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Living standards in a dairy region, 1850–1900: from urban penalty to urban premium

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ABSTRACT

This paper adds to our knowledge and understanding of the time and space dimensions of the shift from an urban penalty to an urban premium effect on the biological standard of living in the second half of the nineteenth century. Although in the literature there is general agreement that urban-rural relations are part of the explanation of declining stature in the period of early economic growth (the so-called Komlos paradox), little is known about its exact timing and spatial dimensions. We use the province of Fryslân, the Netherlands, 1850–1900 as a case study to take a step towards filling this knowledge gap. The area is known for the early modernization of its agriculture, mainly specializing in dairy farming. We would expect a clear development towards an urban premium before 1900, but seek to investigate its timing and placing. This involves running a panel data regression on annual data per municipality, with annual coefficients estimated as interaction effects. The proportion of military conscripts that met the minimum height requirement is the explained variable. Population density and milk supply are the explanatory variables. Our analysis adds to the existing literature on the urban penalty and premium by, first, explicitly focusing on differences over time as well as over space in the relation between urbanization and living standards; second, by using population density data, which is a continuous variable, instead of a simple urban-rural dichotomous variable; and third, by taking into account the importance of dairy farming. The results show that the effect of the availability of milk, the dairy premium, was significantly positive over the period 1850–1900, but remained relatively constant. The effect of population density, however, shows a clear temporality, transitioning from statistically significant negative (urban penalty) to statistically significant positive (urban premium) from 1877 onwards.

In this paper we analyse the development over space and time of living standards in an early modernizing dairy farming region: the province of Fryslân, the Netherlands, in the period 1850–1900. We do so to examine two persistent results of anthropometric research on the nineteenth century that are often labelled together as the 'antebellum (or early industrial) growth puzzle'.[1] They are, firstly, a temporary decline in living standards in the period in which modern economic growth started (or the 'Komlos paradox'), and, secondly, a gradual reversal of the relation between population density and living standards, such that urban areas first had lower biological living standards, but later had higher ones. John Komlos started the discussion on the development of living standards with research on the United States before the Civil War (hence 'antebellum'), but the puzzle (or paradox) of declining stature in a period of rapid economic growth has also been found in other areas. On further thought, it was not that difficult to solve the puzzle and explain the paradox, as in general it was no more than the existing socioeconomic system needing time to adapt to the structural socioeconomic and technological transformations that modern economic growth brought.[2] What made it show up so clearly in

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[1] J. Komlos, Shrinking in a growing economy? The mystery of physical stature during the industrial revolution, *Journal of Economic History* 58 (1998) 779–802; J. Komlos and J. Baten, Looking backward and looking forward: anthropometric research and the development of social science history, *Social Science History* 28 (2004) 191–210.

[2] S. Kuznets, Modern economic growth: findings and reflections (Nobel memorial lecture), in: S. Kuznets, *Population, Capital, and Growth: Selected Essays*, London, 1971, 165–184.

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anthropometric data is that it related in particular to changes in food supply. Traditional agricultural societies were less specialized and consequently less vulnerable to supply shocks (bad harvests, for example) than modernized societies.[3] Specialization, on the other hand, required accompanying improvements in storage and transport facilities, but there was often a time lag in their provision.[4]

This relates directly to the discussion of living standards in urban as opposed to rural areas. The idea of an urban penalty or urban premium is related to the effect that living in a high-density urban environment has on wellbeing and the standard of living. Since the early days of modern anthropometric research, height differences between cities and rural areas have received attention.[5] There is evidence that during the early stages of industrialization of the economy and modernization of society the stature of urban dwellers was significantly below those of people residing in rural areas. Consequently, they suffered from an urban penalty.[6] Height differences mentioned are in the order of several centimetres.[7] The situation in the Netherlands before 1870 seems to fit this pattern. A study of Dutch prisoners points out that residents of large or middle-sized towns were more stunted than other prisoners.[8] Crude anthropometric data indicate that even in small towns the conditions often were less favourable than in rural areas.[9]

On the other hand, in mature modernized areas, urban centres are seen as focal points for economic growth, and consequently the areas with highest living standards: an urban premium.[10] Nineteenth-century researchers, mainly with a medical background, themselves noticed (or suggested) both the urban penalty in the early period and the urban premium in the later one.[11] Improvements in infrastructure and food processing and storage, the establishment of municipal sanitation departments, and the sharp decrease in food prices after 1883 may all have contributed to the urban penalty's disappearance in the late nineteenth century.[12] In his overview of physical stature in the Netherlands for the birth cohorts 1815–1865, Hans de Beer states that 'There is some evidence that living in an urban environment had fewer disadvantages from the middle of the [nineteenth] century onwards'.[13] This tentatively worded conclusion illustrates that there is general agreement that there was a change, but not on when exactly this change occurred. In this paper we try to give a more specific periodization.

Human height is influenced by the quality and quantity of nutrition and the (adverse) effects of disease and workload.[14] Both may differ between urban and rural areas. Two causes of the urban penalty for early modern areas stand out. In the first place, urban environments generally were less healthy than rural ones. Not only did high population density contribute to the spread of contagious diseases, but it also affected hygienic circumstances. Laurent Heyberger labels this the 'unfavorable epidemiological context of urban areas'.[15] Side effects of high concentrations of people were the inadequate supply of fresh and clean water and insufficient drainage, as well as inadequate removal of garbage, human excrement and animal droppings. Air pollution from manufacturing industries, which had direct and adverse effects on living standards, was also more severe in urban areas.[16]

In the second place, cities had a system of food supply that depended more on the market than in rural areas.[17] For their nutritional intake, urban dwellers relied more on buying food, whereas in rural areas people could grow their own. In the countryside, a substantial proportion of even the non-agricultural workers were able to cultivate grain and potatoes on their plots and breed some animals for meat and dairy products.[18] Although this was more of a relative than an absolute contrast between city and countryside, as a considerable number of urban dwellers also raised their own pig or cattle or grew a small field of grain, the fact that the supply and consequently the prices and availability of foodstuffs in cities were dependent on transportation, often made market dependence a problem, in particular in times of decreasing

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[3] J.W. Drukker and P.G. Tassenaar, Paradoxes of modernization and material well-being in the Netherlands during the nineteenth century, in: R.H. Steckel and R. Floud (Eds), *Health and Welfare During Industrialization,* Chicago, 1997, 331–378; M.R. Haines, Growing incomes, shrinking people – can economic development be hazardous to your health? Historical evidence for the United States, England, and the Netherlands in the nineteenth century, *Social Science History* 28 (2004) 249–270.

[4] W.W. Cronon, *Nature's Metropolis: Chicago and the Great West*, New York, 1991; P.D. Groote, J.P. Elhorst and P.G. Tassenaar, Standard of living effects due to infrastructure improvements in the 19th century, *Social Science Computer Review* 27 (2009) 380–389.

[5] R.W. Fogel, S.L. Engerman and J. Trussel, Exploring the uses of data on height: the analysis of long-term trends in nutrition, labor welfare and labor productivity, *Social Science History* 6 (1982) 401–421; R.A. Margo and R.H. Steckel, Heights of native-born whites during the antebellum period, *Journal of Economic History* 43 (1983) 167–174; L. Heyberger, Received wisdom versus reality: height, nutrition, and urbanization in mid-nineteenth-century France, *Cliometrica* 8 (2014) 115–140.

[6] Drukker and Tassenaar, Paradoxes of modernization; J. Baten and J.E. Murray, Heights of men and women in 19th-century Bavaria: economic, nutritional, and disease influences, *Explorations in Economic History* 37 (2000) 351–369; H. De Beer, Physical stature and biological living standards of girls and young women in the Netherlands, born between 1815 and 1865, *The History of the Family* 15 (2010) 60–75; V. Tassenaar, Development of regional variety of the biological standard of living in the Netherlands, 1812–1913, *Economics and Human Biology* 17 (2019) 151–161.

[7] M. Blum and J. Baten, Anthropometric within-country inequality and the estimation of skill premia with anthropometric indicators, *Jahrbuch Für Wirtschaftswissenschaften/Review of Economics* (2011) 107–138; P. Riggs, The standard of living in Scotland, 1800–1850, in: J. Komlos (Ed), *Stature, Living Standards, and Economic Development*, Chicago, 1994, 60–75.

[8] De Beer, Physical stature and biological living standards.

[9] V.M. Oppers, *Analyse van de Acceleratie van de Menselijke Lengtegroei door Bepaling van het Tijdstip van de Groeifasen,* Amsterdam, 1963; M. Kopczynski, The physical stature of Jewish men in Poland in the second half of the nineteenth century, *Economics and Human Biology* 9 (2011) 203–210.

[10] J. Reis, 'Urban premium' or 'urban penalty'? The case of Lisbon, 1840–1912, *Historia Agraria: Revista De Agricultura e Historia Rural* 47 (2009) 69–94.

[11] L. Egeling, Verslag namens de Commissie voor Statistiek der Nederlandsche Maatschappij tot Bevordering der Geneeskunst, *Nederlandsch Tijdschrift voor Geneeskunde* 2 (1858) 481–489; J. Zeeman, Rapport van de Commissie voor Statistiek over de lotelingen van de provincie Groningen van 1836–1861, *Nederlandsch Tijdschrift voor Geneeskunde* 5 (1861) 691–723; L. Bolk, Over de lichaamslengte der Nederlandse bevolking in Nederland, *Nederlands Tijdschrift voor Geneeskunde* 53 (1909) 1703–1721. See also V. Tassenaar, Antropometrie als instrument voor de geneeskunst. Onderzoek en publicaties van Nederlandse medici (1849–1869), *Studium* 7 (2014) 65–81.

[12] P. Groote, J. Jacobs and J.E. Sturm, Output effects of transport infrastructure: the Netherlands, 1853–1913, *Tijdschrift voor Economische en Sociale Geografie* 90 (1999) 97–109; P. Groote and V. Tassenaar, Hunger and migration in a rural-traditional area in the nineteenth century, *Journal of Population Economics* 13 (2000) 465–484; M.S.C. Bakker, Techniek en voeding in verandering, in: H.W. Lintsen (Ed), *Geschiedenis van de Techniek in Nederland; de Wording van een Moderne Samenleving 1800–1890; Deel I Techniek en Modernisering; Landbouw en Voeding*, Zutphen, 1992, 253–277; H. Van Zon, Openbare hygiëne, in: H.W. Lintsen (Ed), *Geschiedenis van de Techniek in Nederland; de Wording van een Moderne Samenleving 1800– 1890. Deel II Gezondheid en Openbare Hygiëne; Waterstaat en Infrastructuur; Papier, Druk en Communicatie*, Zutphen, 1993, 47–77; J.L. Van Zanden and A. van Riel, *Nederland 1780 –1914. Staat, Instituties en Economische Ontwikkeling*, Amsterdam, 2000.

[13] De Beer, Physical stature and biological living standards, 70.

[14] Baten and Murray, Heights of men and women; V. Tassenaar, *Het Verloren Arcadia: De Biologische Levensstandaard in Drenthe, 1815–1860*, Capelle aan den IJssel, 2000.

[15] Heyberger, Received wisdom versus reality, 116–117.

[16] Reis, 'Urban premium' or 'urban penalty'?

[17] Komlos, Shrinking in a growing economy; Tassenaar, *Het Verloren Arcadia.*

[18] E. Depauw, Tall farmers and tiny weavers: rural living standards and heights in Flanders, 1830–1870, *Tijdschrift voor Sociale en Economische Geschiedenis* 14 (2017) 56–84.

supply (seasonal or incidental, such as crop failures or blockades) or falling relative incomes in urban areas.[19]

In particular, the availability of high-protein products (such as milk), which have a favourable effect on physical wellbeing and consequently on the biological standard of living, was more restricted in urban areas than in rural ones.[20] The limited storage life of fresh milk made transport even over short distances almost impossible.[21] Also, the quality of these products often was lower, partly due to meddling by suppliers and brokers.[22]

In anthropometric research, the discussion over the balance between these factors — 'care and cure' versus food — is still unresolved. We want to add to this debate, in particular by focusing on the time-space patterns of changes in the effects of population density and the supply of fresh milk on the biological standard of living. As we only have aggregated data available at the level of municipalities, we will not be able to directly test effects for individuals, and we must be aware of the risk of the ecological fallacy.[23]

Our study focuses on one province of the Netherlands, namely Fryslân, in the second half of the nineteenth century. Fryslân is a very interesting case, as it is an area that modernized relatively early, in particular by specializing in market oriented dairy farming.[24] Fryslân traditionally consisted of forty-one municipalities, of which eleven were classified as cities, and the remaining thirty as rural (omitting the Wadden Islands which have been left out of our analysis).[25] Crucially, these urban municipalities only contained the city itself without large tracts of rural hinterland. This makes the high population density in cities more visible. Both aspects — the focus on dairy farming and the spatial-administrative differentiation between urban and rural areas — make Fryslân an interesting laboratory for using data on biological standards of living (derived from the heights of young men measured for military conscription) and milk production to examine the change from an urban penalty to an urban premium, and the role that the availability of dairy products played in this.

Our analysis adds to the existing literature in three ways. First, we analyse and explain differences in living standards over time as well as over space, in an integrated (panel data) analysis. Previous studies have often focused on long term development or on regional differences, but not both at the same time in an integrated analytical framework. Second, we integrate data on population density and the availability of milk, instead of focusing on one and omitting the other (or using it at best as a control variable). Both explanatory variables, as well as the explained variable, are measured at the same geographical level, namely the municipality. Finally, we apply population density data for the municipalities as a continuous variable that indicates the level of urbanization. Often urbanization is measured not as a continuous variable, but as a discrete (dichotomous) one, with 'urban' and 'rural' as the only possible values.[26] Our option obviously gives a higher level of information to be used in the model and consequently a higher power of statistical testing. It allows for annual variation in the degree of urbanization that is not possible with a dichotomous variable. Obviously, 'urbanization' as a concept encompasses more aspects than just population density, but the latter is the most widely used indicator of the former and seems suitable for our analysis.[27] The factors mentioned above in the discussion of the urban penalty (nutritional situation and disease environment) relate to the number of people living together in a restricted area. As a result, we are able to go beyond testing simply whether an urban penalty or urban premium existed at a specific moment in time in a specific area, and we can move towards an assessment of how large (or small) it was, how it developed over time and space, and how it interacted with the availability of milk as the main high-protein foodstuff.

Data: Population density, dairy production and conscript height

The province of Fryslân is located in the north of the Netherlands. Its northern and western parts had fertile clay soils on which a modern and efficient system of agriculture had developed relatively early, well before the middle of the nineteenth century.[28] Agriculture focused here on relatively large scale dairy farming. The eastern part of the province had sandier soils, which were in the nineteenth century still interspersed with peat extraction areas. On these sandy soils, the agricultural system was less market oriented and efficient than in the clay areas. Fig. 1 shows the tripartite regionalization as mapped in 1922 by the Dutch central statistical office (CBS), in its first regional subdivision of the Netherlands, developed in cooperation with the Royal Dutch Geographical Society (KNAG). The southwestern parts of the province were originally covered with peat. Drainage and digging of that peat from the late Middle Ages led to a gradual subsidence of ground levels. Consequently, the soil became less suitable for arable or mixed farming. Farmers in the region started to specialize in dairy farming, with some additional manufacturing, and turned the southwest into pastureland.[29] To meet the demand for cereals, the region had to import grain, mainly from the Baltic. Thanks to the resulting development of interregional trade, the central places in the area became nodes in the trade network. The northern rim of the province consisted of fertile clay soils and was higher above groundwater levels than the southwestern area. This was particularly so for the areas that had been reclaimed from the sea. This allowed farmers to specialize in labour-intensive arable farming. In this part of Fryslân potatoes gradually became a dominant crop. They were mainly exported to Holland and the rest of Europe.[30] This area was less homogenous than the southwest, and pastureland was present as well, in particular in lower-lying areas.[31] The third region, in the east, consisted of a combination of peat and sandy soils that until the advent of artificial fertilizers only allowed some barely profitable mixed farming and small-scale peat digging.

[19] Heyberger, Received wisdom versus reality.

[20] Tassenaar, *Het verloren Arcadia*; Komlos and Baten, Looking backward and looking forward; J. Baten, Protein supply and nutritional status in nineteenth-century Bavaria, Prussia and France, *Economics and Human Biology* 7 (2009) 165–180; Blum and Baten, Anthropometric within-country inequality.

[21] Baten, Protein supply and nutritional status.

[22] J.A. Verdoorn, *Het Gezondheidswezen te Amsterdam in de 19e eeuw*, Nijmegen, 1981; De Beer, Physical stature and biological living standards.

[23] H. De Beer, Dairy products and physical stature: a systematic review and meta-analysis of controlled trials, *Economics and Human Biology* 10 (2012) 299–309.

[24] M. Knibbe, *Agriculture in the Netherlands 1851–1950: Production and Institutional Change*, Amsterdam, 1993.

[25] Although most were the size of towns, we prefer labelling them all as cities to keep to the local tradition.

[26] For example, De Beer, Physical stature and biological living standards.

[27] L. Wirth, Urbanism as a way of life, *The American Journal of Sociology* 44 (1938) 1–24; S. Milgram, The experience of living in cities, *Science* 167 (1970) 1461–1468.

[28] H. De Vries, *Landbouw en Bevolking tijdens de Agrarische Depressie in Friesland (1878–1895)*, Wageningen, 1971.

[29] R. Vermoesen, The Low Countries, 1000–1750, in: L. van Molle and Y. Segers (Eds), *Rural Economy and Society in North-Western Europe, 500–2000. The Agro-food Market: Production, Distribution and Consumption*, Turnhout, 2013, 199–223.

[30] P.R. Priester, *De Economische Ontwikkeling van de Landbouw in Groningen 1800–1910: een Kwalitatieve en Kwantitatieve Analyse*, Groningen, 1991; R.F.J. Paping, *Voor een Handvol Stuivers*, Groningen, 1995.

[31] M. Knibbe, *Lokkich Fryslân. Landpacht, Arbeidsloon en Landbouwproductiviteit in het Friese Kleigebied*, Groningen/Wageningen, 2006.

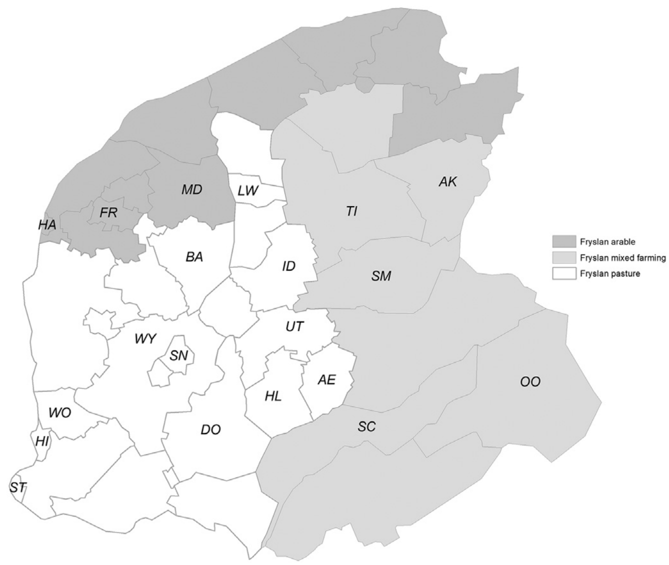

Fig. 1. Regional subdivision of Fryslân in 1922 (CBS), with names of municipalities mentioned in the text. AK = Achtkarspelen, AE = Aengwirden, BA = Baarderadeel, DO = Doniawerstal, FR = Franeker, HA = Harlingen, HL = Haskerland, HI = Hindeloopen, ID = Idaarderadeel, LW = Leeuwarden, MD = Menaldumadeel, OO = Ooststellingwerf, SM = Smallingerland, SN = Sneek, ST = Stavoren, TI = Tietjerksteradeel, UT = Utingeradeel, WO = Workum and WY = Wymbritseradeel.

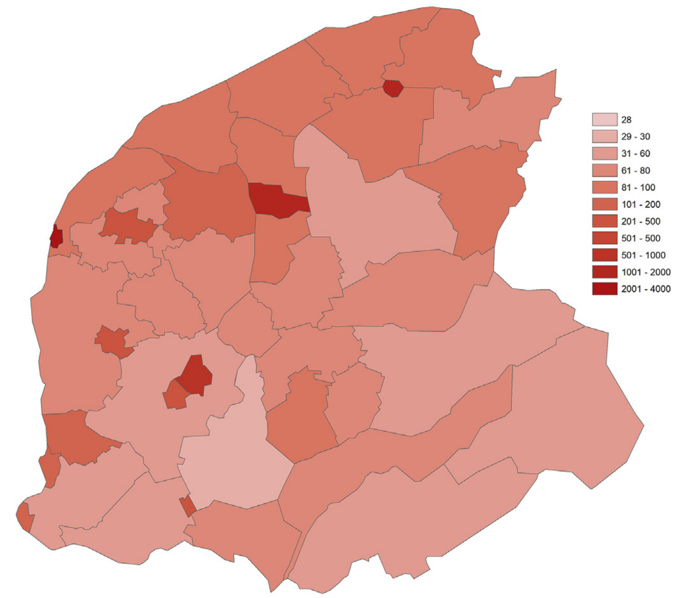

Fig. 2. Population density by municipality, 1857 (inhabitants per square kilometre).

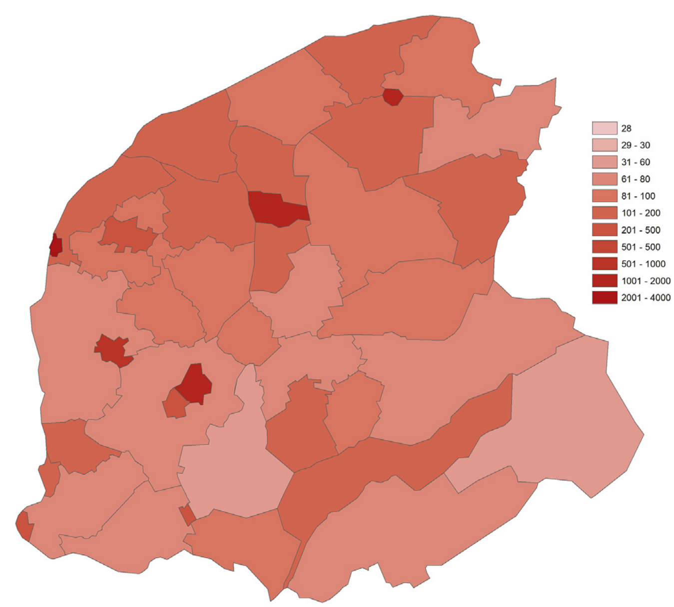

Fig. 3. Population density by municipality, 1898 (inhabitants per square kilometre).

The resulting rural poverty made the area one of the cradles of socialist political thinking in the Netherlands in the nineteenth century.[32]

Data on population size per municipality were taken from the *Historische Databank Nederlandse Gemeenten* (Historical Database of Dutch Municipalities) which has been made available on a CD accompanying an atlas of social change in the Netherlands.[33] Areal size of each municipality was calculated in a Geographical Information System (ESRI ArcGIS 10.2) from a shapefile with the municipal boundaries for 1850.[34] Fryslân's eleven cities differed greatly in population size, ranging in 1850 from 640 inhabitants (Stavoren) to 24,500 (Leeuwarden). As the area of the urban municipalities was relatively small, rural municipalities sometimes had larger population sizes (but not population densities) than the majority of the cities. The 1899 census data show that the municipalities with lower population densities did not contain towns with high population densities.[35] Even the town of Drachten, which in the twentieth century had important central place functions, contained only 2500 inhabitants in 1899, which was not even twenty-five percent of the municipal population. This contrasts sharply with, for example, the urban municipality of Sneek, where the population of the eponymous city itself (11,100 people) accounted for ninety-two percent of the total municipal population. As a result of this, municipal data on population density are a valid indicator of urbanity.

Figs. 2 and 3 are maps of population densities for the municipalities for 1850 and 1900. The highest municipal population densities were recorded in the cities of Harlingen and Leeuwarden (in 1850, respectively 3200 and 1260 inhabitants per square kilometre). The city with the lowest population density was Workum with ninety-five inhabitants per square kilometre, which was marginally lower than the non-urban municipality with the highest population density (Menaldumadeel with 101 inhabitants per

[32] J. Frieswijk, The labour movement in Friesland, 1880–1918, *Tijdschrift voor Sociale Geschiedenis* 18 (1992) 370–388.

[33] E. Beekink, O. Boonstra, T. Engelen and H. Knippenberg, *Nederland in Verandering: Maatschappelijke Ontwikkelingen in Kaart Gebracht*, Amsterdam, 2003.

[34] Shapefiles for all municipalities in the Netherlands in the nineteenth century have been made available by Dr Onno Boonstra, downloadable from the DANS website: doi:10.17026/dans- xb9-t677 last accessed 21 August 2018.

[35] Centraal Bureau voor de Statistiek, *Uitkomsten der Achtste Tienjaarlijksche Volkstelling in het Koninkrijk der Nederlanden gehouden op den Een en Dertigsten December 1899 (met Uitzondering van de Beroepstelling en de Woningstatistiek) = Résultats du Huitième Recensement de la Population du Royaume des Pays-Bas au 31 Décembre 1899 (à l'Exception du Dénombrement Professionel et de la Statistique des Habitations)/7, Provincie Friesland = Province de la Frise*, 's-Gravenhage, 1901.

square kilometre).

Annual data on dairy production are not directly available at the municipal level.[36] For the years 1850–1876 and 1889–1900, the annual provincial reports for Fryslân contain data on the number of cattle per municipality.[37] We have used these for the available years and estimated the other years through linear interpolation. The resulting data are in line with the graphs Spahr van der Hoek included in his seminal work on agriculture in Fryslân.[38] For some years detailed figures on the type of cattle are given, subdivided into dairy cows, bulls, oxen and calves, but for most years there is only a total number. The proportion of dairy cows was fairly stable over time at around eighty percent. There were, however, some differences between municipalities, with the northeastern ones having a share of oxen of around ten percent, whereas in the remaining municipalities hardly any oxen were mentioned. As these differences were relatively minor and detailed data were available for only a very limited number of years, we only used the total numbers.[39] Any bias introduced by doing so would most probably work against a hypothesis that would stress the importance of local dairy production.

In 1850 there were 188,000 cattle in Fryslân; in 1900, 239,000. In the period 1850–1900 the municipality with the highest number of cattle per head was Doniawerstal in 1852 with 2.591 cows per head of population. The lowest number was in Harlingen in 1861, with 0.009 cows per inhabitant. Figs. 4 and 5 show maps for the situation in 1860 and 1900.

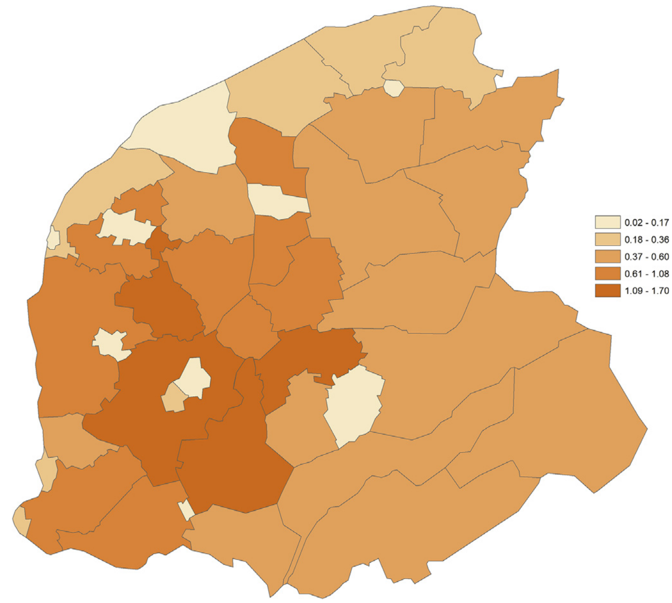

Fig. 4. Number of dairy cattle per inhabitant by municipality, 1857.

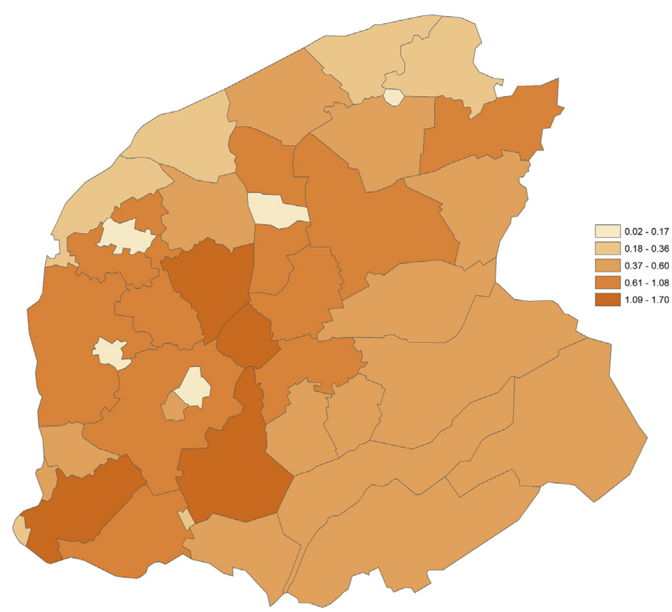

Fig. 5. Number of dairy cattle per inhabitant by municipality, 1898.

The data on the biological standard of living are derived from the military registers. In 1817 the Netherlands introduced general conscription. From this year onwards, all male inhabitants of the Netherlands with Dutch nationality had to be medically examined in the year they reached the age of nineteen. This examination included the measurement of height. Although conscripts had to meet a minimum height to be enrolled in the army, the information on stature was collected and included in the lists for all potential conscripts. Consequently, the available data are not hindered by truncation. In each province, conscription was controlled by a council of three persons: a military commissioner (who supervised the process), a member of the provincial parliament and a member of the local authority. At the beginning of each year the commissioner had to deliver alphabetical lists containing the names of all men aged eighteen (from 1863 onwards it was nineteen) to the provincial government. Registration was not based on the place of residence of the conscripts themselves, but of their parents (or custodians). In a clear majority of cases, the place of residence of the parents and conscript were the same.[40] This meant that conscripts were normally measured in their municipality of birth.

In Fryslân, the original registers of individual conscripts have survived for the period 1850–1915 and are available from the provincial archives.[41] They record, on one line each, place of birth, occupation, parents' occupation and measured height of each conscript who appeared. Also included are specific remarks, for example whether they had any physical or mental disabilities. Fig. 6 gives an example of a page from these military registers. These data would in theory allow analysis on the level of individual conscripts.[42] In most other Dutch provinces, the original registers are not available anymore. What often survives are data on the proportion of conscripts that were below the minimum height requirement, aggregated at the municipal level. Although in Fryslân the individual data are available for our research period

[36] Knibbe, *Agriculture in the Netherlands*.

[37] Tresoar Archieven van het Provinciaal Bestuur van Friesland, 1813–1922, Hoofdonderdeel Provinciale Staten; numbers 527–579, Verslag van den Toestand der Provincie Friesland over … aan de Staten van dat Gewest.

[38] J.J. Spahr van der Hoek and O. Postma, *Geschiedenis van de Friese landbouw*, Leeuwarden, 1952.

[39] See also N. Koepke and J. Baten, Agricultural specialization and height in ancient and medieval Europe, *Explorations in Economic History* 45 (2008) 127–146, for a discussion on the relative importance of milk production as opposed to meat production or the use of cattle as beasts of burden.

[40] Groote and Tassenaar, Hunger and migration.

[41] Tresoar (Frysk Histoarysk en Letterkundich Sintrum Leeuwarden), Archieven van het Provinciaal Bestuur van Friesland, 1813–1922, Hoofdonderdeel Commissarissen-Generaal, sinds 1814 Gouverneur, sinds 1850 Commissaris des Konings (der Koningin): Hoofdarchief 1813–1922, numbers 9534–9659.

[42] Groote and Tassenaar, Hunger and migration.

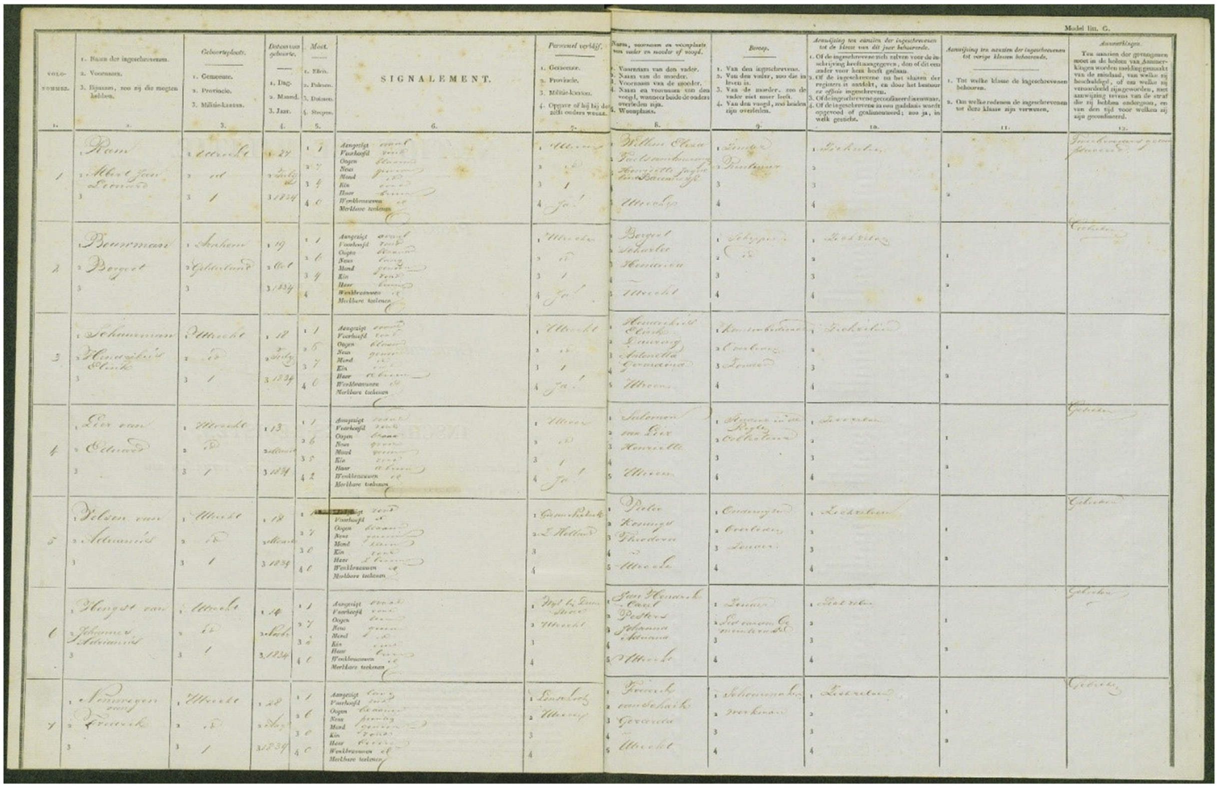

Fig. 6. Example of the main source used: the military registers.

(1851–1900), it would have been too time consuming to collect them. At the municipal level, data on the share of conscripts reaching the minimum height have proven to be a good indicator of the biological standard of living.[43] Consequently, we went through the data of all 188,942 conscripts and counted those that were undersized, as well as those that did not show up. For each municipality and each year, this allowed us to calculate the share of undersized conscripts in those measured (conscripts minus no-shows). A total number of 20,982 conscripts (11.1%) did not show up to be examined.

From 1863 onwards the examination shifted to those who had reached the age of nineteen on January 1st. As a result, at the time of measurement the conscripts were on average a year older than those in the previous period (19¾ years of age instead of 18¾). At this age, boys would still grow if they had to catch up a previous delay in growth.[44] Since catchup potential is related to preceding height development, on average smaller conscripts would have more catchup potential. Although we would have liked to take this into account and vary the assumed catchup per individual (or at least by year as well as municipality), for practical reasons this would have been impossible in the data collection. Therefore, we had to use a constant assumed catchup growth in stature for all conscripts over the period 1863–1900. We followed our own and others' earlier studies in assuming a growth of three centimetres in the nineteenth year of age of the conscripts.[45] Consequently, for the period 1863–1900 we counted conscripts as being undersized if they measured less than 1.60 metres, instead of the official measure of 1.57 metres.

Although at first sight three centimetres may seem a lot for one year's catchup growth, it is based on other research on anthropometric development in the Low Countries. George Alter, Muriel Neven and Michel Oris based their assumed catchup growth of three centimetres on a comparison of Belgian conscripts measured at age twenty for the periods 1806–1816 and 1829–1900, but at age nineteen under Dutch rule between 1816 and 1829.[46] Their data suggests an almost uniform increase of about three centimetres. In fact, the mean height for their nineteen year old conscripts was 161.3 centimetres and for twenty year olds 164.7 centimetres. This difference of 3.4 centimetres, however, also captures the trend in increase in heights over the course of the nineteenth century, as most twenty year old conscripts were measured in the later period. In addition, De Beer shows for Dutch prisoners born in the period 1815–1865 that those of average height measured 159.4 centimetres at age 17–18, and 165.0 at age 19–20. That is a growth of 5.6 centimetres over two years, or almost three centimetres per year. For those who were on the bottom margin of the ninety-five percent confidence interval around the average height, the figures were 158.0 and 164.3 centimetres: 6.3 centimetres in two years.[47] Victor Oppers mentions that in some years no less than forty percent of conscripts grew more than six centimetres after

[43] Drukker and Tassenaar, Paradoxes of modernization; Tassenaar, *Het verloren Arcadia*.

[44] E. Depauw and D. Oxley, Toddlers, teenagers, and terminal heights: the importance of puberty for male adult stature, Flanders, 1800–76, *Economic History Review* 72 (2019) 925–952.

[45] Drukker and Tassenaar, Paradoxes of modernization; J. Jacobs and V. Tassenaar, *Height, Income, Nutrition, and Smallpox in the Netherlands: The Second Half of the 19th Century*, Groningen, 2002.

[46] G. Alter, M. Neven and M. Oris, Stature in transition: a micro-level study from nineteenth-century Belgium, *Social Science History* 28 (2004) 231–247.

[47] H. De Beer, Lichaamslengte en biologische levensstandaard van meisjes en jonge vrouwen in Nederland, 1815–1865, *Tijdschrift voor Sociale en Economische Geschiedenis* 4 (2007) 108–135.

their nineteenth birthday.[48] Erik Beekink and Jan Kok calculated a total catchup growth of 4.2 centimetres for their study of the town of Woerden.[49] These data all refer to total catchup, but Oppers shows that the larger part of the catchup growth would have been reached in the nineteenth year.[50] So it appears safe to assume three centimetres of catchup growth in the nineteenth year of age.[51]

A characteristic of the data we used is that they are proportions. By definition, the proportion of conscripts meeting the minimum height in each municipality ranges between zero and one hundred percent. This has consequences for the way the variable can be used in regression analysis, as explained below.

Development of the biological standard of living over time and space

Of the total number of 167,960 measured conscripts, 138,739 (82.6%) were classified as above the minimum height (using the 1.57 and 1.60 metre minimum height requirements). Fig. 7 shows the proportion of conscripts meeting the minimum height requirement for the whole province of Fryslân in the period 1851–1900, and indicates that before 1856 the biological standard of living declined. Although data on the period before 1851 are not available, it seems logical to see this as the final phase of the decades of decline around the middle of the nineteenth century that is visible in most Dutch provinces.[52] Fryslân was hit hard by the potato famine in this period. From the 1860s onwards a steady increase in the biological standard of living is visible.

The provincial average will obviously hide some intraprovincial differences. To show and analyse this we compiled a series of maps of the biological standard of living over five-year periods. Figs. 8 and 9 show such maps for 1856–1860 and 1896–1900. The gradual rise in the biological standard of living is clear from the gradual brightening of the maps. Where on the first maps there are still large areas with dark brown colouring (low biological standard of living), by the late 1890s bright yellow colours (high biological standard of living) are dominant. The spatial patterns on each map are less straightforward. In the earlier years the urban municipalities, recognizable on the maps from their smaller areal size or by comparison with the maps of population density, seem to be darker than the rural ones.

As we are interested in the relationship between population density, milk supply and the biological standard of living, we undertook a first exploratory visual analysis of the data. Table 1 suggests the existence of an urban penalty for the beginning of our period of analysis (1855–1860). The five municipalities with the highest living standards had relatively low population densities; municipalities with the lowest living standards had higher to extremely high (Harlingen) population densities. Around 1900 this more or less clear picture had become blurred (Table 2). Municipalities with low or high population densities now recorded either low or high living standards. An example is Stavoren, a small port in the western part of Fryslân, which moved from the bottom five in the first period to a top five position at the turn of the twentieth century. More or less the same conclusion can be drawn for the relation between the number of cattle per inhabitant and the biological standard of living. In the early period, a high biological standard of living was associated with many cattle; later the relationship seems less clear.

Methods and analysis: Panel data regression

Our data are panel data, as we have annual data for forty-one municipalities over fifty years, with three variables observed for each year and each municipality. Consequently, the data structure is relatively simple (see Table 3). The total number of observations is 2009.[53] Spatial panel data provide extra information over time series data and cross-section data, as both characteristics (time as well as region) are known for each observation. Consequently, each observation (x_{it}) is noted with two subscripts, with t indicating time and i the individual dimension (municipality in our case). Statistical techniques have been developed that simultaneously handle both.[54] Using such panel data regression techniques, one can study the time-invariant features within each panel, the relationships across panels, and how outcomes of interest change over time. It is the latter that we are particularly concerned with here.

Panel data regression is widely used in the social sciences, epidemiology, econometrics, economic geography, historical geography and economic history. The regression model is given as follows:

$$Y_{it} = a + b_1 X_{1it} + b_2 X_{2it} + \varepsilon_{it}$$

where Y is the dependent (explained) variable, X_1 and X_2 are the independent (explanatory) variables, a and b are coefficients, and ε contains the error components. The subscripts i and t indicate the spatial categories (municipalities) and time (years). The (assumed) character of the error terms (ε) is important in choosing how exactly to estimate the regression. Part of the error term may vary over time, but another part may be time-invariant. If the error is assumed to vary non-stochastically over the individuals and time, so in a structured way, then a fixed effects model can be estimated. If the errors are assumed to vary stochastically, a random effects model must be estimated. The Hausman specification test can be used to support the decision on whether to use a fixed effects model or a random effects model. It compares both estimates and gives a test statistic that follows the χ^2 distribution. If the null hypothesis cannot be rejected (high p-value), the random effects model is preferred due to higher efficiency. In our model, the Hausman test resulted in a χ^2 of 24.48 and a p-value of 1.00. This means that the null hypothesis of the Hausman test cannot be rejected and the random effects model is appropriate.

We used the statistical software program Stata15 from StataCorp to run our panel data regression.[55] The biological standard of living is the dependent variable, and population density and the milk supply are the independent variables. We had to transform some of the variables. The biological standard of living is given by the proportion of conscripts measured in the specific year that were

[48] Oppers, *Analyse van de acceleratie*.

[49] E. Beekink and J. Kok, Temporary and lasting effects of childhood deprivation on male stature: late adolescent stature and catch-up growth in Woerden (the Netherlands) in the first half of the nineteenth century, *The History of the Family* 21 (2016) 1–18.

[50] Oppers, *Analyse van de acceleratie*, graphical annexes, graph 18.

[51] In 1893 the moment of examination was rescheduled from March to October, but during our data collection we did not correct for this minor change for the last seven years of the analysis, see A.J. Groustra, *Militiewet 1901, ter Vergelijking naast de Gewijzigde Militiewet van 1861 Gedrukt*, Haarlem, 1901.

[52] Drukker and Tassenaar, Paradoxes of modernization; Tassenaar, *Het verloren Arcadia*.

[53] No conscripts were measured in 1862 due to the change in the age of measurement.

[54] C. Hsiao, *Analysis of Panel Data*, third edition, Cambridge, 2014 and J.P. Elhorst, Spatial panel data models, in: M.M. Fischer and A. Getis (Eds), *Handbook of Applied Spatial Analysis: Software Tools, Methods and Applications*, Berlin, 2010, 377–407.

[55] F. Belotti, G. Hughes and A.P. Mortari, Spatial panel-data models using Stata, *Stata Journal* 17 (2017) 139–180.

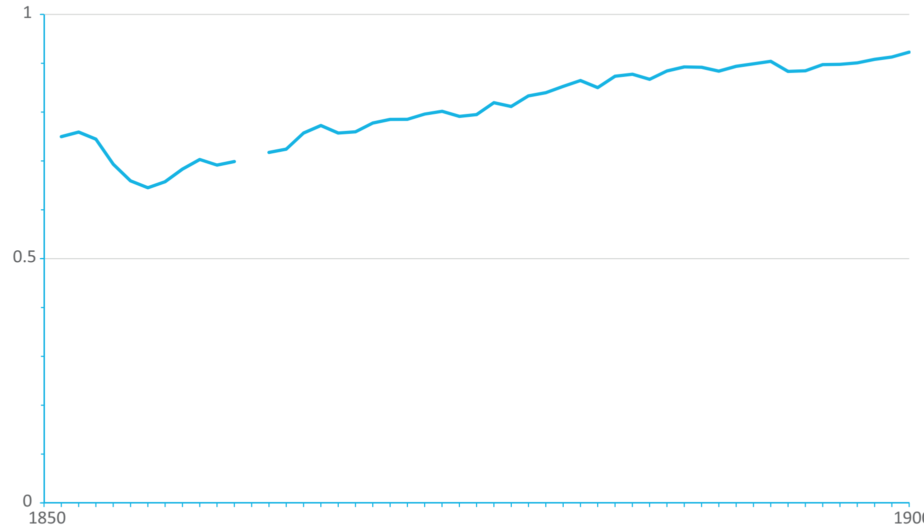

Fig. 7. Development of the biological standard of living in Fryslân, 1851–1900 (proportion of conscripts meeting the minimum height requirement).

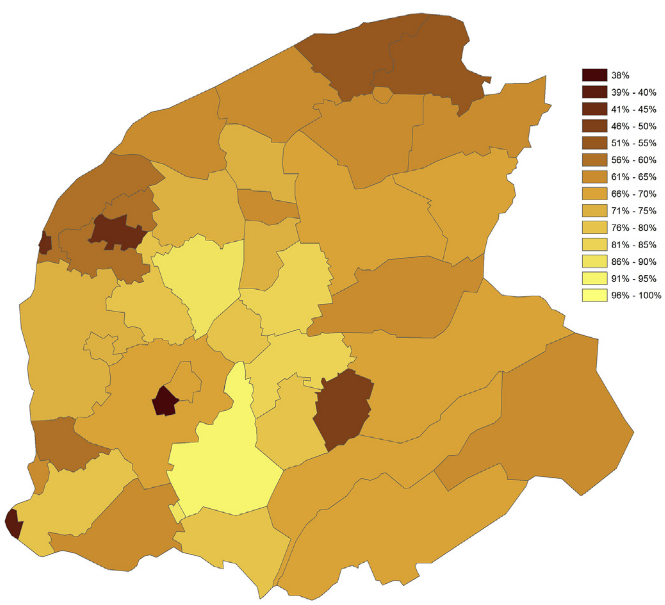

Fig. 8. Biological standard of living by municipality, 1857 (proportion of conscripts meeting the minimum height).

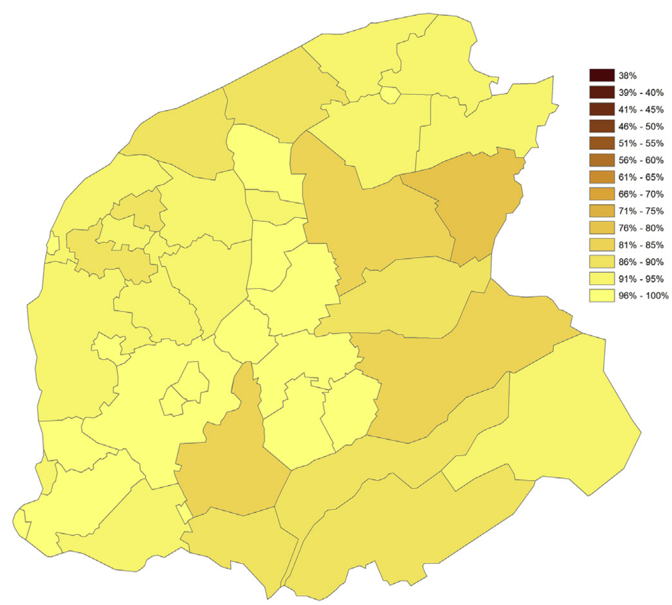

Fig. 9. Biological standard of living by municipality, 1898 (proportion of conscripts meeting the minimum height).

above the minimum height.[56] As the number of conscripts measured in each year for some municipalities was relatively small, we used a three-year moving average. That means that the analysis is performed over the years 1852–1899. The first year, 1852, is used as the base year in the regression. As our proportion data naturally range from zero to one, we applied a logit transformation in order to avoid estimates that could take values (far) outside the 0–1 range.[57] This is a fairly standard procedure when dealing with proportion data.[58] In our case, the logit reads as:

$$\ln \frac{\textit{proportion meeting minimum height}}{(1 - \textit{proportion meeting minimum height})}$$

The independent (explanatory) variables are measured in a straightforward manner. Population density is the registered number of inhabitants per square kilometre for each municipality in each year. To take account of the large differences in population densities between municipalities we used the natural log of the densities in the model. Milk supply is measured as the number of dairy cattle per municipality, divided by its population in the same

56 Often the proportion of undersized conscripts is used, but we prefer the inverse proportion (the oversized). The latter has the advantage of having the same sign as the standard of living: a rise in the share of oversized means a rise in the biological standard of living.

57 To avoid dividing by zero, we subtracted 0.0001 from the reported biological standard of living proportion, both in the numerator and in the denominator.

58 C. Baum, Stata tip 63: modeling proportions, *Stata Journal* 8 (2008) 299–303.

Table 1
Municipalities with the highest and lowest biological standard of living, 1855–1860.

Top-5 biological standard of living (good)				Bottom-5 biological standard of living (bad)			
	% > minimum height	population density (population per km^2)	Number of cattle per inhabitant		% > minimum height	population density (population per km^2)	Number of cattle per inhabitant
Utingeradeel	84%	65	1.50	Franeker	47%	323	0.18
Doniawerstal	82%	28	1.99	Harlingen	49%	3585	0.02
Idaarderadeel	82%	67	1.11	Aengwirden	56%	72	0.22
Baarderadeel	79%	70	1.22	Leeuwarden	58%	1191	0.06
Wymbritseradeel	79%	58	1.48	Stavoren	58%	140	0.41

Table 2
Municipalities with the highest and lowest biological standard of living, 1896–1900.

Top-5 biological standard of living (good)				Bottom-5 biological standard of living (bad)			
	% ≥ minimum height	population density (population per km^2)	Number of cattle per inhabitant		% ≥ minimum height	population density (population per km^2)	Number of cattle per inhabitant
Hindeloopen	98%	144	0.57	Achtkarspelen	85%	113	0.72
Stavoren	98%	339	0.38	Tietjerksteradeel	85%	86	1.12
Idaarderadeel	97%	80	1.36	Smallingerland	85%	86	0.50
Haskerland	97%	129	0.62	Ooststellingwerf	87%	42	0.55
Menaldumadeel	96%	129	0.66	Schoterland	88%	101	0.53

Table 3
Structure of the panel data: observations on population density (inhabitants/km^2), the biological standard of living (% of conscripts meeting the minimum height), and number of cattle per inhabitant, for fifty (forty-nine) years and forty-one municipalities.

	1851			1852			Next year
Municipality	stand.liv.	pop.dens.	cattle/inh	stand.liv.	pop.dens.	cattle/inh	…
Achtkarspelen	60.3%	77.6	0.708	69.8%	78.4	0.739	…
Aengwirden	68.6%	65.2	0.219	77.4%	66.9	0.231	…
Next municipality	…	…	…	…	…	…	…

year so that the variable indicates the availability of milk (and buttermilk) for the inhabitants. Earlier studies have shown that this indicator has a strong explanatory value for differences in height.[59] Milk and buttermilk were mainly consumed locally and hardly outside the municipal boundaries, due to the limited shelf life of these products. Improvements in conservation, cooling and infrastructure probably reduced the impact of this indicator towards the end of our period of study. However, we do not have data available that could be used in the estimation to control for this.

As we are interested in the development over time of the effects of population density and milk supply, we included interaction effects of our explanatory variables with time (which is the variable 'year' in our analysis). This gives annual coefficients for both variables that have to be interpreted alongside the main effects coefficient. Although it may sound unfamiliar to calculate time effects as interactions, it is no different from standard interaction effects in regression. In regression analysis, interactions are used to show how the effect of a predictor variable (X_1) on outcome Y, can vary according to some other predictor variable (X_2). This other variable is often another characteristic of the subject studied, but in a panel data setting time is an obvious candidate as well. What we essentially suggest is that some variables' effect on the outcome may change over time. This is not the same as adding time as a main effect to the model, as such a 'time' variable is averaged over the entire population, instead of the value of the other variables at stake.

Results: Urbanism, milk and the standard of living

The random effects panel regression estimation leads to a significant model (Wald $\chi^2 = 1400.71$; $p = 0.000$) with a (within) R^2 of 0.49. To further assess the validity of the analysis, we inspected the residuals of the model estimation. Positive residuals mean that the municipality did worse in reality than predicted by the model, and negative residuals that the municipality did better in reality than the model predicts. Graphing the residuals (Y-axis) against the population densities (X-axis) for all years suggests that the model predicts relatively well, and that there is no obvious bias (Fig. 10). In a panel data analysis, spatial residuals analysis is of crucial importance.[60] Mapping of the residuals per municipality also led to the conclusion that spatial components did not disturb the estimation (see, for example, the residuals maps for 1858 and 1898 in Figs. 11 and 12).

In terms of the specific relations between the variables, the

[59] Baten and Murray, Heights of men and women; Tassenaar, *Het verloren Arcadia*; Baten, Protein supply. Baten used a fixed milk production per cow when estimating the per capita milk consumption. In his regression analysis he used a dummy variable indicating regions with milk consumption above four hundred litres of milk per year.

[60] J. Baten, Kartographische Residuenanalyse am Beispiel der regionalökonomischen Lebensstandardforschung über Baden, Württemberg und Frankreich, in: D. Ebeling (Ed), *Historisch-thematische Kartographie; Konzepte, Methoden, Anwendungen*, Bielefeld, 1999, 98–109.

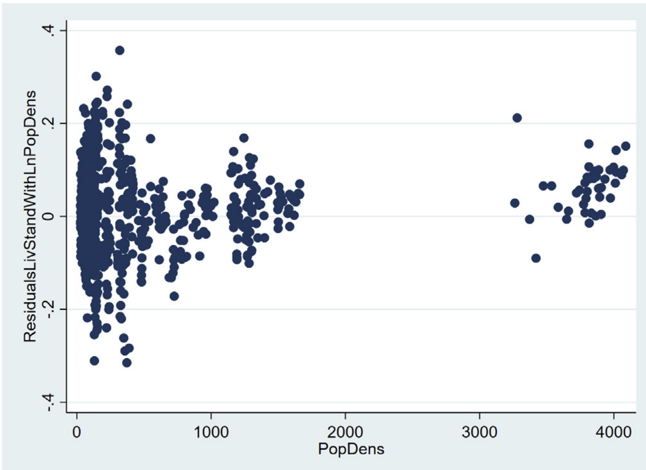

Fig. 10. Residuals of the regression estimation, by population density, for all years.

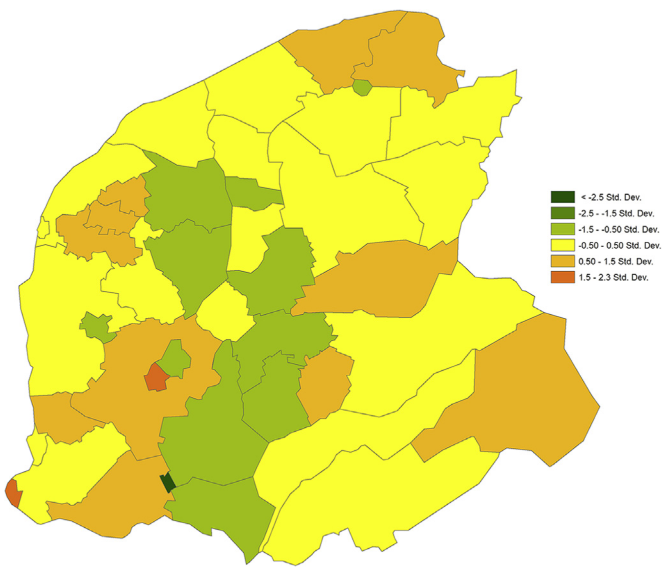

Fig. 11. Map of the residuals of the regression estimation per municipality, 1857.

estimated regression equation shows the value of the constant to be 1.179 (p-value: 0.000). This would indicate the result of the regression equation if both explanatory variables (population density and number of cattle) had a value of zero. The corresponding percentage of conscripts meeting the minimum height in this situation is calculated from the inverse logit and would be seventy-six percent. The main effect of population density is -0.063 ($p = 0.117$) and the main effect of milk supply (cattle per head) is 0.626 ($p = 0.003$). So population density does not have a significant overall effect, but milk supply does, and it is positive. The annual (interaction) effects of population density and milk supply on the living standard are given in Fig. 13 and the table in the Appendix. These annual effects need to be interpreted in combination with the main effects. The annual coefficients for population density start below zero at the beginning of the period, and gradually rise. They are only statistically significant negative in 1856. In 1861 the annual coefficient turns positive, and from 1874 onwards is statistically significant as well. Its lowest value (the peak urban penalty) is reached in 1856, and its highest value (the peak urban premium) is in 1894. The annual coefficients for milk supply do not show a clear trend over time and never differ significantly from zero. As the main effect is much larger than the annual coefficients, and is (statistically significant) positive, it is clear that milk has had a stable positive effect on the standard of living. Towards the end of our period of study, however, it becomes more volatile, with its lowest value in 1894 and 1895 and its highest ones only few years later, in 1898 and 1899.

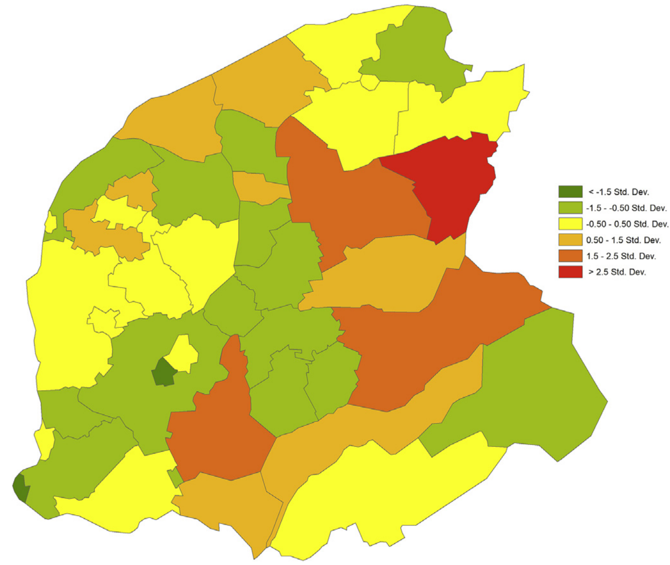

Fig. 12. Map of the residuals of the regression estimation per municipality, 1898.

Discussion: From urban penalty to urban premium

A first conclusion from these results is that we are now able to pinpoint the reversal from a (premodern) penalty to a (modern) premium of high population density on the biological standard of living in the province of Fryslân to the period 1857–1873. This confirms, but specifies, earlier statements of this change as happening ‘from the middle of the nineteenth century onwards’.[61] A second conclusion is that dairy production has had a stable and positive effect on local living standards, both in the period of the urban penalty and of the urban premium. Fryslân seems to have conformed to what theory and previous research on other areas have suggested. As the model that we had to estimate is rather complex, it is difficult, however, to grasp the exact size of the effects that the different coefficients have on the biological standard of living. To enable easier interpretation of the model we designed a what-if table (Table 4) in which the effects on the biological standard of living of changes in (1) dairy provision and (2) population density over time are shown for a virtual municipality for three years (1856, 1875, 1894). These are the years with the highest urban penalty (1856) and urban premium (1894), as well as an in-between year (1875). The table shows what a doubling of the population density, of the number of cattle per inhabitant, and of both, would mean for the estimated standards of living. The table shows that in 1856 and 1875 the effect of the availability of milk was more important than that of population density. Even in

[61] De Beer, Physical stature and biological living standards, 70. On the other hand, Komlos, Shrinking in a growing economy, presumed that the urban penalty lasted until the early twentieth century.

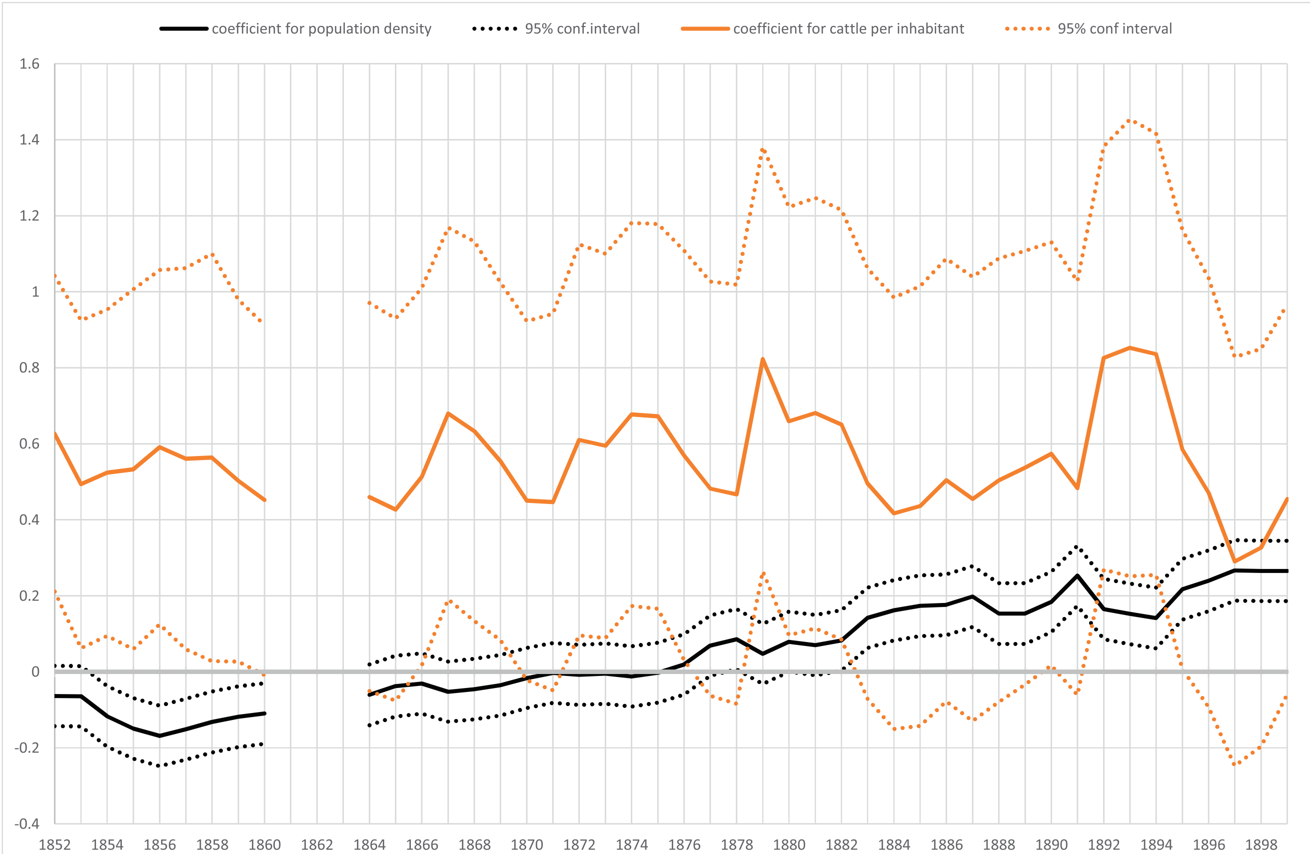

Fig. 13. Regression coefficients with 95% confidence intervals: (natural log of) population density respectively cattle per head of population, annual coefficients, calculated as the aggregate of the main effect and the annual interaction effects.

Table 4
What-if analysis for a virtual (average) municipality based on the estimation regression coefficients.

Municipality	Year	Population density	No of cattle per inhabitant	Estimated proportion meeting minimum height	Effect of doubling of …	… on estimated proportion meeting minimum height
virtual	1856	250	1.0	0.697		
virtual	1856	250	2.0	0.806	Cattle	+0.109
virtual	1856	500	1.0	0.672	Population	−0.025
virtual	1856	500	2.0	0.787	Both	+0.090
virtual	1875	250	1.0	0.862		
virtual	1875	250	2.0	0.925	Cattle	+0.062
virtual	1875	500	1.0	0.862	Population	+0.000
virtual	1875	500	2.0	0.924	Both	+0.062
virtual	1899	250	1.0	0.957		
virtual	1899	250	2.0	0.972	Cattle	+0.015
virtual	1899	500	1.0	0.964	Population	+0.007
virtual	1899	500	2.0	0.977	Both	+0.020

the period of the urban penalty, a doubling of the number of cows per inhabitant in a municipality would easily overcome the negative effect of a doubling of population size, at least for a more or less average municipality. In the period of the urban premium both effects converge. At the peak of the urban premium, in 1894, a doubling of the population density even leads to an increase in the biological standard of living that is slightly above the effect of a doubling of the number of cattle per head. The relative convergence is, of course, caused by the reversal of the effect of population density from penalty to premium.

Taken together this means that for the province of Fryslân, and in particular its western parts, dairy-oriented agriculture played an important role in overcoming the negative effects on living standards of (the early stages of) modern economic growth (the Komlos paradox).[62] The availability of milk made it possible to ease the transition towards a modern socioeconomic system.[63] This contrasts with Scott Carson's conclusion for nineteenth-century Pennsylvania that the negative effect of living close to a

[62] Komlos, Shrinking in a growing economy.
[63] See also Tassenaar, *Het Verloren Arcadia*.

metropolitan area more than counteracted the positive effect of living in a dairy area.[64] The fact that Carson's data were based on imprisoned adults probably plays a role in this, as incarcerated people may well have had less access to dairy products than Fryslân's conscripts had.

The fact that the effect of dairy production on living standards remained more or less stable over time is mirrored by its effects over space. Living standards in the southwestern part of Fryslân remained higher than in the rest of the province during the whole period of study. On top of that, the reversal from urban penalty to urban premium had its effects primarily in the western part, where most of the cities were located. Whereas these cities were pockets of relatively low living standards until the 1860s, they became an integral part of the area with high living standards from the 1880s onwards. At the same time, the stability of the effect of local dairy farming is rather puzzling. If economic modernization played a key role in the reversal of urban penalty to urban premium, and in particular through infrastructural improvements and the resulting market integration, then the local availability of high-protein foodstuffs in the immediate surroundings would have become less important. One could, after all, have imported dairy products from further away as well. The development of (mechanically) refrigerated transport, however, started relatively late (even in the US only from around the 1870s).[65] Consequently, the effects of technological progress in the conservation and transport of fresh milk may have materialized only after 1900.

Our final conclusion focuses on the causes of the transition from an urban penalty to an urban premium. The transition seems to have been caused more by the lack of 'care and cure' factors in urban areas than by a change in high-protein food intake. Whereas the urban penalty gradually disappeared during the second half of the nineteenth century, the positive effect on stature of the availability of high-protein products, especially milk, was stable over time. This importance of the progression in care and cure in explaining the change from an urban penalty to an urban premium in Fryslân supports the conclusion earlier drawn by De Beer that improvements in medical care and hygienic circumstances have been the prime cause of the increase in height of the Dutch population in the last part of the nineteenth century.[66] Thanks to economies of scale such care and cure improvements appeared earlier in urban than in rural settings. Their effects were also larger in urban areas due to their low starting levels. Nevertheless, our analysis shows a relative convergence of both effects with the population density effect (care and cure) catching up with the effect of local dairy production. As such, the analysis does not negate the impact of food availability, decreasing food prices, improved nutritional quality through technical progress in preservation and transport, and a more stable food supply. However, a comparable analysis with more explanatory variables that explicitly cover aspects such as infrastructural development, and over a larger area, would be necessary to gain more insight into this.

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Declaration of competing interest

None.

Appendix Table. Estimated coefficients (constant, main effects and year−interaction effects)

	Coefficient	p−value	Coefficient	p−value
constant	1.1729	0.00		
	Population density		**Dairy cattle per head**	
main effect	−0.0634	0.12	0.6265	0.00
year effects				
1852				
1853	−0.0009	0.99	−0.1328	0.66
1854	−0.0537	0.26	−0.1026	0.73
1855	−0.0853	0.07	−0.0933	0.77
1856	−0.1051	0.03	−0.0352	0.91
1857	−0.0875	0.07	−0.0659	0.84
1858	−0.0685	0.15	−0.0624	0.86
1859	−0.0545	0.25	−0.1235	0.70
1860	−0.0462	0.33	−0.1740	0.58
1861				
1862				
1863				
1864	0.0030	0.95	−0.1665	0.62
1865	0.0258	0.59	−0.1996	0.54
1866	0.0326	0.49	−0.1131	0.73
1867	0.0112	0.81	0.0535	0.87
1868	0.0182	0.70	0.0066	0.98
1869	0.0283	0.55	−0.0726	0.82
1870	0.0473	0.32	−0.1762	0.58
1871	0.0605	0.20	−0.1797	0.58
1872	0.0555	0.24	−0.0163	0.96
1873	0.0589	0.22	−0.0317	0.92
1874	0.0514	0.28	0.0511	0.88
1875	0.0613	0.20	0.0456	0.89
1876	0.0831	0.08	−0.0570	0.87
1877	0.1326	0.01	−0.1444	0.68
1878	0.1492	0.00	−0.1592	0.65
1879	0.1107	0.02	0.1964	0.58
1880	0.1427	0.00	0.0331	0.93
1881	0.1339	0.01	0.0544	0.88
1882	0.1460	0.00	0.0239	0.95
1883	0.2057	0.00	−0.1309	0.71
1884	0.2255	0.00	−0.2094	0.55
1885	0.2375	0.00	−0.1901	0.60
1886	0.2400	0.00	−0.1220	0.74
1887	0.2616	0.00	−0.1714	0.64
1888	0.2169	0.00	−0.1226	0.73
1889	0.2170	0.00	−0.0892	0.80
1890	0.2473	0.00	−0.0530	0.88
1891	0.3165	0.00	−0.1433	0.68
1892	0.2288	0.00	0.1995	0.57
1893	0.2160	0.00	0.2261	0.54
1894	0.2052	0.00	0.2096	0.56
1895	0.2806	0.00	−0.0417	0.91
1896	0.3033	0.00	−0.1548	0.66
1897	0.3303	0.00	−0.3361	0.33
1898	0.3291	0.00	−0.2997	0.37
1899	0.3292	0.00	−0.1720	0.60

[64] S.A. Carson, Health during industrialization: evidence from the nineteenth-century Pennsylvania state prison system, *Social Science History* 32 (2008) 347–372.
[65] Cronon, *Nature's Metropolis*.
[66] H. De Beer, *Voeding, Gezondheid en Arbeid in Nederland tijdens de Negentiende Eeuw. Een bijdrage tot de Antropometrische Geschiedschrijving*, Amsterdam, 2001.