.

3.2 Data

This subsection describes the data used for the outcome of interest, our two variables of interest and other control variables. We discuss each in turn.

Outcome and variables of interest

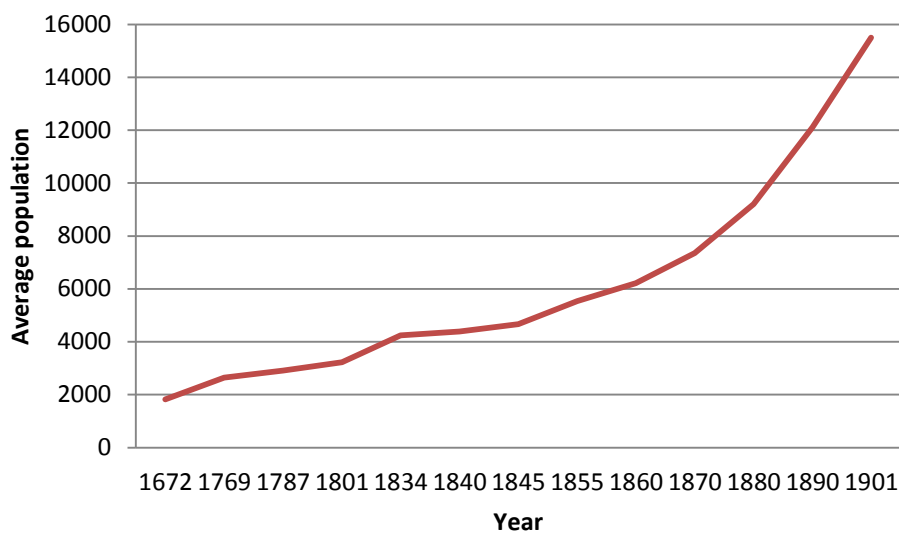
Market town populations: The data for populations of market towns have been compiled by “den digitale byport” (the digital town gate).²² The market towns had the privileges of carrying out trade, craftsmanship and other bourgeois business until the Trade Act of 1857 (Christensen and Mikkelsen, 2006; Degn, 1987). This had been the case since the Market Town Act of 1422, which meant that trade was transferred to market places and fairs, and thus peasants were prohibited from selling or buying goods in the countryside. While privileges were lost in 1857, this was arguably a common shock, and we therefore do not believe that it poses a threat to identification.

We use data on the kingdom of Denmark to keep focus on an area with similar institutions. Parts of present-day southern Denmark near the German land border were part of duchies which were under the rule of the Danish king, but had their own institutions. Further, these

²²“Den digitale byport” is hosted by the University of Aarhus. The website serves as an information and data resource for researchers working on Danish town development, see <http://dendigitalebyport.byhistorie.dk/privilegier/>.

parts²³ were no longer under Danish rule after the Danish-Prussian war of 1864. The population data are available at irregular time periods. The first complete data for market town populations are from 1672 as compiled by Degn (1987). The next data are census data for 1769, which was the first census for the whole country and not just the towns. Census data are further available for the following years: 1787, 1801, 1834, 1840, 1845, 1855, 1860, 1870, 1880, 1890, and 1901. We use all these data in our estimations. Figure 4 shows the change in the average town population among the 56 towns that has population data throughout the considered period. There is a positive change in the average population through the period, but the most outspoken increases seem to take place after 1845.

Figure 4: Average market town population 1672-1901



Source: “den digitale byport”, <http://dendigitalebyport.byhistorie.dk/privilegier/>.

To allow for checking whether there were effects of the potato after 1700 as assumed by Nunn and Qian (2011), we focus on a balanced panel of market towns from 1672-1901. Starting in 1672 allows us to test whether the effects of the potato are already present in 1769. This would be the case if the adoption after 1700 fits the Danish case. The focus on a balanced panel, however, comes at the cost of losing observations from the island Bornholm. Yet, leaving out the market towns of Bornholm also grants us some benefits. First, Bornholm is a small, remote island, and we do not wish results to be dependent of special remote island dynamics. Second, Bornholm never had serfdom as in the rest of the country. Finally,

²³This area is known collectively as Southern Jutland (“Sønderjylland”) or North Schleswig (“Nordslesvig”).

Bornholm has deposits of brown coal which was mined during the period studied (Encyclopedia Denmark), and we have no data that allow us to control for this.

Potato suitable soils: We use a raster file from the Food and Agriculture Organization (FAO) which gives data for soil suitability of growing potatoes under conditions of rainfed agriculture; see Figure 5 and Nunn and Qian (2011) for details. We use as a baseline soil with at least a good level of suitability. To construct our measures, we use the fact that the market towns had local markets. We approximate the local market by a circle with a radius of 10 kilometers measured from the center of the town. The local markets varied historically from 1 (approximately 7.5 kilometers) to 4 Danish miles. In many cases, the radius was 2 miles, but the historical narrative suggests that this could often not be enforced.²⁴ We examine the robustness of this choice in the empirical analysis by choosing different radiuses. Thus, we calculate the share of soil with at least good suitability in a circle with a 10 kilometer radius as a benchmark. The share is calculated from the land mass within this 10 kilometer circle around each town. This is what we use to construct our *potato* measure in equations (1) and (2). The measure reflects the underlying suitability for growing potatoes. Similar measures are constructed for circles with a radius of 5 kilometers and 20 kilometers to check for the sensitivity of the distance from town.

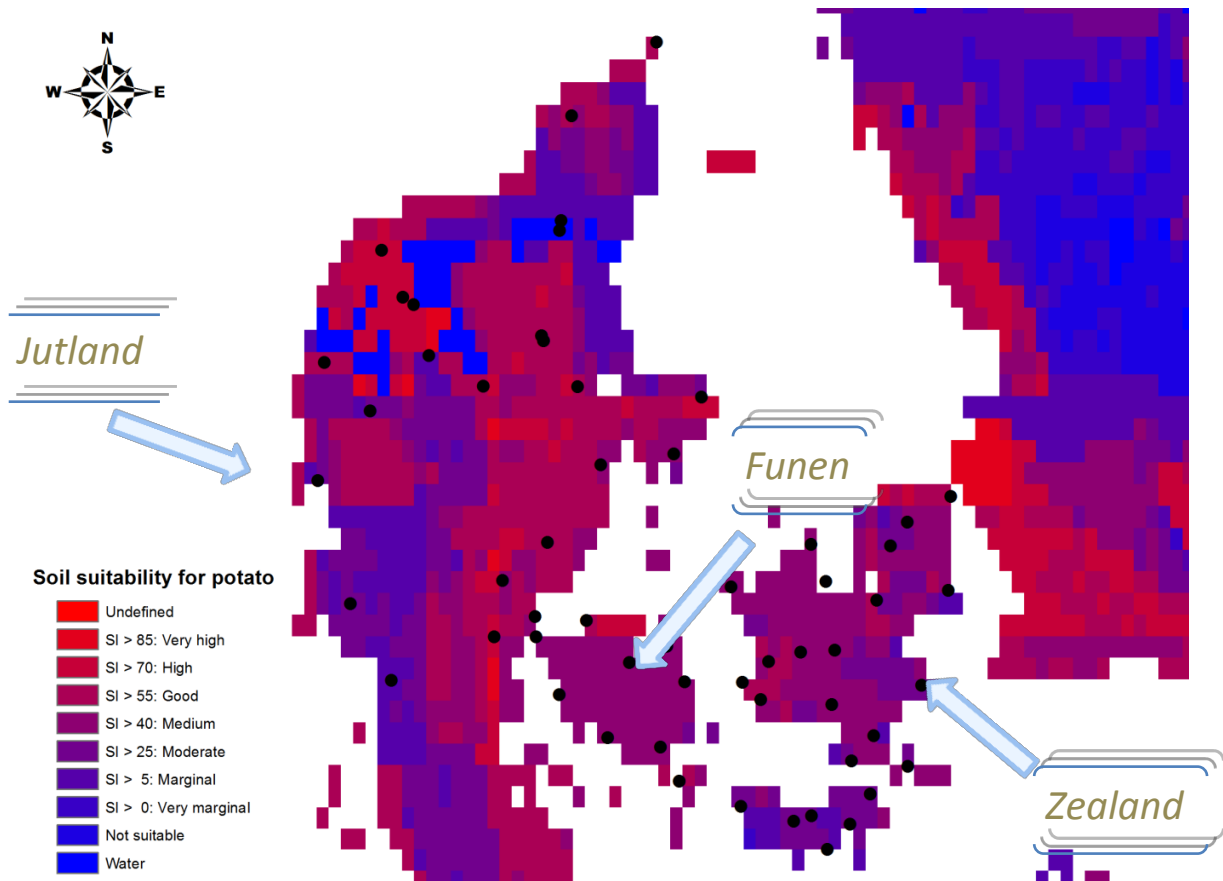
One concern about our use of the suitability maps from FAO may be that the soil conditions given on modern maps do not resemble those of the past. In the Danish case qualitative sources suggest that the ‘best’ potatoes are those grown on sandy soils and not the heavier clay soils (Madsen-Mygdal, 1938: p. 708). According to Madsen-Mygdal (1912), Denmark has good conditions for growing potatoes mainly due to the presence of sandy soils in Jutland.²⁵ Potato cultivation on these soils produces the best and tastiest potatoes. Two reasons are given by Madsen-Mygdal (1912, 1938). First, they are less susceptible to potato blight. Second, they are said to produce the most reliable food, industrial and fodder potatoes. Potatoes may be cultivated on heavier, clay soils with high yields, but the quality is lower as the potatoes tend to become “too big, watery and poor tasting.” (p. 708). This would also mean that the sandy soils are likely to be able to take better advantage of using potatoes as a

²⁴This is indicated in the market town descriptions by “den digitale byport.”

²⁵Jutland is the western peninsula of Denmark which has a land border with Germany to the south, see Figure 5.

source of food for human beings. Moreover, the historical narrative suggests that there were not large differences in yields across Danish localities, Bjørn (1988, p.45).²⁶

Figure 5: Soil suitability for growing potatoes



Note: Each town is shown by a dot.

Source: FAO raster data on soil suitability for potato.

The sandy soils are to a higher degree present in Jutland where we also find many areas with good soil suitability for growing potatoes under rainfed conditions according to the FAO legend. A map of the soil suitability for growing potatoes is shown in Figure 5, which shows the soil suitability levels and the location of towns. The areas in Jutland which have good soil suitability or better tend to be clayey sand soils or a mix of sand soils and clayey sand soils.

²⁶Data from the first agricultural census of 1837 supports this view, as soil suitability does not predict yields. It should be noted that these measures do not make quality adjustments. The historical narrative suggests that most areas would have similar yields, but these similarities do not correct for quality differences. Thus, it is plausible that quality-adjusted yields would vary across localities according to soil suitability.

The eastern islands of Funen and Zealand have less soil with good suitability or better.²⁷ The areas with medium suitability overlap with the heavier clay soils located in the eastern part of the country. This is particular true for the islands Lolland and Falster in southeast Denmark which have the heaviest soils in Denmark. Given this, we hypothesize that the towns that benefit most from potato adoption will be the ones that have better conditions for potato production.

We also note that Andersen, Jensen and Skovsgaard (2013) establish that the soil conditions of the late 20th century closely resemble those of late 19th century suggesting that present day soil maps proxy well for the past.

Clover adoption, 1805: We use Kjærgaard’s map for the distribution of clover adoption in 1805 which was collected on the basis of all “18th manor archives and a number of other sources” (Kjærgaard, 1995:p.6).²⁸ We calculate our clover measure from a digitized version of Kjærgaard’s map using the buffers described above. We measure the effect of clover by using data on the areas that had adopted this crop by 1805. According to Figure 2, clover had not been adopted in many areas prior to 1805. The 1805 distribution is probably close to an “equilibrium distribution”, and will include many areas with good suitability for growing clover. Yet, it is likely to be endogenous, and we therefore implement an instrumental variables strategy based on soil suitability for growing alfalfa as explained next. We also exploit Kjærgaard’s data for four available periods between 1775 and 1805.

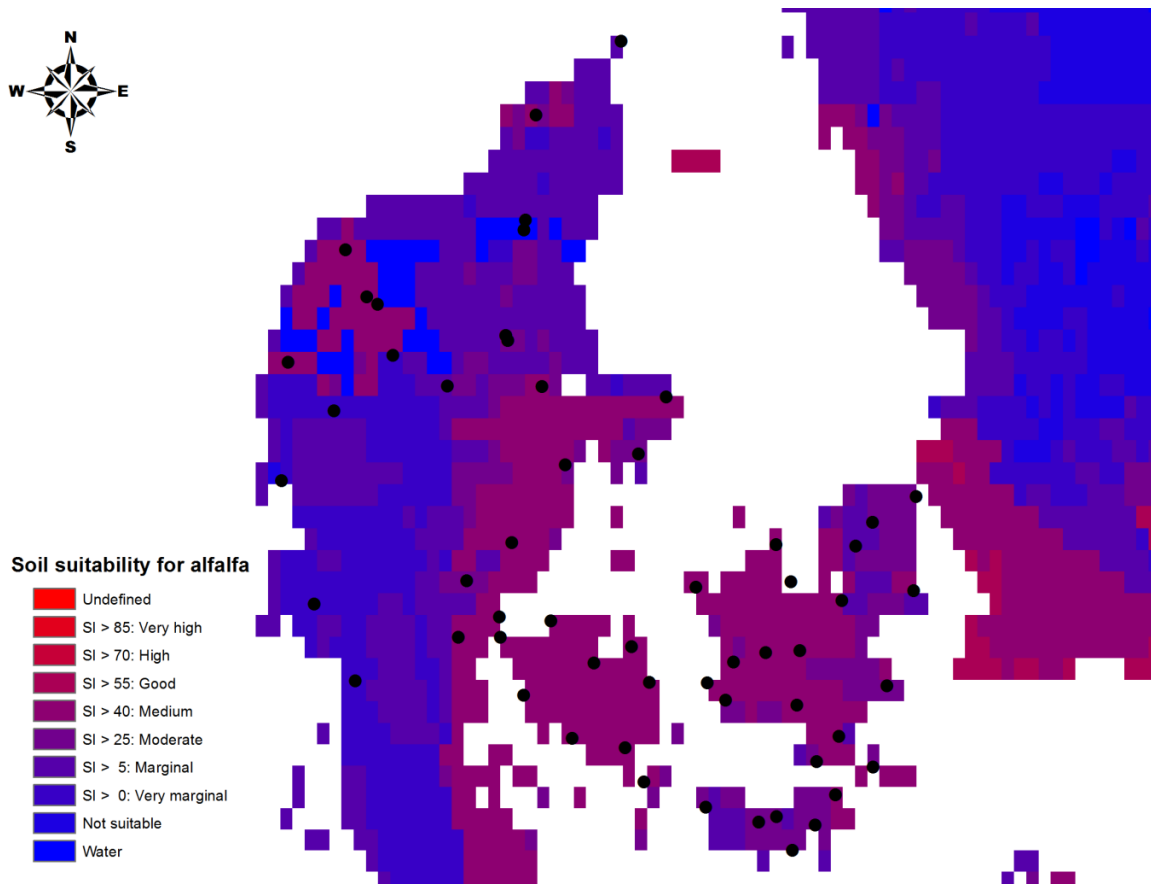
Alfalfa suitable soil: As for potatoes, we use a raster file from the Food and Agriculture Organization (FAO), see Figure 6. Clover and alfalfa are both legumes, and according to Danish supplier “Hunsballe”,²⁹ both clover and alfalfa prefer clay and clayey soils. This suggests that suitability for growing alfalfa also captures suitability for growing clover. Thus, we could interpret the measure more broadly as “suitability for growing legumes.” As Figure 6 indicates, the best soils for growing alfalfa have medium suitability, and we use this as our measure of alfalfa suitability.

²⁷It may be noted that western Zealand, where Søren Pedersen lived, has some soil of good suitability for growing potatoes.

²⁸For a more detailed description of methodological issues of establishing the maps of clover adoption in Denmark, see Kjærgaard (1991).

²⁹ Hunsballe is a supplier of amongst others clover seeds to the Danish agricultural sector dating back to 1921.

Figure 6: Soil suitability for growing alfalfa



Notes: Each town is shown by a dot.

Source: FAO raster data on soil suitability for alfalfa.

Alfalfa may have been grown in small amounts, but as stressed by Kjærgaard (1995) clover was the legume par excellence in Denmark. Kjærgaard (1991, p.71) notes that alfalfa was not widely adopted for climatic reasons. The historical narrative supports this. Brøndegaard (1978), for example, stresses that alfalfa was not widely adopted in the 19th century. This is also corroborated by handbooks on agriculture edited by Madsen-Mygdal (1912, 1938). Madsen-Mygdal (1912, p. 452) explains that Danish farmers had made many attempts at growing alfalfa which had been unsuccessful, and therefore they viewed the crop as too uncertain. He concludes that many farmers believed that alfalfa was unlikely to ever gain importance for this reason. In the 1938 version of the same handbook, it is reiterated that many farmers held the view that alfalfa is too uncertain under Danish conditions, Madsen-Mygdal (1938). This suggests that since alfalfa was not widely adopted in the period studied,

suitability for growing alfalfa does not affect town populations directly.³⁰ Thus, alfalfa suitability plausibly satisfies the exclusion condition for an instrumental variable.

As noted, Danish soils have at best medium soil suitability for alfalfa under rain-fed conditions. This is in line with the historical narrative which also indicates that clover was much better suited for Danish soils. Therefore, it is plausible that these soils capture the areas with better than medium suitable soil for growing clover.

Thus, the relevance of suitability for growing alfalfa and the exclusion restriction are plausibly satisfied. Regarding the relevance condition, we can further point to evidence from the agricultural census of Prussia of 1886 available in Prussian Economic History Database (Becker et al., 2012). Prussian farmers grew alfalfa perhaps due to better climatic conditions³¹ and, in fact, yields for clover and alfalfa are strongly correlated, see Appendix B.

Yet, alfalfa suitability is also required to be uncorrelated with the error term. This would fail if all clay soils in general were experiencing productivity changes. We return to this below.

Town and period fixed effects

We include town and period fixed effects to avoid confounding the effects of our variables of interests with town-specific and time-specific common factors:³²

Town fixed effects: These variables will capture spatial heterogeneity in terms of direct fixed effects of, for instance, soil quality and location in contrast to our focus on time-varying effects that arise due to the interaction between soil quality and the breakthrough of new crops. We also capture fixed effects of the geographic factors stressed by Percoco (2013),

³⁰Madsen-Mygdal (1912) speculated that alfalfa could be grown with success in some areas of Denmark as also indicated by the map. His discussion suggests that this is due to the climate, but he explains that the reason why growing alfalfa had failed was likely that farmers had not respected the requirements for growing alfalfa. He also mentions that some of these requirements have only recently become known.

³¹In line with this, Madsen-Mygdal (1912) emphasizes that countries with a continental climate, rather than a coastal climate, may obtain higher yields of alfalfa. Moreover, none of the present day Danish towns of Aabenraa, Sønderborg, Tønder or Haderslev—which in 1886 were part of Germany—grew any alfalfa, though they did grow clover. Data on alfalfa are also absent from the agricultural censuses for Denmark for the 19th century.

³²Most of the market towns have easy access to the sea. In fact, 50 out of 56 towns have direct access to the sea or rivers. In general, variation in distance to sea or rivers is limited for the Danish market towns, and we therefore do not control for a time-varying effect of this. Yet, we note that the town fixed effects capture direct access to the sea, and any direct effect of this.

such as altitude, and initial access to main roads. By including these, we make sure that we are not simply capturing town fixed effects.

Time fixed effects: Since we are interested in the differential impact of potatoes and clover on development, we need to include time effects such that any effect we are estimating is relative to a common shock and aggregate changes. Controlling for common shocks is also important, since the period studied was a time of institutional changes at the country level. For example, 18th century Denmark had serfdom which tied rural workers to the country side and this may have hampered town growth by itself (e.g. Christensen, 1945). Serfdom was a common shock to the whole country, and it is accordingly important to control for it. Similarly, in 1849 Denmark introduced male suffrage (e.g. Aidt and Jensen, 2014), which may also have affected overall growth, and this again will be captured by common time effects

4. Main results

The following subsections present our main results. We first present the results for the flexible model, then we move on to the non-flexible model for potatoes, and finally present flexible and non-flexible instrumental variables estimates.

Results from the flexible model

The results for the flexible model are shown in Table 1. We report two types of test statistics. The first estimate uses the standard errors corrected for town-specific clustering, whereas the second type is Conley t-statistics for which standard errors are corrected for spatial correlation in the error term. These allow for direct dependence between towns that are within 2 degrees, or roughly 222 kilometers, of each other.

We estimate models with the potato only, and then with the potato and the two legume measures separately. All three models suggest that there is little effect of the potato initially. The coefficients are small and imprecisely estimated until 1845, at which point significance is achieved for model 2 regardless of the assumed error structure. The other models suggest significance from 1855 to 1860. We note that the effect gets larger over time. ³³ This possibly captures that potatoes spread, but it may also capture that new types of potatoes which were more resistant to potato blight were introduced from England, Germany and the

³³Strictly speaking this means that the breakthrough takes places after 1801, and thus we code a dummy which is 1 from 1834 onwards and 0 otherwise.

US from the 1880s. Since these results are consistent with our prior knowledge of a breakthrough of the period 1820-1830, we estimate non-flexible models with a breakthrough date from 1834 onwards

As noted by Nunn and Qian (2011, p.613), a concern with this type of analysis is that areas that experienced rapid population growth also developed new types of potatoes that could be grown in these localities. Importantly in the Danish case, significant potato breeding started only from 1913 at the State Research Station of Tylstrup in Northern Jutland, which demonstrates that breeding is unlikely to have been a consequence of town population growth (Tolstrup, 2001).³⁴ Further discussion as to why breeding should not be regarded a major concern is provided by Nunn and Qian (2011).

Regarding the roles of clover and legumes, we get results suggesting that clover did have an effect on market town populations, but since we have significance for most of the period, we might suspect endogeneity bias, which we deal with below. When we use the alfalfa measure which is plausibly exogenous, we observe marginal significance in 1769 with standard errors correcting for clustering, but significance then disappears in 1787 and 1801, and then significance becomes more systematic from 1840 onwards. The coefficient on the alfalfa measure increases from 1787 to 1901 (with a small dip in 1880), whereas the clover measure increases until 1870 after which it decreases. The early effects of clover can plausibly be related to reverse causality as the measure represents the 1805 clover distribution. This may suggest that the clover adopting areas had higher urban population growth before adoption. The effects in the final years are more difficult to explain, but they might suggest that population pressure is taking off in the adopting areas. We deal with the endogeneity of clover below.

Results from non-flexible model

The non-flexible models reported in Table 2 all confirm that the potato had a positive and significant effect on town populations from 1834 onwards. The coefficient is fairly stable, though a little larger when we control for clover. The results on the flexible part of the models are largely unchanged.

³⁴We have also investigated whether it would be more appropriate to use medium or better soil suitability for potato soil suitability. We find that when we control for alfalfa that the effects of the potato are positive, but not significant at conventional levels. This squares with the historical narrative which emphasizes that it was the sandy soils in Jutland with good soil suitability that benefitted the most as we find consistently significant effects when we use soils with good soil suitability for growing potatoes.

Instrumental variables estimation

As we argued above, alfalfa did not have its breakthrough in Denmark until the 20th century for climatic reasons and knowledge about growing methods. Yet, suitability of growing clover and alfalfa are likely to be linked since they tend to grow on similar types of soils. Thus, it seems plausible that the exclusion restriction and the relevance condition are both satisfied. Yet, one could imagine that omitted variables are correlated with the soil types and the spread of clover are present. We deal with this concern in the robustness section below.

Table 3a reports the flexible instrumental variables estimation. The first stages that use time dummies interacted with suitability for growing alfalfa all show a positive coefficient on the corresponding year. For example, the coefficient on alfalfa*I(t=1769) is positive and highly significant. The Angrist-Pischke (2009) multivariate F-test of excluded instruments is 19.03 and highly significant with similar values for other years. Thus, the relevance of the instruments is established. The results are consistent with the early effects being zero since the associated coefficients are statistically insignificant.³⁵ Marginal significance is obtained from around 1840, which is in line with a breakthrough of clover after 1801 (which means from 1834 in our dataset).

³⁵A caveat to these estimations is that standard errors which correct for clustering by town may be invalid as reported by our statistical software. We therefore report standard errors which correct for heteroscedasticity only. Yet we note that this correction matters little for our other results in terms of significance when not correcting for clustering. Moreover, the potentially invalid standard errors that correct for clustering for the IV estimation give similar results. We also investigate reverse causality in a different manner below, where we correct for clustering, and note that we get results in line with the IV results.

Table 1: Flexible OLS estimates with 10 kilometer buffers

Regressors	Model 1			Model 2			Model 3		
	B	OLS	Conley	β	OLS	Conley	OLS	Conley	
		T-statistics			T-statistics		T-statistics		
Potato*I(t=1769)	0.012	0.076	0.096	0.137	0.834	1.192	0.006	0.038	0.047
Potato*I(t=1787)	0.018	0.117	0.146	0.126	0.796	1.049	0.014	0.09	0.108
Potato*I(t=1801)	0.058	0.356	0.459	0.188	1.197	1.441	0.052	0.331	0.407
Potato*I(t=1834)	0.089	0.473	0.674	0.251	1.391	1.732	0.082	0.448	0.611
Potato*I(t=1840)	0.106	0.56	0.792	0.266	1.474	1.773	0.099	0.537	0.73
Potato*I(t=1845)	0.158	0.864	1.332	0.324	1.805	2.304	0.15	0.844	1.235
Potato*I(t=1855)	0.306	1.464	2.202	0.47	2.43	3.135	0.297	1.448	2.066
Potato*I(t=1860)	0.371	1.725	2.486	0.543	2.735	3.419	0.361	1.725	2.344
Potato*I(t=1870)	0.452	2.021	2.669	0.614	2.951	3.625	0.442	2.043	2.538
Potato*I(t=1880)	0.546	2.312	3	0.658	2.905	3.748	0.537	2.348	2.88
Potato*I(t=1890)	0.702	2.692	3.989	0.801	3.135	4.856	0.692	2.773	3.952
Potato*I(t=1901)	0.815	2.786	3.962	0.914	3.189	4.747	0.804	2.861	3.96
Clover*I(t=1769)				0.455	2.391	3.223			
Clover*I(t=1787)				0.393	2.069	2.677			
Clover*I(t=1801)				0.478	2.788	3.822			
Clover*I(t=1834)				0.591	3.489	4.526			
Clover*I(t=1840)				0.584	3.404	4.511			
Clover*I(t=1845)				0.605	3.287	4.135			
Clover*I(t=1855)				0.6	3.306	3.995			
Clover*I(t=1860)				0.629	3.458	4.754			
Clover*I(t=1870)				0.589	2.94	4.557			
Clover*I(t=1880)				0.411	1.694	2.761			
Clover*I(t=1890)				0.36	1.217	2.199			
Clover*I(t=1901)				0.361	1.058	2.153			
Alfalfa*I(t=1769)							0.238	1.795	2.097
Alfalfa*I(t=1787)							0.167	1.174	1.391
Alfalfa*I(t=1801)							0.199	1.449	1.541
Alfalfa*I(t=1834)							0.272	1.724	1.884
Alfalfa*I(t=1840)							0.292	1.843	2.129
Alfalfa*I(t=1845)							0.305	1.965	2.394
Alfalfa*I(t=1855)							0.335	1.89	2.5
Alfalfa*I(t=1860)							0.371	2.067	2.71
Alfalfa*I(t=1870)							0.388	2.026	2.533
Alfalfa*I(t=1880)							0.346	1.656	2.065
Alfalfa*I(t=1890)							0.388	1.669	2.156
Alfalfa*I(t=1901)							0.431	1.661	2.243

Notes: All estimations control for year fixed effects and town fixed effects. Standard OLS estimates for robust SE clustering-corrected by town. Conley estimates corrected for spatial dependence in SE. The potato suitability measure is good or better (denoted Potato). The alfalfa suitability measure is medium or better (denoted Alfalfa). Clover is the share of land used for cultivating clover (denoted Clover). All are computed using the log transformation as in equations (1) and (2). I(t=c) is the dummy for year c. The dataset is a balanced panel with 56 market towns for 13 years yielding 728 observations

Table 2: Non-Flexible OLS estimates (potato only) with 10-kilometer buffers

Regressors	Model 1			Model 2			Model 3		
	β	OLS	Conley	β	OLS	Conley	β	OLS	Conley
		T-statistics			T-statistics			T-statistics	
Potato* I^{post}	0.372	2.992	4.508	0.425	3.481	4.954	0.367	3.064	4.563
Clover*I(t=1769)				0.391	2.244	2.521			
Clover*I(t=1787)				0.334	1.807	2.101			
Clover*I(t=1801)				0.389	2.175	3.032			
Clover*I(t=1834)				0.673	4.073	5.911			
Clover*I(t=1840)				0.658	3.911	5.788			
Clover*I(t=1845)				0.653	3.834	5.387			
Clover*I(t=1855)				0.579	3.081	4.109			
Clover*I(t=1860)				0.574	3.032	4.311			
Clover*I(t=1870)				0.501	2.436	3.392			
Clover*I(t=1880)				0.302	1.248	1.769			
Clover*I(t=1890)				0.184	0.648	0.956			
Clover*I(t=1901)				0.132	0.408	0.631			
Alfalfa*I(t=1769)							0.238	1.799	2.083
Alfalfa*I(t=1787)							0.168	1.179	1.391
Alfalfa*I(t=1801)							0.2	1.456	1.567
Alfalfa*I(t=1834)							0.266	1.647	1.646
Alfalfa*I(t=1840)							0.286	1.77	1.865
Alfalfa*I(t=1845)							0.3	1.912	2.146
Alfalfa*I(t=1855)							0.334	1.893	2.426
Alfalfa*I(t=1860)							0.371	2.085	2.701
Alfalfa*I(t=1870)							0.39	2.052	2.608
Alfalfa*I(t=1880)							0.349	1.689	2.219
Alfalfa*I(t=1890)							0.395	1.709	2.454
Alfalfa*I(t=1901)							0.44	1.7	2.569

Notes: All estimations control for year fixed effects and town fixed effects. Standard OLS estimates for robust SE clustering corrected by town. Conley estimates corrected for spatial dependence in SE. The potato suitability measure is good or better (denoted Potato). The alfalfa suitability measure is medium or better (denoted Alfalfa). Clover is the share of land used for cultivating clover (denoted Clover). All are computed using the log transformation as in equations (1) and (2). I^{post} is equal to one from 1834 onwards and zero otherwise. $I(t=c)$ is the dummy for year c. The dataset is a balanced panel with 56 market towns for 13 years yielding 728 observations.

Table 3a: Flexible IV estimation

Regressors	IV	First stage	OLS
	Log population	Clover* I(t=1769)	Log population
Potato* I^{post}	0.534*** (6.48)	0.0706** (3.12)	0.425*** (3.48)
Clover* I(t=1769)	0.729 (1.43)		0.391** (2.24)
Clover* I(t=1787)	0.513 (0.99)		0.334* (1.81)
Clover* I(t=1801)	0.612 (1.25)		0.389** (2.17)
Clover* I(t=1834)	0.802 (1.62)		0.673*** (4.07)
Clover* I(t=1840)	0.864* (1.77)		0.658*** (3.91)
Clover* I(t=1845)	0.908* (1.90)		0.653*** (3.83)
Clover* I(t=1855)	1.010** (2.14)		0.579** (3.08)
Clover* I(t=1860)	1.124** (2.39)		0.574** (3.03)
Clover* I(t=1870)	1.183** (2.49)		0.501** (2.44)
Clover* I(t=1880)	1.058** (2.11)		0.302 (1.25)
Clover* I(t=1890)	1.198** (2.15)		0.184 (0.65)
Clover* I(t=1901)	1.336** (2.14)		0.132 (0.41)
Alfalfa* I(t=1769)		0.327*** (4.36)	
Kilometers buffer	10	10	10
N	728	728	728

Notes: t statistics in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, robust SE. All estimations control for year fixed effects and town fixed effects. Standard OLS estimates for robust SE. The Potato suitability measure is good or better (denoted Potato). The alfalfa suitability measure is medium or better (denoted Alfalfa). Clover is the share of land used for cultivating clover (denoted Clover). All are computed using the log transformation as in equations (1) and (2). I^{post} is equal to one from 1834 and zero otherwise. $I(t=c)$ is the dummy for year c . The first stage is for Clover* $I(t=1769)$. Alfalfa interactions with time dummies for other years than 1769 are suppressed. I^{post} is equal to one from 1834 onwards and zero otherwise. The dataset is a balanced panel with 56 market towns for 13 years yielding 728 observations.

Table 3b: Non-flexible IV estimation

Regressors	IV	First stage	OLS
	Log population	Clover share	Log population
Potato* I^{post}	0.534*** (6.54)	-0.283*** (-9.33)	0.425*** (6.49)
Clover* I^{post}	0.590*** (3.58)		0.194** (2.41)
Alfalfa* I^{post}		0.333*** (12.45)	
N	728	728	728
Kilometers buffer	10	10	10
N	728	728	728
F statistic	155.027		

Notes: t statistics in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, robust SE. All estimations control for year fixed effects and town fixed effects. Standard OLS estimates for robust SE. The Potato suitability measure is good or better (denoted Potato). The alfalfa suitability measure is medium or better (denoted Alfalfa). Clover is the share of land used for cultivating clover (denoted Clover). All are computed using the log transformation as in equation (1). I^{post} is equal to one from 1834 and zero otherwise. (t=c) is the dummy for year c. The first stage is for Clover* I(t=1769). Alfalfa interactions with time dummies for other years than 1769 are suppressed. I^{post} is equal to one from 1834 onwards and zero otherwise. The dataset is a balanced panel with 56 market towns for 13 years yielding 728 observations.

Given the results for the flexible model, Table 3b follows the assumption of Falbe-Hansen (and Kjærgaard) in assuming that the widespread adoption happened from 1834 onwards (i.e. effects are assumed to appear after 1801). We note that the F-statistic is large suggesting that the instrument is strong. We used the IV model in Table 3b to calculate counterfactual contributions from potatoes and clover to market town population growth from 1672 to 1901, i.e. we use the estimated model to remove the effects of clover and potatoes in 1901. These calculations suggest that clover and potatoes can account for roughly 14 percent of the increase in log town populations from 1672 to 1901. On its own, clover can account for 7.7 percent, whereas potatoes can account for 6.4 percent. These effects are modest, yet not trivial. We next turn to checking robustness of results.

4.1 Robustness

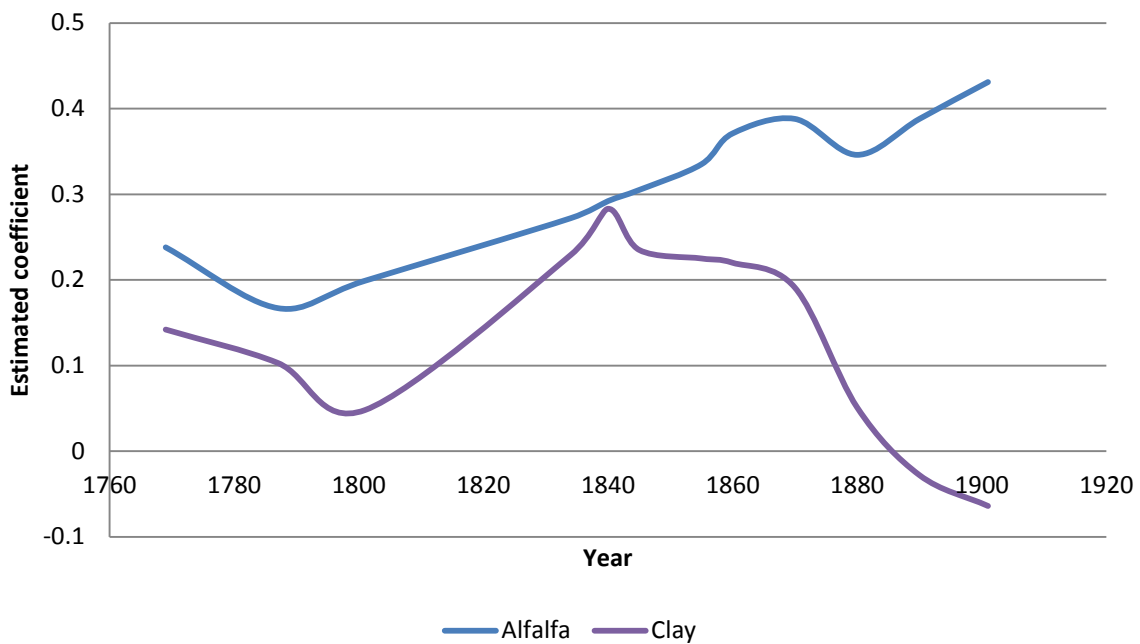
In this section, we consider a number of robustness checks. First, we dig into whether our results on clover simply capture a general development on clay soils which would affect the interpretation as well as the plausibility of the exclusion restriction for alfalfa suitability. Second, we consider institutional heterogeneity. Third, we investigate the size of the local markets as indicated by the size of the circles around the towns. Finally, we discuss results based on a larger set of market towns for which data are not available for all years.

General productivity increase of clay soils

While our use of suitability measures as sources of exogenous variation go some way in establishing that the results represent causal effects, concerns may remain. For example, we noted above that alfalfa and clover both tend to grow better on clay soils. Thus, a concern would be that we are simply capturing the effect of other variables that make clay soils more productive. Mokyr (1990, p.59) notes that new ploughs with a curved mouldboard were introduced in the Netherlands in the 17th century. The new ploughs had iron mouldboards as wood is difficult to shape into the desired form. They also tended not to have wheels, and fewer draft animals were needed. Further, the Rotherham plough or swing plough with an iron mouldboard was patented in England in 1730. It was first introduced in Denmark in 1770, though its general diffusion was much slower. According to Falbe Hansen (1887, pp.137-38), the swing plough replaced the old wheel plough with a wooden mouldboard gradually over time, but also led to improvements on the old wheel plough. He notes that in 1820, there were 10-wheeled ploughs for every swing plough. Kjærgaard (1991, p.111) argues that the diffusion was faster, and that ploughs with iron mouldboards were used on no less than two thirds of Danish farms at the end of the 18th century. As noted by Christensen (1996, p.640), contemporaries stressed that the functions of the plough were to turn the soil—which incorporates for example animal manure into the soil—and to cut the roots of weeds. Both the older heavy ploughs and the swing ploughs could carry out these functions, and they were arguably more important on clay soils where turning the soil was important for e.g. effective weed control because these soils offer more resistance than lighter soils (Andersen et al., 2013). Qualitative evidence on the use of the swing plough is given by Dinesen (1915, pp.138-39). He recalls that the wheel plough drawn by four horses was replaced by the swing plough on his father's farm on west Zealand in the 1840s. He describes the soils as

clay soils. This suggests that the clay soils may have gotten more productive because of new ploughs as well as the cultivation of clover. We address this concern by running a regression on the potato variable and the share of clay soil interacted with time dummies. If our IV results for clover and our reduced form results for alfalfa are simply capturing that the clay soils get more productive for a variety of reasons, we should expect to obtain a similar pattern as for alfalfa.

Figure 7: Clay soils and alfalfa suitable soil



Source: Own estimation results based on FAO raster data on soil suitability for alfalfa and raster data on clay soils.

The model with potato and alfalfa suitability may be viewed as a reduced form model as both measures are plausibly exogenous. If the plausibly exogenous variation in alfalfa captures an effect of clay soils, we would expect a similar pattern for the coefficients when we replace the alfalfa measure by clay soils. Model 3 in Table 4 which includes the share of clay soil suggests that it is unlikely that the results are driven by a general effect of clay soils. While the coefficients are positive and rising until 1840, they actually decrease from this period onward, and eventually become negative. Moreover, the t-statistics are never near significance at any conventional level. This suggests that, if anything, it was the clay soils, which were suitable for legumes that got more productive. This is also apparent from Figure 7, which plots the estimated coefficients for clay soils and alfalfa (interacted with time dummies). Andersen et al. (2013) provide evidence that the older heavy plough was

important for urbanization in clay soil areas in Denmark and Europe in general. Our results suggest that the new ploughs of the 18th century were perhaps not as big improvements as believed by some contemporaries. In fact, ploughing contests carried out from 1770-1820 also suggest that heavy ploughs could still compete with swing ploughs. For example, this was the case in the 1803 tests carried out by the Danish veterinary school (Christensen, 1996: p.632).

Institutional variation

The focus on Danish market towns means that the time fixed effects capture the institutional changes common to all parts of the country. While, all of the country had serfdom (known as “stavnsbaand”) from 1733 to 1800, the eastern islands of Zealand, Falster, Lolland and Møn had a version of serfdom known as “vornedskab” till 1701. The timing of the effects observed in the estimations above suggests that this is not a major concern, but we still test whether our results are driven by differences in institutional shocks by examining whether we get similar results if we focus on the parts of the country which have variation in soil suitability and a common institutional history. This leads us to focus on the island of Funen and the peninsular of Jutland. This leaves us with 35 market towns. The results in Table 5 suggest that our results are, in fact, not driven by this difference in institutional shocks. Yet, Table 5 shows marginal significance in 1769 and 1801 for the alfalfa measure, and this may be indicative of early effects of clover. We investigate this carrying out instrumental variables estimations on the reduced sample, and we find results similar to those for the full sample with no early effects, see Table 6a and 6b. We also looked at a measure that tracks time variation in clover adoption from 1775 to 1805, and find again that the early coefficients are statistically insignificant, see the next subsection.

Alternative measure of clover adoption

The instrumental variables estimates in Tables 3a, 3b, 6a and 6b suggest that there is no early effect of clover. As an alternative way of testing this, we exploit Kjærgaard’s maps, construct the adoption measure for each of the years 1775, 1785, 1795, and 1805, and run a new model where time dummies are interacted with the adoption measure for the closest year. The results are shown in models 2 and 3 in Table 7. We observe that the coefficient on the 1775 clover measure interacted with the dummy for the year 1769 is small and insignificant regardless of type of standard errors. The coefficient on the measure for 1787 doubles, but is still insignificant. For the 1795 measure interacted with the dummy for 1801, the coefficient

falls and is again insignificant with both type of specification. For years from 1834 onwards (i.e. after 1805), the coefficient is larger than for other years, and much more precisely estimated. Using the Conley type standard errors to correct for spatial correlation, we obtain significance at the one percent level. With standard errors that correct for clustering, significance is close to the 10 percent level from 1834. We therefore conclude that the signal of an effect becomes much stronger after 1805. For the Jutland and Funen sample in model 3, the coefficients show a less monotonic relationship, but the coefficients in the early periods are all insignificant with both types of standard errors, and significance is only achieved after 1805 at the ten percent level using standard errors that correct for clustering, and at the one percent level using the Conley standard errors. Thus, this approach is largely in line with the instrumental variables approach. Yet, we note that this clover adoption measure may still include some biases.

Alternative definition of local markets

We also check that the results are not driven by the choice of radius around a market town. Table 8 shows some representative results. Smaller radiuses of 5 kilometers tend to reduce the size of the effect, whereas larger radiuses make the effect slightly larger, though we observe that with the larger local markets we generally get less precise estimates. Thus, we conclude that results are not driven by the choice of the local market size.

Unbalanced panel

We have also re-estimated all models using a larger panel of market towns for which data are not available for all years, i.e. unbalanced data. This means that we can check whether, for example, excluding the remote island of Bornholm matters. The results, which are available upon request, are in fact very similar to those from the balanced panel. Moreover, with the unbalanced panel, we do not observe even marginal significance in 1769 for alfalfa as we do in Table 1. This reinforces our interpretation that there are no systematic early effects of clover as also shown in Tables 3, 4 and 7.

Table 4: Non-Flexible OLS estimates (potato only) with 10 kilometer buffers with reduced form for clay soils

Regressors	Model 1			Model 2			Model 3		
	OLS	Conley		OLS	Conley		OLS	Conley	
	β	T-statistics		β	T-statistics		β	T-statistics	
Potato* I^{post}	0.372	2.992	4.508	0.425	3.481	4.954	0.387	2.986	4.368
Alfalfa*I(t=1769)				0.238	1.795	2.097			
Alfalfa*I(t=1787)				0.167	1.174	1.391			
Alfalfa*I(t=1801)				0.199	1.449	1.541			
Alfalfa*I(t=1834)				0.272	1.724	1.884			
Alfalfa*I(t=1840)				0.292	1.843	2.129			
Alfalfa*I(t=1845)				0.305	1.965	2.394			
Alfalfa*I(t=1855)				0.335	1.89	2.5			
Alfalfa*I(t=1860)				0.371	2.067	2.71			
Alfalfa*I(t=1870)				0.388	2.026	2.533			
Alfalfa*I(t=1880)				0.346	1.656	2.065			
Alfalfa*I(t=1890)				0.388	1.669	2.156			
Alfalfa*I(t=1901)				0.431	1.661	2.243			
Clay* I(t=1769)							0.142	0.828	0.811
Clay* I(t=1787)							0.103	0.503	0.529
Clay* I(t=1801)							0.048	0.261	0.23
Clay* I(t=1834)							0.229	1.068	1.035
Clay* I(t=1840)							0.283	1.325	1.378
Clay* I(t=1845)							0.235	1.152	1.186
Clay* I(t=1855)							0.225	0.972	1.078
Clay* I(t=1860)							0.22	0.89	0.979
Clay* I(t=1870)							0.191	0.729	0.768
Clay* I(t=1880)							0.051	0.178	0.181
Clay* I(t=1890)							-0.028	-0.088	-0.084
Clay* I(t=1901)							-0.064	-0.176	-0.169

Notes: All estimations control for year fixed effects and town fixed effects. Standard OLS estimates for robust SE clustering-corrected by town. Conley estimates corrected for spatial dependence in SE. The potato suitability measure is good or better (denoted Potato). The alfalfa suitability measure is medium or better (denoted Alfalfa). Clay is the share of land which is classified as clay soils. All are computed using the log transformation as in equations (1) and (2). I^{post} is equal to one from 1834 onwards and zero otherwise. $I(t=c)$ is the dummy for year c. The dataset is a balanced panel with 56 market towns for 13 years yielding 728 observations

Table 5: Non-Flexible OLS estimates (potato only) with 10 kilometer buffers, Jutland and Funen

Regressors	Model 1			Model 2			Model 3		
	OLS	Conley		OLS	Conley		OLS	Conley	
	β	T-statistics		β	T-statistics		β	T-statistics	
Potato* I^{post}	0.375	2.225	3.607	0.484	2.584	4.509	0.346	2.254	3.66
Clover*I(t=1769)				0.379	2.002	2.181			
Clover*I(t=1787)				0.382	1.946	2.014			
Clover*I(t=1801)				0.441	2.338	3.002			
Clover*I(t=1834)				0.803	4.477	6.526			
Clover*I(t=1840)				0.798	4.411	6.271			
Clover*I(t=1845)				0.799	4.486	6.159			
Clover*I(t=1855)				0.701	3.595	4.872			
Clover*I(t=1860)				0.654	3.243	4.616			
Clover*I(t=1870)				0.547	2.46	3.283			
Clover*I(t=1880)				0.316	1.224	1.72			
Clover*I(t=1890)				0.177	0.582	0.985			
Clover*I(t=1901)				0.116	0.332	0.589			
Alfalfa*I(t=1769)							0.322	1.889	2.228
Alfalfa*I(t=1787)							0.267	1.444	1.773
Alfalfa*I(t=1801)							0.309	1.735	1.852
Alfalfa*I(t=1834)							0.413	1.967	1.875
Alfalfa*I(t=1840)							0.431	2.04	2.093
Alfalfa*I(t=1845)							0.435	2.151	2.226
Alfalfa*I(t=1855)							0.454	1.989	2.325
Alfalfa*I(t=1860)							0.493	2.144	2.748
Alfalfa*I(t=1870)							0.509	2.091	2.547
Alfalfa*I(t=1880)							0.464	1.793	2.195
Alfalfa*I(t=1890)							0.554	1.931	2.56
Alfalfa*I(t=1901)							0.593	1.825	2.528

Notes: All estimations control for year fixed effects and town fixed effects. Standard OLS estimates for robust SE clustering-corrected by town. Conley estimates corrected for spatial dependence in SE. The potato suitability measure is good or better (denoted Potato). The alfalfa suitability measure is medium or better (denoted Alfalfa). Clover is the share of land used for cultivating clover (denoted Clover). All are computed using the log transformation as in equations (1) and (2). I^{post} is equal to one from 1834 onwards and zero otherwise. $I(t=c)$ is the dummy for year c. The dataset is a balanced panel with 35 market towns for 13 years yielding 455 observations.

Table 6A: IV estimation, flexible for Funen & Jutland only

Estimator	IV	First stage	OLS
	Log population	Clover*1769	Log population
Potato* I^{post}	0.602*** (5.70)	6.665*** (40.30)	0.484*** (5.03)
Clover*I(t=1769)	0.698 (1.54)		0.379* (1.80)
Clover*I(t=1787)	0.578 (1.24)		0.382* (1.68)
Clover*I(t=1801)	0.669 (1.53)		0.441*** (2.02)
Clover*I(t=1834)	0.845* (1.95)		0.803*** (4.11)
Clover*I(t=1840)	0.883** (2.07)		0.798*** (4.13)
Clover*I(t=1845)	0.892** (2.14)		0.799*** (4.21)
Clover*I(t=1855)	0.934** (2.26)		0.701*** (3.72)
Clover*I(t=1860)	1.018** (2.47)		0.654*** (3.43)
Clover*I(t=1870)	1.053** (2.55)		0.547** (2.90)
Clover*I(t=1880)	0.954** (2.20)		0.316 (1.57)
Clover*I(t=1890)	1.149** (2.33)		0.177 (0.75)
Clover*I(t=1901)	1.235** (2.21)		0.116 (0.42)
Alfalfa* I(t=1769)		0.461*** (4.74)	
Kilometers buffer	10	10	10
N	455	455	455

Notes: All estimations control for year fixed effects and town fixed effects. Standard OLS estimates for robust SE clustering-corrected by town. Conley estimates corrected for spatial dependence in SE. The potato suitability measure is good or better (denoted Potato). The alfalfa suitability measure is medium or better (denoted Alfalfa). Clover is the share of land used for cultivating clover (denoted Clover). All are computed using the log transformation as in equations (1) and (2). I^{post} is equal to one from 1834 onwards and zero otherwise. I(t=c) is the dummy for year c. The dataset is a balanced panel with 35 market towns for 13 years yielding 455 observations

Table 6B: Non-flexible IV estimation

	IV	First stage	OLS
	Log population	Clover share	Log population
Potato* I^{post}	0.602*** (5.74)	-0.502*** (-16.57)	0.484*** (4.96)
Clover* I^{post}	0.510*** (3.79)		0.245** (2.49)
Alfalfa* I^{post}		0.508*** (18.19)	
Constant	6.881*** (102.21)	0.0748** (2.99)	6.935*** (98.95)
N	455	455	455
Kilometers buffer	10	10	10
N	728	728	728
Kleibergen-Paap rank Wald F statistic (weak identification)	330.9		

Notes: t statistics in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, robust SE. All estimations control for year fixed effects and town fixed effects. Standard OLS estimates for robust SE. The potato suitability measure is good or better (denoted Potato). The alfalfa suitability measure is medium or better (denoted Alfalfa). Clover is the share of land used for cultivating clover (denoted Clover). All are computed using the log transformation as in equations (1) and (2). I^{post} is equal to one from 1834 and zero otherwise. I^{post} is equal to one from 1834 onwards and zero otherwise.

Table 7: Early effect of clover based on standard OLS and Conley SE correcting for spatial dependence, 10 kilometers Buffer

Regressors	Model 1			Model 2			Model 3		
	β	OLS	Conley	β	OLS	Conley	β	OLS	Conley
		T-statistics			T-statistics			T-statistics	
Potato* I^{post}	0.425	3.481	4.954	0.425	3.499	4.915	0.484	2.604	4.492
Clover*I(t=1769)	0.391	2.244	2.521						
Clover*I(t=1787)	0.334	1.807	2.101						
Clover*I(t=1801)	0.389	2.175	3.032						
Clover*I(t=1834)	0.673	4.073	5.911						
Clover*I(t=1840)	0.658	3.911	5.788						
Clover*I(t=1845)	0.653	3.834	5.387						
Clover*I(t=1855)	0.579	3.081	4.109						
Clover*I(t=1860)	0.574	3.032	4.311						
Clover*I(t=1870)	0.501	2.436	3.392						
Clover*I(t=1880)	0.302	1.248	1.769						
Clover*I(t=1890)	0.184	0.648	0.956						
Clover*I(t=1901)	0.132	0.408	0.631						
Clover1775* I(t=1769)				0.005	0.006	0.009	0.555	0.739	0.901
Clover1785* I(t=1787)				0.187	0.821	1.129	0.272	0.889	1.108
Clover1795* I(t=1801)				0.128	0.62	1.029	0.142	0.508	0.665
Clover1805* I(t>=1834)				0.222	1.601	2.682	0.292	1.743	3.251

Notes: All estimations control for year fixed effects and town fixed effects. Standard OLS estimates for robust SE clustering-corrected by town. Conley estimates corrected for spatial dependence in SE. The potato suitability measure is good or better (denoted Potato). Clover is the share of land used for cultivating clover in 1805. Clover1775, Clover1785, Clover1795, Clover805 denote the share of land for cultivating clover in 1775, 1785, 1795 and 1805 respectively. All are computed using the log transformation as in equations (1) and (2). I^{post} is equal to one from 1834 and zero otherwise. $I(t=c)$ is the dummy for year c. The dataset used for model 1 and 2 is a balanced panel with 56 market towns for 13 years yielding 728 observations. In model 3, we use the 35 markets town on Funen and in Jutland.

Table 8: The effect of potato as of 1830 based on standard OLS and Conley SE correcting for spatial dependence, 5, 10 and 20 kilometers buffer

Regressors	Model 1			Model 2			Model 3		
	β	OLS	Conley	β	OLS	Conley	β	OLS	Conley
		T-statistics			T-statistics			T-statistics	
Potato* I^{post}	0.277	2.692	4.59	0.367	3.064	4.563	0.415	2.961	4.131
Alfalfa*I($t=1769$)	0.238	1.799	2.083	0.238	1.799	2.083	0.238	1.799	2.083
Alfalfa*I($t=1787$)	0.168	1.179	1.391	0.168	1.179	1.391	0.168	1.179	1.391
Alfalfa*I($t=1801$)	0.2	1.456	1.567	0.2	1.456	1.567	0.2	1.456	1.567
Alfalfa*I($t=1834$)	0.271	1.681	1.672	0.266	1.647	1.646	0.29	1.775	1.784
Alfalfa*I($t=1840$)	0.291	1.803	1.894	0.286	1.77	1.865	0.31	1.892	2
Alfalfa*I($t=1845$)	0.306	1.942	2.189	0.3	1.912	2.146	0.325	2.03	2.287
Alfalfa*I($t=1855$)	0.339	1.914	2.497	0.334	1.893	2.426	0.358	1.999	2.565
Alfalfa*I($t=1860$)	0.376	2.101	2.771	0.371	2.085	2.701	0.395	2.195	2.832
Alfalfa*I($t=1870$)	0.396	2.063	2.669	0.39	2.052	2.608	0.415	2.148	2.731
Alfalfa*I($t=1880$)	0.355	1.694	2.263	0.349	1.689	2.219	0.374	1.786	2.354
Alfalfa*I($t=1890$)	0.401	1.709	2.481	0.395	1.709	2.454	0.42	1.795	2.577
Alfalfa*I($t=1901$)	0.446	1.701	2.607	0.44	1.7	2.569	0.465	1.78	2.67
Buffer size		5			10			20	

Notes: All estimations control for year fixed effects and town fixed effects. Standard OLS estimates for robust SE clustering-corrected by town. Conley estimates corrected for spatial dependence in SE. The potato suitability measure is good or better (denoted Potato). The alfalfa suitability measure is medium or better (denoted Alfalfa). Clover is the share of land used for cultivating clover. All are computed using the log transformation as in equations (1) and (2). I^{post} is equal to one from 1834 and zero otherwise. $I(t=c)$ is the dummy for year c . The dataset is a balanced panel with 56 market towns for 13 years yielding 728 observations.

5. Conclusion

In this paper, we have evaluated the impact of clover and potatoes on Danish market town populations. We have presented evidence suggesting that both clover and potato mattered for development. In this way, the Danish case suggests that there is room for a role for both.

We are also able to demonstrate that our findings are unlikely to be driven by institutional heterogeneity, and that the results regarding clover do most likely not simply reflect that for example new ploughs were introduced. Moreover, if one accepts the exclusion restriction, which is that soil suitability for alfalfa, only works through the adoption of clover, we also provide an estimate of the causal effect of clover adoption. This effect seems to become

larger (see Table 3) over time, and supports the hypothesis that clover did contribute to the development of urban population.

Regarding the potato, our results are in line with the views of historians and other writers on its general breakthrough. This timing of the breakthrough is roughly 70-80 years later than the date used by Nunn and Qian (2011), and suggests that country heterogeneity in the adoption of the potato may be substantial. Moreover, using market towns we find that the potato can explain 6.6 percent of the change in the growth of market town populations. While lower than what found by Nunn and Qian, our results corroborate the overall conclusion of Nunn and Qian (2011) in the sense that the potato had importance. Further, the IV estimates suggest that clover may have been marginally more important than the potato for urbanization in Denmark.

The results for clover are of interest on their own as they demonstrate that Kjærsgaard (1991), Allen (2008) and others have rightly emphasized its developmental importance. The estimated effects suggest that the importance of clover for urbanization was about 7.7 percent of total market town population growth.

One may ask whether the results translate to other contexts.³⁶ As noted above, clover has also been deemed important for the case of England as suggested by Allen's estimates and the ones by Chorley (1981) for northwest Europe. This indicates some generality of our results, but as noted above, the English system of crop rotation was slightly different than the one used in Denmark. Moreover, alfalfa may have played some role in the German case as suggested by the Prussian Economic History Database. Nonetheless, the results indicate the importance of legumes in general and specifically depending on climatic conditions and knowledge, the different types of legumes were adapted at different stages across Europe.

Finally, we wish to discuss some caveats regarding the present research. First, our estimates do not disentangle the specific mechanism. Both clover and potatoes arguably helped directly to increase the production of food for human consumption, but also indirectly by working as animal fodder. The results of Allen (2008) suggest that the direct effect as a matter of biology should be there, but in practice it is likely to be difficult to disentangle these effects. Nonetheless, this is an important topic for future research. Second, our results are conditional on country-wide institutional changes, which are confounded with other common time

³⁶The work by Bustos et al. (2013) suggests that agricultural innovations may even drive local development today. They investigate the impact of genetically modified soy beans using data from Brazil.

specific effects. While we measure the importance of (parts of) geography, the effects of institutional change cannot be estimated, and we cannot evaluate the relative of importance of institutions vs. geographical factors. As suggested by Acemoglu et al. (2005b), institutions may be a fundamental cause of economic growth. One promising avenue for future research is to dig deeper into institutional changes across relatively homogenous geographies.

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Appendix A

Data sources:

Town population data come from “Den digitale byport” available at <http://www.byhistorie.dk/den-digitale-byport/>

Suitability maps are available from FAO’s Global Agro-Ecological Zones (GAEZ) database: <http://webarchive.iiasa.ac.at/Research/LUC/SAEZ/index.html>

Clover maps are digitized from original maps in Kjærsgaard (1991).

Information on growing clover and alfalfa in Denmark available from (only available in Danish- fact sheets are available upon request from the authors): <http://butik.hunsballe.dk/shop/frontpage.html>

Information on clay soils in Denmark – soil map digitized by Andersen, Jensen and Skovsgaard (2013) from Frandsen (1988).

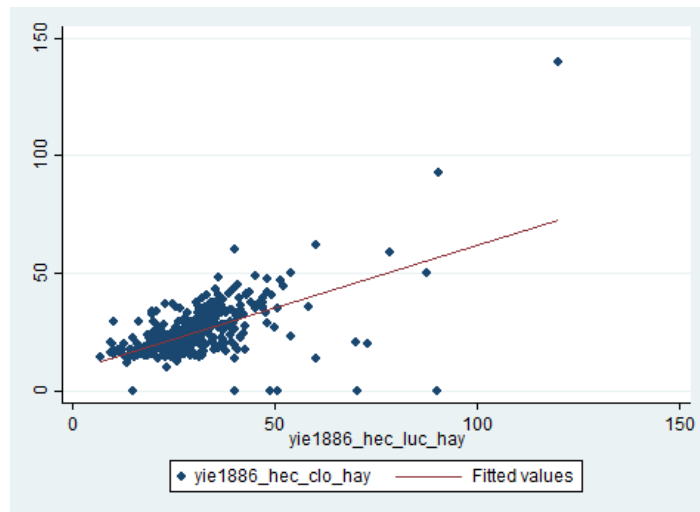
The Prussian Economic History database is described in Becker et al. (2010) and can be accessed at:

<http://www.cesifo-group.de/ifoHome/facts/iPEHD-Ifo-Prussian-Economic-History-Database.html>

Appendix B

In this appendix, we demonstrate that Prussian counties with higher alfalfa yields also tend to have higher clover yields. The data cover 518 counties in total. We run regressions for the 367 counties that produce some alfalfa, and find a positive and significant relationship. We can also include those with zero observations indicating zero production, though these seem less plausible to include. Yet including the zero observations does not change the results, and they are robust to Tobit estimation. Figures A1 and A2 show the associations between the yield measures with and without the zero observations.

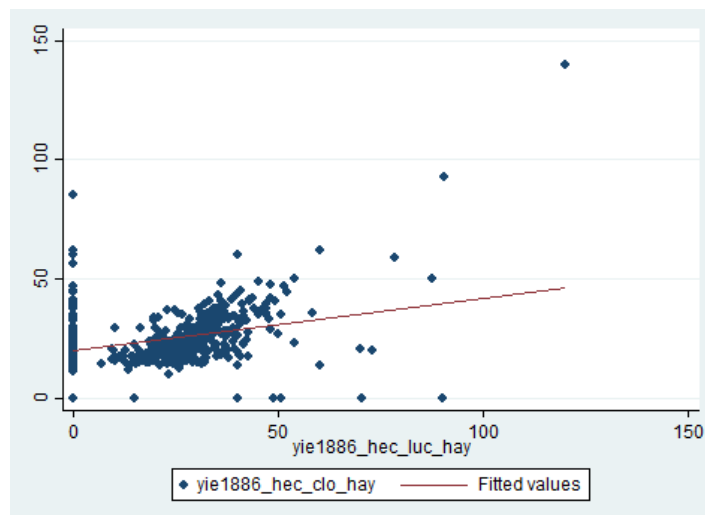
Figure A1: Alfalfa yields and clover yields, no zero observations.



Notes: yie1886_hec_luc_hay = alfalfa yield; yie1886_hec_clo_hay= clover yield.

Source: The agricultural census of Prussia of 1886 available in Prussian Economic History Database (Becker et al., 2012)

Figure A2: Alfalfa yields and clover yields, with zero observations.



Notes: yie1886_hec_luc_hay = alfalfa yield; yie1886_hec_clo_hay= clover yield.

Source: The agricultural census of Prussia of 1886 available in Prussian Economic History Database (Becker et al., 2012)

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