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Drivers of Industrialisation:
intersectoral evidence from the Low Countries in the nineteenth century

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Abstract

In this paper, we trace the causes of regional industrial development in the nineteenth century Low Countries by disentangling the complex relationship between industrialisation, technological progress and human capital formation. We use sectoral differences in the application of technology and human capital as the central elements to explain the rise in employment in the manufacturing sector during the nineteenth century, and our findings suggest a re-interpretation of the deskilling debate. To account for differences among manufacturing sectors, we use population and industrial census data, subdivided according to their present-day manufacturing sector equivalents of the International Standard Industrial Classification (ISIC). Instrumental variable regression analysis revealed that employment in the manufacturing sector was influenced by so-called upper-tail knowledge and not by average educational levels, providing empirical proof of a so-called deskilling industrialisation process. However, we find notable differences between manufacturing sectors. The textiles and clothing sectors show few agglomeration effects and limited use of steam-powered engines, and average education levels cannot adequately explain regional industrialisation. In contrast, the location of the fast-growing and innovative machinery-manufacturing sector was more influenced by technology and the availability of human capital, particularly upper-tail knowledge captured by secondary school attendance rates.

1. Introduction

Various theories have been developed regarding the rise and spread of industrialisation during the nineteenth century (e.g., Clark 2007; De Vries 2008; Van Zanden 2008; Allen 2009; Mokyr 2009; Wrigley 2010), most of which propose a causal relation between either industrialisation and technological progress, or human capital formation and technological progress. However, although many studies have attempted to empirically validate these theories, their findings are far from unanimous. This ambiguity is partly attributable to the heterogeneity of proxies used for different countries and time periods. Industrialisation, for example, has been captured using employment statistics (Becker, Hornung, and Woessman 2011), output numbers, average income levels (Squicciarini and Voigtlander 2016) and the number of steam engines (Franck and Galor 2015; Franck and Galor 2016; Minns, De Pleijt and Wallis 2017). Likewise, human capital has been proxied by literacy rates (Franck and Galor 2016), the skill-intensity of occupations (Weisdorf, Nuvolari, and De Pleijt 2015), primary school attendance rates (Becker, Hornung and Woessman 2011), secondary school attendance rates (Franck and Galor 2015) and even book subscriptions (Squicciarini and Voigtlander 2016).

A second source of ambiguity is the difference in ideas regarding the causal relations among industrialisation, human capital and technology. Although all three key variables are widely studied, most studies focus on explaining industrialisation. Based on standard growth theories, some studies argue that human capital was beneficial for the industrial and overall economic growth of Britain during its Industrial Revolution of the 18th and 19th century (see, e.g., Meisenzahl and Mokyr 2012; De Pleijt 2015; Feldman and Van der Beek 2016). In other words, changes in the labour market of the first industrialiser were ‘skill demanding’. This is specified in a new stream of literature that points to ‘upper-tail knowledge’ possessed by the wealthy, knowledgeable elite as a dominant factor in shaping the first phase of industrialisation as opposed to ‘lower-tail knowledge’ (e.g., Mokyr 2005; Mokyr and Voth 2009; Weisdorf, Nuvolari and De Pleijt 2015; Feldman and Van der Beek 2016; Mokyr 2017). In contrast, other studies claim that industrialisation was accompanied by a ‘deskilling’ of the workforce (see, e.g., Nicholas and Nicholas 1992; Mitch 1993; Crafts 1996; Goldin and Katz 1998; Clark 2005; Minns, De Pleijt and Wallis 2017).

Another related causal relation focused on in the literature is that of human capital formation as the cause of technological development (Weisdorf, Nuvolari and De Pleijt 2015), often using the distribution of steam engines as a proxy for technology. However, several of the aforementioned studies (Franck and Galor 2015, 2016; Minns, De Pleijt and Wallis 2017) also use the number of steam engines as a proxy for industrialisation. This makes it difficult to interpret their empirical results because they demonstrate an intertwined statistical relationship between human capital, technology and industrialisation, with the latter two mainly measured by steam engines. This becomes even more problematic once we consider the very unequal regional and sectoral distribution of this general-purpose technology. In mid-nineteenth century Belgium, 71% of steam engines were installed in the mining and metallurgy sectors (Van Neck 1979). Such an uneven distribution existed in the Netherlands as well, where in 1839 57 % of the steam engines exclusively operated in the textiles manufacturing sector (Lintsen and Steenaard 1991). The implementation of steam engines also varied between regions, as the replacement costs were heavily dependent on which energy sources were dominant in a region before the introduction of steam. For instance, Dutch entrepreneurs faced high costs for

replacing their abundant wind and water mills, and thus made the shift to steam engines much later than other countries in Western Europe (Lintsen and Steenaard 1989).

There is thus a diverse literature that examines the interconnections among industrialisation, technological advancements and human capital growth. While industrialisation seems to be driven by both human capital and technology, the possible endogeneity between these two factors complicates the identification of causal links. Yet, it is also possible that this simultaneity only existed in the first industrialiser, as Britain compromised the core regions of innovation, while in the case of later industrialisers, technology, most notably steam engines, was imported and did not result from an organic process of human capital formation and innovation. Hence, it is possible that in contrast to Britain (Weisdorf, Nuvolari, and De Pleijt 2015), there was no causality between human capital and technological change in most countries on the European mainland, as was the case for France (Franck and Galor 2015).

In this paper, we present a case study of the Low Countries in which we deal with these problems systematically by considering the use of various proxy data, the contrasting effect of human capital and the possible endogeneity of results. We focus on Belgium and the Netherlands because the development of technology did not result from human capital growth in these two countries (see Section 2), so the problem of reverse causality between technology and human capital is unlikely to exist. In addition, to avoid the earlier stated problem of endogeneity between industrialisation, technology and human capital, we use a Two-Stage Least Squares (2SLS) estimator while controlling for spatial correlations. Because these regions include both early (the Charleroi–Liège axis) and late (the northern regions of Groningen and Drenthe) industrialising regions (Mokyr 1976), they are perfect for studying the regional drivers of industrialisation. Moreover, these regions present great geographical diversification in terms of manufacturing sectors, making them highly suitable for studying intersectoral effects.⁴ In Section 2 we discuss the data and construct a new dataset on employment in the manufacturing sector. Our methodology is dealt with in Section 3. We present our results in Section 4, and end with a brief conclusion.

2. Data and Evidence

To empirically test the various drivers of industrialisation, we collected panel data by province and time period. Indeed, as O’Brien (1986: 297) suggests, ‘Industrialization [...] was a regional and not a national process’. Hence, ignoring regional effects such as differences in institutions and culture would introduce an omitted variable bias into our analysis. A fixed-effect specification could also remove the effect of otherwise unobserved trade and transportation costs, which are also likely to be correlated with technology and human capital. We include data for 1820, 1850 and 1890, subdivided for each province in the Netherlands and Belgium. Our choice of years is based on data availability, mostly following the publication of industry censuses. We also need to take account of political and geographic changes during this period. In 1820,

⁴ While the industrial heartland located alongside the Charleroi–Liège axis had focused from medieval times on heavy manufacturing such as the production of iron, steel, copper, zinc and other metallurgic products, the textiles and clothing industries were dominant early on in the cities of Ghent, Antwerp, Rotterdam, Tilburg and Zwolle.

Belgium and the Netherlands existed under the ‘United Kingdom of the Netherlands’ (1815–1839), the territory of which differed slightly from the provincial boundaries of the later Belgian and Dutch states, in particular the provinces of Limburg and Luxembourg. To cater for these differences in provincial boundaries, we use the population ratio in Limburg and Luxembourg in 1820 and 1850 to synchronise the variables for 1820 with those for 1850 and 1900 in these provinces. The data by province and period include the three abovementioned indicators, industrialisation (total employment by manufacturing sector), technology (total number of steam engines and total induced horsepower) and human capital (primary school attainment, secondary school attainment and child employment). We add several additional control variables and a spatial lag to capture other factors that might have influenced the industrialisation process.

Our dependent variable is total industrial employment by sector. For 1820, we use Brugmans (1956) and the revised supplement of Dansma, De Meere and Noordegraaf (1979). Both sources include data from the industrial census conducted on 31 December 1819 in the former Dutch and Belgian United Kingdom of the Netherlands. For 1850, we use the Belgian industry census. Because this census mainly contains the number of employees working in larger factories, we combine the data with the occupational statistics from the population census to include the Belgian handicraft and domestic industry. For the Netherlands, we use the number of employees in the occupational records of the population census of 1849. For 1896, we use the Belgian industry census, which includes a detailed account of factory, handicraft and household manufacturing employment. Because no data exist for the Netherlands around this period, we rely on manufacturing data, which were routinely included in the local municipal reports. Again, to avoid an incomplete image of the total manufacturing sector, we cross-check our data for 1896 in both countries with the occupational records in their respective population censuses. Unfortunately, merely collecting these data is insufficient given the changes in industrial classification schemes that took place over time and between what would become the Netherlands and Belgium. Hence, we reclassify all sectors according to the International Standard Industrial Classification of All Economic Activities (ISIC), revision 4. The result is reported in Table 1.

Table 1. Sectoral employment in the Dutch and Belgian manufacturing sectors in 1820, 1850 and 1900

		1820	1850	1900
10	Manufacture of food products	54 190	59 590	219 269
11	Manufacture of beverages	16 626	18 119	45 398
12	Manufacture of tobacco products	2 588	5 768	56 361
13	Manufacture of textiles	321 036	408 750	287 176
14	Manufacture of wearing apparel	35 296	175 212	257 426
15	Manufacture of leather and related products	31 449	42 903	115 836
16	Manufacture of wood and of products of wood and cork, except furniture	30 354	45 775	89 153
17	Manufacture of paper and paper products	3 394	5 667	16 466
18	Printing and reproduction of recorded media	1 251	6 164	38 667
19	Manufacture of coke and refined petroleum products	0	0	7 036
20	Manufacture of chemicals and chemical products	7 337	9 097	23 607
21	Manufacture of pharmaceutical products, medicinal chemical and	0	114	10 439
22	Manufacture of rubber and plastics products	0	1 103	3 085
23	Manufacture of other non-metallic mineral products	19 786	38 742	90 543
24	Manufacture of basic metals	3 552	4 461	83 625
25	Manufacture of fabricated metal products, except machinery and	36 352	37 503	129 706
26	Manufacture of computer, electronic and optical products	1 488	2 495	11 113
27	Manufacture of electrical equipment	0	311	1 567
28	Manufacture of machinery and equipment n.e.c.	1 979	19 477	36 822
29	Manufacture of motor vehicles, trailers and semi-trailers	5 926	6 328	11 813
30	Manufacture of other transport equipment	3 094	11 582	47 885
31	Manufacture of furniture	7 034	9 196	18 409
32	Other manufacturing	5 166	9 848	39 101
33	Repair and installation of machinery and equipment	0	0	2 368
	Total manufacturing sector	587 898	918 205	1 642 871

The second category is technology, i.e., steam engines and horsepower, by year and industrial sector. For Belgium, we obtain the information for 1820 from Van Neck's (1979) list of all steam engines and their total horsepower (HP) in Belgium during 1800–1850. For 1850, we use the number of steam engines recorded in the industrial census of 1850. For the Netherlands in 1820 and 1850, we use a combination of sources in accordance with Griffiths (1979) and Lintsen (1995). Primarily, we use the inventory of all steam plants in the first half of the nineteenth century according to the Ministry of Internal Affairs, which was collected by Steenaard (1989). As this does not provide a complete count of all steam engines in the Netherlands (Lintsen and Steenaard 1989), we augment it with the surveys of steam plants in the Netherlands conducted by the provincial governors in 1851.⁵ For Belgium in 1900, we use the steam engines listed in the industrial census of 1896, and for the Netherlands in 1900, we use the steam engines listed in the municipal reports. As these municipal reports lack data for some of the larger cities, we refer to Struve and Bekaar,⁶ who also listed the steam engines for each factory in the Netherlands, to fill in the missing municipalities.⁷

The third category consists of indicators of human capital: primary school attainment, secondary school attainment and child employment. The percentages of primary and secondary attendance are obtained from various educational reports on primary and secondary schools. For 1820, we use the *Verslag over de Scholen van het Koninkrijk* of 1827, which reported on the schools in the aforementioned United Kingdom of the Low Countries. For the Dutch percentages for 1850 and 1900, we use the education report (*Verslag van den Staat der Hooge, Middelbare en Lagere Scholen in het Koninkrijk der Nederlanden*). For Belgium in 1850 and 1900, we turn to the annual national statistics, or *Annuaire Statistique de la Belgique et la Congo Belge*. For the average school attendance, we estimate the total school attendance as the share of children attending school in the population eligible for schooling. For primary schools, we use the provincial population aged between 6 and 14 in 1820, 1850 and 1900. For secondary schools, we use the provincial population aged

⁵ These surveys are held in the archive of the Dutch Ministry of Manufacturing (*ARA Nationale Nijverheid*). The following codes provide the dates when the lists of steam engines were sent by the provincial governments and their inventory number. For Drenthe: *ARA Nationale Nijverheid*, 07/03/1851, number 66. For Friesland: *ARA Nationale Nijverheid*, 24/03/1851, number 122. For Gelderland: *ARA Nationale Nijverheid*, 31/03/1851, number 95. For Groningen: *ARA Nationale Nijverheid*, 24/03/1851, number 123. For Limburg: *ARA Nationale Nijverheid*, 22/08/1851, number 130. For Noord-Brabant: *ARA Nationale Nijverheid*, 15/04/1851, number 67. For Noord-Holland: *ARA Nationale Nijverheid*, 16/04/1851, number 75. For Overijssel: *ARA Nationale Nijverheid*, 05/04/1851, number 103. For Utrecht: *ARA Nationale Nijverheid*, 08/03/1851, number 102. For Zeeland: *ARA Nationale Nijverheid*, 17/04/1851, number 63. For Zuid-Holland: *ARA Nationale Nijverheid*, 25/03/1851, number 60.

⁶ To access the article and for more information, please consult <http://www.neha.nl/struve/>.

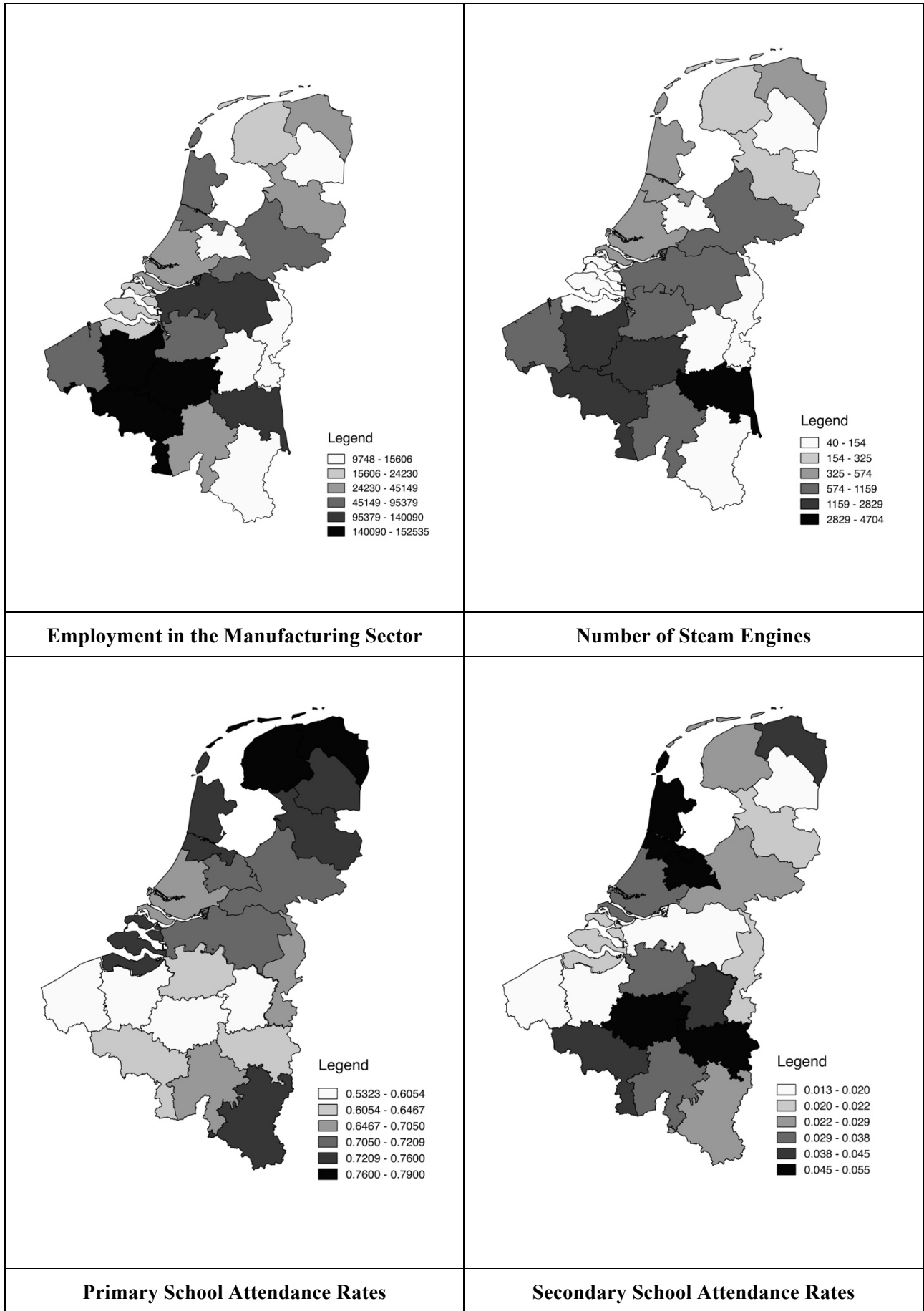
⁷ During the nineteenth century, the replacement of mills by steam engines varied by region and depended on the cost-benefit analysis of the individual entrepreneurs who introduced these machines (Lintsen and Steenaard 1989). Because we have insufficient evidence on the geographical distribution of mills, the use of steam engines as an indicator of technology could be biased against regions that made the shift towards steam-driven technology later, or regions with less active textile and mining sectors. Furthermore, we did not collect evidence on the number of steam boilers, as they were not always listed in the databases. This is a significant loss, as the number of steam boilers is a commonly used indicator of the power of the steam engines used. However, we believe that including both the number of steam engines and their total induced steam power in HP provides a satisfactory solution, or at least provides a sense of the scale of these steam engines.

between 12 and 18 in 1820, 1850 and 1900.⁸ Although we are aware of the potential overlap between the primary and secondary school age groups, it is not always possible to distinguish between them for all regions and benchmark years. However, as the switch from primary to secondary education depended on meeting the standard requirements for secondary education, and the age at which this occurred differed from student to student (Mandemakers 1996), this overlap should not have a great influence on the results. As there does not seem to be a correlation between primary and secondary school attendance over provinces in 1900 (Figure 1), we can indeed justify the distinction between so-called ‘upper-tail knowledge’, captured by secondary school attendance, and ‘average human capital’, captured by primary school attendance rates, that has been made in the recent literature (e.g., Mokyr 2005; Mokyr and Voth 2009; Weisdorf, Nuvolari and De Pleijt 2015; Feldman and Van der Beek 2016; Mokyr 2017).

We include child employment, coal output, population, mortality and newspaper subscriptions as control variables. Child employment is directly linked to both human capital and industrialisation. Given that the availability of coal is often portrayed as playing a determining role during the start-up phase of industrialisation, we also include coal output. We add total population as a proxy for market potential and labour. Lastly, we need alternative indicators to control for urbanisation, which was recorded in different ways across the various Belgian and Dutch population censuses. We include mortality rates because they were notably higher among larger cities, and include the number of newspaper subscriptions per capita as a fitting additional indicator of urbanisation.

⁸ Because of the great variety of school systems in the nineteenth century, we need to select which schools to include in our data. For 1820, we use the *Latijnse scholen* and *Gymnasia* in the former United Kingdom of the Netherlands. For 1850 in the Netherlands, we use the *Latijnse scholen* and *Gymnasia*. For 1850 in Belgium, we use the *Athènes Royaux*, the *établissements communaux subventionnés sur le trésor public* of the first and second level, the *établissements exclusivement communaux* of the first and second level, the *établissements du clergé dirigés par les évêques* both *patronnés* and *non-patronnés*, *les congrégations religieuses* both *patronnés* and *non-patronnés* and *les jésuites* and the *établissements dirigés par des particuliers, non patronnés*. For 1900 in the Netherlands, we use the *Gymnasia*, the *middelbaar onderwijs voor meisjes*, the *hogere burgerscholen* and the *gymnastieklessen en volledig onderwijs*. For 1900 in Belgium, we use the *Athènes Royaux*, the *collèges communaux*, the *collèges patronnées*, the *garçons ecoles moyennes de l'état*, the *garçons ecoles moyennes communales*, the *garçons ecoles moyennes patronnées*, the *filles ecoles moyennes de l'état*, and the *filles ecoles moyennes communales*. We exclude vocational schools as they were not reported in the aforementioned sources. The various reforms in both countries' educational systems might cause a bias in our statistics. However, as the educational reforms in both countries were intended to increase school enrolment (see Fig. 1), we do not believe this effect is considerable.

Figure 1. Indicators of industrialisation, technology and human capital in 1900



Child employment data are reported in all of the respective industrial censuses, and the documented number of child workers under the age of 18 more or less corresponds to the population eligible for secondary schooling. There is even evidence of child labourers under the age of 12, because many young children participated with their parents in domestic textiles and clothing manufacturing (Vandenbroeke 1979). However, as the censuses did not subdivide child workers according to age in the same way, we choose to aggregate all child workers in the manufacturing sector, regardless of age, into one variable. For coal output in Belgium during 1820–1850, we use the study by Pluymers (1992). For 1900, we rely on the annual Belgian report of the Mining Administration (*Administration des mines*), a sub-office of the Ministry of Industry and Labour (*Ministère de l'industrie et du travail*).⁹ For evidence on the coal output in the Dutch province of Limburg, we turn to the statistics collected by the TU Delft.¹⁰ The mortality rates and population statistics are from the 1850 and 1900 population censuses. For 1820, we use the 1824 edition of the statistical report *Opgave der Bevolking van het Koninkrijk der Nederlanden*. For evidence on the number of newspapers sold, we turn to a multitude of publications documenting statistics on this topic. Newspaper publishers paid a tax on newspapers in the United Kingdom of the Netherlands. Data on the total tax revenues for both domestic and foreign newspapers in 1826 (Garnier 1828: 193, 260) enable us to calculate the per capita daily sales of newspapers across the provinces of the Low Countries. Newspapers continued to be taxed in the Netherlands after 1850, so we again use the total amount of tax paid in each Dutch province, as collected by Hemels (1969), to calculate the per capita consumption of newspapers. For Belgium in 1850, Malou (1843) provides the total number of newspaper subscriptions at the provincial level in 1842. For Belgium in 1900, we turn to the 1900 edition of the statistical report of *Chemins de Fer, Postes et Télégraphes*, which reports the number of newspaper subscriptions. For the Dutch statistics in 1900, we use the number of subscriptions to one of the most popular Dutch newspapers, *Nieuws van den Dag*, in 1885. Lastly, we use the data to calculate the total number of daily newspapers sold per capita.

3. Conceptual Framework

Instead of a cross section, we estimate a fixed-effect panel specification that eliminates or at least reduces the impact of unobserved region- and sector-specific factors, including trade, transportation costs and institutions. For each manufacturing sector, we estimate three specifications: an Ordinary Least Squares (OLS) estimate of the model with and without spatial lags, and the main specification, in which we use a 2SLS estimator to account for the endogeneity of the spatial lag (Manski 1993) and the potential simultaneity between industrialisation and the human capital and technology variables.

⁹ *Statistique des mines, minières, carrières; usines métallurgiques et appareils à vapeur pour l'année 1900.*

¹⁰ Coal production since the nineteenth century in the Netherlands, according to <http://www.citg.tudelft.nl/index.php?id=18387&L=0/>.

The main specification is of the mixed spatial autoregressive (MRSAR) type:

$$\mathbf{y} = \rho \mathbf{W}\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \mathbf{u} \quad (1)$$

where \mathbf{W} denotes the spatial weight matrix, \mathbf{X} is the matrix of exogenous explanatory variables (for simplicity we do not add endogenous covariates to the notation). The vectors of coefficients are denoted ρ , $\boldsymbol{\beta}$, and vector \mathbf{u} is the error term. The variable $\mathbf{W}\mathbf{y}$ is usually referred to as the spatial lag of the dependent variable, and is the weighted sum of the value of the dependent variable in all geographical units weighted by some measure of distance or proximity. In this paper, we use contiguity weights, which take the value of one for any pair of provinces that share a common border and zero otherwise. Hence, the coefficient of the spatial lag variable can be interpreted as the effect of industrial employment in neighbouring provinces on the industrial employment in a particular province. A significant positive coefficient indicates the tendency for industrial employment to cluster geographically, whereas a significant negative coefficient indicates dispersion; that is, industrial production is widely spread across the area, giving rise to a checkerboard pattern in an extreme case.

A natural set of instruments can be derived by expressing the reduced form of (1):

$$\mathbf{y} = (\mathbf{I} - \rho \mathbf{W})^{-1} (\mathbf{X}\boldsymbol{\beta} + \mathbf{u}) = (1 + \rho \mathbf{W} + \rho^2 \mathbf{W}^2 + \rho^3 \mathbf{W}^3 + \dots) (\mathbf{X}\boldsymbol{\beta} + \mathbf{u}) \quad (2)$$

That is, the first and higher order spatial lags of the exogenous explanatory variables can serve as excluded instruments of the spatial lag (Kelejian and Prucha 1998). Because these spatial lags are exogenous, they potentially serve as proper (relevant) instruments for any additional endogenous covariates. These are not entered in the main specification as explanatory variables (the exclusion restriction is fulfilled), and thus are exogenous (as they are reweighted versions of exogenous variables) and likely to be correlated with other explanatory variables (relevance). For every specification, we test the relevance of the instruments with an under-identification test (H0: the instruments are not correlated with the endogenous variables), and test the specification using a Hansen test of over-identifying restrictions (H0: the instruments fulfil the exogeneity and exclusion assumptions). We also determine the set of endogenous covariates using a series of tests based on the difference between the Hansen test statistics.

Our set of instruments consists of the spatial lags of the logarithm of horsepower and coal output, mortality and the relative measure of child employment. We keep the number of instruments low to maintain the power of the over-identifying restrictions test (Roodman 2009). In all samples, the Hansen test of the null hypothesis that our instruments are valid cannot be rejected even at 50%, which is far from the risky border-line cases mentioned by Roodman (2007). In all samples, while the spatial lag is endogenous as expected, the successive exogeneity tests indicate that only the number of newspapers sold is subject to endogeneity. Hence, we find no statistical evidence of reverse causality between industrialisation and human capital or industrialisation and measures of technology in any of the samples. Hence, the direct causal interpretation of their respective

coefficients is possible, and our initial hypothesis on the lack of simultaneity is confirmed. The simultaneity between the number of newspapers sold (a measure of urbanisation) and industrial employment is not unexpected, as industrialisation fundamentally changed the nature of urbanisation in the nineteenth century.

4. Results

4.1. Results for all manufacturing sectors

First, we estimate the three empirical specifications for all manufacturing sectors (Table 2). Regarding the presence of spatial clustering, or agglomeration, we find that instrumenting for the endogeneity of the spatial lag and some of the explanatory variables causes the significant positive coefficient in column 2 to become statistically insignificant and approach zero. After correcting for the endogeneity bias, industrial employment can be sufficiently explained by the explanatory variables and there is no further evidence of any spill-over effects.

Besides the absence of an agglomeration (or de-agglomeration) effect, our results relate to technology and human capital. For technology, the coefficient of the number of steam engines, most of which were imported from Britain during the early nineteenth century (Van Neck 1979; Lintsen and Steenaard 1991; Lintsen 1995), is insignificant. In contrast, horsepower yields a small but positive and statistically significant coefficient. One possible explanation is that technology had the greatest benefits for larger factory-based firms that used heavier steam engines with greater horsepower. However, in the Low Countries at the beginning of the nineteenth century, most workers were still employed in the handicraft and domestic industries, not in the larger factories that relied on steam power (see Table 5). Therefore, our results seem to indicate a positive relationship between the demand for labour and capital accumulation during the nineteenth century: the increasingly capital-intensive business activity also seemed to require more employees. With no evidence of a substitution of labour in favour of capital, we can conclude that the introduction of steam engines did not result in technological unemployment. The specific case of the Low Countries as an importer of English technology may also have influenced these results: Belgian and Dutch importers of steam engines were mostly successful factories that intended to set up large-scale operations with many employees.

With regard to human capital, the coefficients are negative for primary education but positive for secondary education. For every additional percentage point of secondary school attainment, employment in manufacturing grew by 20.5%. Indeed, secondary school attendance does a much better job of explaining industrial employment during the nineteenth century than does primary school attendance: for every additional percentage point of primary school attainment, industrial employment seems to have shrunk by 1.51%. This makes it likely that industrialisation was more affected by the nearby presence of a possible entrepreneurial or knowledgeable elite than by the general educational level of the population, consistent with the assessments of Mokyr (2011, 2017) and Squicciarini and Voigtlander (2016). The significant positive coefficient of

mortality points to the urban environment where most of this cheap labour was situated: laborers in manufacturing invested less in human capital, possibly influenced by their lower life expectancy. Furthermore, well-educated, wealthy citizens, who lived longer and invested more in human capital and secondary school education, mostly lived in urban environments.

Table 2. Fixed effect panel estimates of ISIC sectors 10–33 (all manufacturing sectors)

VARIABLES	(1) Ln Employment Manu. Sectors	(2) Ln Employment Manu. Sectors	(3) Ln Employment Manu. Sectors
<i>Spatial lag ln Employment</i>		0.696*** (0.0565)	-0.026 (0.143)
<i>Relative Employment in Industry</i>	12.05*** (1.865)	7.550*** (1.354)	11.96*** (2.023)
<i>Ln Steam Engines</i>	0.0850 (0.123)	0.109 (0.110)	0.0323 (0.121)
<i>Ln Horse Power of Steam Engines</i>	0.235*** (0.0688)	0.151** (0.0646)	0.268*** (0.0697)
<i>Primary School Attendance</i>	-1.925** (0.719)	-2.669*** (0.474)	-1.512*** (0.505)
<i>Secondary School Attendance</i>	18.30** (7.269)	12.78** (5.305)	20.50*** (6.338)
<i>Child Employment</i>	5.690*** (1.962)	6.722*** (1.738)	6.134*** (1.754)
<i>Ln Population</i>	0.405 (0.350)	0.873*** (0.203)	1.827*** (0.655)
<i>Ln Coal Output</i>	-0.0592 (0.0488)	-0.0641 (0.0391)	-0.0687* (0.0338)
<i>Ln Sold Newspapers</i>	-0.0265 (0.0579)	-0.289*** (0.0510)	-0.397** (0.178)
<i>Mortality</i>	0.037** (0.0176)	0.021** (0.00778)	0.052*** (0.0167)
Observations	1,740	1,740	1,740
R-squared	0.316	0.540	0.275
Endogenous expl. vars	SpatiallaglnEmp LnSoldNewspapers	SpatiallaglnEmp lnSoldNewspapers	SpatiallaglnEmp lnSoldNewspapers
Excluded instruments	NA	NA	Spatial lags of: ln horse power, mortality, ln coal output, childemploye nt
Underidentification-test stat.	NA	NA	17.23
p-value	NA	NA	0.000634
J-stat	NA	NA	0.906
d.f.	NA	NA	2
p-value	NA	NA	0.636

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

These estimates are essentially averages over 23 manufacturing sectors, and thus may cover up significant differences between the various manufacturing sectors. For instance, Becker, Hornung and

Woessman (2011) found that basic education levels, proxied by primary school enrolment, led to higher profits in non-manufacturing but not in textile manufacturing. Given the potential differences between manufacturing sectors, in the following subsection we repeat our regression results for different ISIC sectors.

4.2. Sectoral differences between manufacturing sectors

We subdivide the manufacturing sectors into three categories. The first comprises the textiles and clothing sectors, defined as ISIC categories 13 (textiles), 14 (apparel) and 15 (leather and related products). The second comprises the machinery and equipment sectors, defined as ISIC Revision 4 categories: 26 (electronic and optical products), 27 (electrical equipment), 28 (machinery and equipment), 29 (motor vehicles, trailers and semi-trailers) and 30 (other transport equipment). The third category is rather imprecisely defined as ‘others’, consisting of the remaining manufacturing sectors. These sectors are chosen for four main reasons. First, as Crafts and Harley (1992) observed, industrialisation was initially confined to growth in a limited set of manufacturing sectors, pointing to the catalytic effect of the textiles and clothing sectors. This also seems to be true for the Low Countries, in light of the annual compound growth rates of our sector groups (see Table 4). This also fits with our second reason: regressions on various sectors (available on request) show that the results, as already stated in point 1, were most significant in the textiles and clothing sectors on the one hand and the machinery and equipment sectors on the other hand.

Table 3. Employment in the four main manufacturing sectors in the Low Countries, based on the Dutch and Belgian censuses of population and industry

	Textiles and Clothing Sectors	Machinery and Equipment Sectors	Other Manufacturing Sectors	Total Manufacturing Sector
1820	387 781	12 487	187 630	587 898
1850	626 865	40 193	251 147	918 205
1900	660 438	109 200	873 233	1 642 871

Table 4. Compound annual growth rates in employment by sector in the Low Countries

	Textiles and Clothing Sectors	Machinery and Equipment Sectors	Other Manufacturing Sectors	Total Manufacturing Sector
1820 – 1850	1.80 %	4.43 %	1.09 %	1.67 %
1850 - 1900	0.10 %	2.02 %	2.52 %	1.17 %

Table 5. Employment in the four main manufacturing sectors in the Low Countries in 1900, subdivided into factory-, handicraft- and domestic-based manufacturing

	Textiles and Clothing Sectors	Machinery and Equipment Sectors	Other Manufacturing Sectors	Total Manufacturing Sector
Factory-based *	124 104	40 917	258 193	423 214
Handicraft-based**	420 295	68 234	604 451	1 092 980
Domestic-based***	113 007	49	13 621	126 677
Total	657 406	109 200	876 265	1 642 871

* Factory = an establishment where either more than 20 people were employed or an operating steam engine was active

** Handicraft = an establishment where less than 20 people were employed and no operating steam engine was active

*** Domestic = part-time production, which took place not at a fixed work space but at the home of the employees

Third, these sectors vary widely in size: for the 1820–1900 period, the textiles and clothing sectors account for 40.20%–65.96% of the total labour force in the manufacturing sector, whereas machinery accounts for 2.12%–6.65% (see Table 3). In other words, the textiles and clothing sectors represent an early phase of industrialisation, whereas the machinery and equipment sectors represent a second phase. This is in line with our fourth reason, namely that the clothing/textiles and machinery/equipment sectors vary in terms of their organisational structures and their respective drivers of growth. Because the clothing/textiles and machinery/equipment sectors grew considerably faster than other sectors in the first half of the nineteenth century, (Table 4), growth in the former sectors did not benefit from rising activity in the latter sectors, implying that the growth in the clothing/textiles and machinery/equipment sectors must have originated mainly from the factors of production. However, even though that might be true, there could be another reason for growth in the clothing/textiles and machinery/equipment sectors. In the textiles and clothing sectors, the replacement of domestic-based manufacturing with modernised forms of production occurred gradually, as did the substitution of handicraft-based production in favour of factory-driven production in the clothing and textiles sectors (Table 5). The machinery and equipment manufacturing sectors, however, were characterised by the emergence of new sectors with high annual compound growth rates (see Table 4), which relied mainly on steam-driven factory work (see Table 5).

The results of the OLS, OLS with spatial lag and 2SLS with spatial lag are presented in Tables 6–8. The negative and insignificant coefficient for the spatial lag in column 3 of Table 6 indicates that agglomeration effects did not play an important role in the textiles, apparel and leather manufacturing sectors. This is not surprising, given that tanners, tailors, shoe-workers and others were active in almost every town during the nineteenth century. Although certain textile production centres, particularly the provinces of East Flanders, West Flanders and Overijssel, rose in importance during the nineteenth century, the distribution of the sector was still fairly evenly distributed over the territory of the Low Countries at the end of the century. In contrast to the results for the general and clothing manufacturing sectors, the machinery and equipment sectors show positive and significant results for agglomeration, indicating clustering (see column 3 of Table

7). The highly significant positive coefficients for population suggest that machinery enterprises tended to start their operations near other machinery producing centres with high population densities. In addition, the industrial employment coefficients are notably higher than those in the clothing and general manufacturing sectors. Given the high growth rates in the machinery and equipment sectors (see Table 4), we can also assume that the owners of machinery enterprises decided where to start their operations, whereas the textiles and clothing factories tended to be pre-existing businesses that expanded their activities at the same business location.

Table 6. Fixed effect panel estimates of ISIC sectors 13–15 (textiles and clothing sectors)

VARIABLES	(1) Ln Employment Manu. Sectors	(2) Ln Employment Manu. Sectors	(3) Ln Employment Manu. Sectors
<i>Spatial lag ln Employment</i>		0.207** (0.0849)	-0.0798 (0.207)
<i>Relative Employment in Industry</i>	6.650*** (0.518)	5.898*** (0.516)	6.970*** (1.004)
<i>Ln Steam Engines</i>	0.0689 (0.0739)	0.0938 (0.0679)	0.0701 (0.0804)
<i>Ln Horse Power of Steam Engines</i>	0.0239 (0.0477)	0.0255 (0.0448)	0.0121 (0.0544)
<i>Primary School Attendance</i>	-0.408 (0.684)	-0.977 (0.732)	-0.183 (0.879)
<i>Secondary School Attendance</i>	9.620* (5.699)	11.28** (5.465)	8.505 (6.395)
<i>Child Employment</i>	9.538*** (1.331)	9.488*** (1.270)	9.613*** (1.373)
<i>Ln Population</i>	1.314*** (0.288)	1.166*** (0.287)	1.124** (0.451)
<i>Ln Coal Output</i>	-0.101** (0.0454)	-0.111** (0.0474)	-0.0958** (0.0477)
<i>Ln Sold Newspapers</i>	-0.0721 (0.0688)	-0.119 (0.0742)	0.0157 (0.159)
<i>Mortality</i>	0.0601*** (0.0104)	0.0504*** (0.0115)	0.0622*** (0.0139)
Observations	180	180	180
R-squared	0.806	0.816	0.794
Endogenous expl. vars			SpatiallaglnEm p lnSoldNewspap ers
Excluded instruments			Spatial lags of mortality lncoal output, childemploye ment
Underidentification-test stat.			14.93
p-value			0.000572
J-stat			0.151
d.f.			1
p-value			0.698

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 7. Fixed effect panel estimates of ISIC sectors 26–30 (machinery and equipment sectors)

VARIABLES	(1) Ln Employment Manu. Sectors	(2) Ln Employment Manu. Sectors	(3) Ln Employment Manu. Sectors
<i>Spatial lag ln Employment</i>		0.764*** (0.0691)	0.775*** (0.148)
<i>Relative Employment in Industry</i>	21.43 (15.82)	12.56 (9.348)	12.51 (8.515)
<i>Ln Steam Engines</i>	0.172 (0.350)	0.153 (0.290)	0.0149 (0.297)
<i>Ln Horse Power of Steam Engines</i>	0.489** (0.235)	0.310 (0.189)	0.376* (0.199)
<i>Primary School Attendance</i>	-5.378*** (1.889)	-5.678*** (1.563)	-5.233*** (1.564)
<i>Secondary School Attendance</i>	13.27 (20.35)	7.554 (16.33)	19.21 (17.43)
<i>Child Employment</i>	0.0485 (0.192)	-0.501*** (0.158)	-1.263*** (0.281)
<i>Ln Population</i>	0.848 (0.906)	1.878*** (0.711)	4.568*** (1.007)
<i>Ln Coal Output</i>	-0.277** (0.127)	-0.144 (0.111)	-0.158 (0.103)
<i>Ln Sold Newspapers</i>	0.0330 (0.0397)	0.00662 (0.0268)	0.0272 (0.0280)
<i>Mortality</i>	-0.990 (4.741)	7.795** (3.455)	7.407* (4.119)
Observations	300	300	300
R-squared	0.382	0.650	0.603
Endogenous expl. vars.			SpatiallaglnEmp lnSoldNewspapers
Excluded instruments			Spatial lags of lnsteam engines, mortality lncoal output, childemployment lnpopulation
Underidentification-test stat.			25.78
p-value			3.50e-05
J-stat			2.907
d.f.			3
p-value			0.406

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 8. Fixed effect panel estimates of ISIC sectors 10–12, 16–26 and 31–33 ('other' sectors)

VARIABLES	(1) Ln Employment Manu. Sectors	(2) Ln Employment Manu. Sectors	(3) Ln Employment Manu. Sectors
<i>Spatial lag ln Employment</i>		0.625*** (0.0918)	-0.151 (0.186)
<i>Relative Employment in Industry</i>	15.84*** (2.427)	11.04*** (2.332)	17.09*** (2.997)
<i>Ln Steam Engines</i>	-0.0380 (0.0744)	-0.237*** (0.0554)	-0.212 (0.190)
<i>Ln Horse Power of Steam Engines</i>	0.215*** (0.0652)	0.135** (0.0634)	0.249*** (0.0682)
<i>Primary School Attendance</i>	0.313 (0.400)	0.723*** (0.252)	1.001 (0.746)
<i>Secondary School Attendance</i>	0.0382** (0.0147)	0.0264*** (0.00758)	0.0493** (0.0180)
<i>Child Employment</i>	0.0518 (0.119)	0.0905 (0.108)	0.0466 (0.123)
<i>Ln Population</i>	-1.438* (0.777)	-2.025*** (0.536)	-1.426* (0.777)
<i>Ln Coal Output</i>	18.40** (8.537)	12.47* (6.420)	22.89** (9.075)
<i>Ln Sold Newspapers</i>	-0.0207 (0.0537)	-0.0441 (0.0477)	-0.0516 (0.0444)
<i>Mortality</i>	6.578*** (2.174)	6.179** (2.210)	6.824*** (2.035)
Observations	1,260	1,260	1,260
R-squared	0.336	0.501	0.237
Endogenous expl. vars	NA	NA	SpatiallaglnEmp lnSoldNewspap ers
Excluded instruments	NA	NA	Spatial lags of lnhnp, mortality, Incoal output, childemploye ment
Underidentification-test stat.	NA	NA	12.03
p-value	NA	NA	0.00729
J-stat	NA	NA	0.592
d.f.	NA	NA	2
p-value	NA	NA	0.744

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Steam engines and horsepower had little effect on employment in the textiles and clothing sectors (Table 6), which makes sense given the relatively slow mechanisation in these sectors. The textiles and apparel sectors were still driven by the hand power of domestic and handicraft textile workers, while the bigger factories were increasingly driven by steam engines (see Table 5). More specifically, in 1896, 127,136 people were employed in what we consider as factories (businesses that either used a steam engine or had more than 20 employees per business establishment), 420,295 people were employed in handicraft-based production (those that did not use a steam engine and had less than 20 employees per business establishment) and 113,007 employees worked in the domestic textiles and clothing sector (part-time labourers with no fixed workplace,

operating within their own home and often with the help of other family members). In contrast, the coefficients for horsepower are high in the machinery sector, whereas those for steam engines are low. This can be explained by the higher horsepower per steam engine ratio in this highly automated industry, where heavier and stronger steam engines were used.

Of course, this high level of mechanisation in the growing machinery and equipment manufacturing sector, indicated by the high coefficients for steam engines and horsepower (see Table 8), also relates to the high number of factories in this sector (see Table 5). The high number of factories also explains the high coefficients for child employees and population density: factory owners in the fast-growing (see Table 4) machinery sector were not necessarily looking for an educated, skilled labour force, but rather for a large labour force willing to start work on the assembly line. The previously noted negative effects of primary school attendance in the general manufacturing sectors are not evident in the results for the textiles and clothing manufacturing sector, which at first sight seems to lead to the conclusion that human capital did not play a role in the industrialisation process of this sector. However, it could also be due to the combination of factory-, handicraft- and domestic-based employment in our dataset, because it is highly likely that human capital had different effects on these categories of organisation.

The different effects on human capital over the organisation of labour would also explain why there were more children employed in the textiles and apparel sectors than the machinery sectors, although primary school education rates were still lower in regions where machinery and equipment firms existed. In other words, even though more children worked in the textiles sector, basic education attendance suffered more from the presence of the machinery sector. The coefficients of child employment are also noticeably higher in the clothing sector than the machinery and other manufacturing sectors. For every percentage point increase in child employment, industrial employment increased by 9.6% in the clothing sector, 7.4% in the machinery sector and 6.1% in the other manufacturing sectors (see Tables 6–9). One possible explanation is that domestic manufacturing, which was high among the textiles and clothing sectors, had a higher demand for child employees than the newly opened factories, the majority of which were in the machinery and equipment sectors.

Bearing in mind both the high negative coefficients of primary school attendance for the machinery and equipment sectors and the earlier mentioned possibility of reverse causality, we could argue that factory-based manufacturing had a more disruptive effect on primary school attendance, as shown by the results for the machinery and equipment sectors (see column 3 in Table 7), than did domestic-based manufacturing, as shown by the results for the textiles and clothing sectors (see Table 6). Clearly, the factories would have gained little from a well-educated workforce, because the workers were responsible for a particular, well-defined part of the production process. Becker, Hornung and Woessman (2011) pointed to a similar effect in the Prussian textiles sector, where basic education had little effect on employment rates. Similarly, O'Rourke, Rahman and Taylor (2013) argued that innovation in textiles sectors was more oriented towards unskilled than skilled

labour. This is in line with studies that have found that new production techniques emerged in regions with an abundance of unskilled labour (e.g., Goldin and Sokoloff 1982; Acemoglu 2002).

The regression estimates for the effect of secondary schooling rates are notably lower for the textiles and clothing sectors than for the machinery and equipment and other manufacturing sectors, suggesting that the beneficial effect of ‘upper class knowledge’ for the textiles and clothing sector was negligible in the Low Countries. However, the effect of secondary education was high and significant for the machinery and equipment sectors. Based on the weak and insignificant effect in the textiles and clothing sectors and given the high proportion of domestic-based production in these sectors (see Table 5), we hypothesise that upper-tail human capital levels were not particularly important for employment in domestic-based production, but were important for factory and handicraft based production, as shown in the results for the machinery and equipment sectors. As factory-based production was more orientated towards the retail trade, this sector had a greater need for well-educated, trained workers than industrial sectors that relied on a large amount of cheap labour. In line with the recent literature on the contrasting effects of upper- and lower-tail knowledge (e.g., Weisdorf, Nuvolari and De Pleijt 2015; Squicciarini and Voigtlander 2016), we conclude that the nearby presence of local knowledgeable elites strongly influenced the settlement of factories during the industrial age.

We find no significant results for the ‘other sectors’ (see Table 8): the ISIC manufacturing sectors excluding the textiles, clothing, machinery and equipment manufacturing sectors. This is not surprising given the high diversity among these sectors: they contained both newly founded, fast-growing and mechanised manufacturing sectors such as the chemical industry and the metallurgy sector, and old-fashioned and less-mechanised industry sectors such as food production and processing. To discover similar intersectoral differences to those we found for the clothing and machinery sector, we need to abandon this aggregated level and turn to more in-depth subdivisions of manufacturing sectors, which is beyond the scope of this paper.

4.3. Cross-sectoral effects between the textiles and clothing sectors and the machinery and equipment sectors

However, we are interested in the mutual relationships between these different sectors, and any intersectoral effects. Because we do not have proper instruments to identify causal relationships, we use lagged explanatory variables in Table 9; i.e., we examine the effects of the variables in 1820 and 1850 on sectoral industrial employment in 1850 and 1900, respectively. Based on these results, we can make two observations. First, it seems that the presence of textiles and clothing firms had a stronger pull effect on the presence of firms in the machinery and equipment sectors than vice versa. This hypothesis seem to be re-confirmed by the results in Tables 6-8, which indicate that the agglomeration forces were stronger for the machinery and equipment sectors than for the clothing and textiles sectors, or the other sectors. A possible major reason why the nearby presence of employment in the textiles and clothing manufacturing sectors seems to have been of key importance for setting up a business in the machinery and equipment sectors, was that the mechanisation of the textiles and clothing sectors in the Low Countries began before the rise of the machinery and equipment

sectors. Second, we find no significant effects for the other sectors, neither in relation to the textiles and clothing sectors or the machinery and equipment sectors.

Table 9. OLS estimation of the relation between the textiles and clothing sectors, machinery and equipment sectors and other manufacturing sectors (lagged results)

VARIABLES	(1) Ln Employment Machinery Sectors	(2) Ln Employment Clothing Sectors	(3) Ln Employment Other Sectors
<i>Constant</i>	11.89** (4.895)	16.44*** (1.940)	9.750*** (2.392)
<i>Lagged Ln Employment Machinery Sectors</i>		0.173** (0.0747)	0.222 (0.176)
<i>Lagged Ln Employment Clothing Sectors</i>	0.496** (0.232)		0.413 (0.302)
<i>Lagged Ln Employment Other Sectors</i>	-0.494 (0.496)	-0.280 (0.184)	
<i>Ln Steam Engines</i>	0.0718 (0.173)	0.0639 (0.0910)	0.213* (0.121)
<i>Ln Horse Power of Steam Engines</i>	0.204 (0.284)	0.139 (0.121)	-0.0124 (0.152)
<i>Primary School Attendance</i>	-3.573*** (0.988)	-1.651*** (0.323)	-1.802*** (0.607)
<i>Secondary School Attendance</i>	13.65 (11.86)	-4.301 (5.873)	6.669 (11.01)
<i>Child Employment</i>	-2.500 (2.643)	0.709 (1.404)	-4.441*** (1.287)
<i>Ln Population</i>	-0.162 (0.249)	-0.325*** (0.106)	-0.220 (0.147)
<i>Ln Coal Output</i>	-0.00438 (0.0376)	-0.0591*** (0.0126)	0.00853 (0.0243)
<i>Ln Sold Newspapers</i>	-0.102 (0.104)	0.0292 (0.0336)	-0.206** (0.0762)
<i>Mortality</i>	0.00724 (0.0254)	-0.0209** (0.00880)	-0.000417 (0.0243)
Observations	40	40	40
R-squared	0.703	0.846	0.857
Number of prov	20	20	20

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Second, we find no relation between the other sectors on the one hand and the textiles and clothing sectors or the machinery and equipment sectors on the other hand. Similar to the view of Crafts and Harley (1992), this finding may point to an initial process of high growth and mechanisation in a confined set of sectors, which in the case of the Low Countries seems to be in the textiles and clothing sectors, leading to mechanisation in other manufacturing sectors, such as machinery and equipment manufacturing. Given the spectacular growth rates of the machinery and equipment sectors (Table 4), it is no wonder that agglomeration processes played a stronger role in these sectors. The rise in employment in the machinery sectors was mainly

due to newly founded factories that were set up in specifically chosen areas, while the growth in employment in the textiles and clothing sectors was mostly due to the expansion of already-existing centres of textile production. The entrepreneurs in the machinery sector actively decided to start their business activities near the existing textiles and clothing production centres, lured by the proximity of similar products, people and ideas.

5. Conclusion

The industrialisation process in the Low Countries seems to have been pushed by labour, physical capital, technology and human capital, although these factors had widely diverse effects in different sectors. Manufacturing firms tended to emerge in densely populated regions during the nineteenth century. We found no empirical evidence of agglomeration in the clothing or other manufacturing sectors; however, we did find such evidence for the machinery and equipment manufacturing sectors, especially when we controlled for the employment of a sector in a province as a share of the total employment in all provinces. The high growth rates in the machinery and equipment sectors gave entrepreneurs in these sectors more opportunities to choose the locations of their activities compared with the other manufacturing sectors in the Low Countries. A comparison of our results in the textiles and clothing sectors and the machinery and equipment sectors suggest that machinery and equipment enterprises tended to be attracted to centres of textiles and clothing production, not surprisingly the clothing and textiles sectors were the sectors in which relatively early steam engines came to be introduced in the Low Countries.

The nearby presence of textiles and apparel factories also had spill-over effects on capital, technology and upper-tail knowledge. In the nineteenth century, steam engines seemed to complement rather than replace employment in the Belgian and Dutch manufacturing sectors. This effect was also noticeably stronger in the mechanised machinery sector than in the clothing and other manufacturing sectors, which were still dominated by a high proportion of domestic and handcraft businesses. Our results concerning human capital seem to support the deskilling hypothesis. While average human capital levels, proxied by primary school attendance, had a significant negative effect on industrial employment, secondary school attendance had the opposite effect. In accordance with the recent literature on the contrasting effects of upper and lower-tail knowledge (e.g., Weisdorf, Nuvolari and De Pleijt 2015; Squicciarini and Voigtlander 2016), we similarly noted a positive effect of newspaper subscriptions and secondary school attendance on industrialisation, and a negative effect of primary school education on employment in the manufacturing sector, particularly the machinery and equipment sectors.

Bibliography

- Acemoglu D (2002) Technical change, inequality, and the labor market. *Journal of economic literature* 40:7-72.
- Becker SO, Hornung E, Woessman L (2011) Education and catch-up in the industrial revolution. *American Economic Journal: Macroeconomics* 3:92-126.
- Boonstra O (2009) Regionale verschillen in de daling van het analfabetisme in Nederland, 1775 - 1900. Working Paper of the Scientific Research Community Historical Demography WOG_HD/2009-11.
- Brugmans IJ (1956) Statistieken van de Nederlandse nijverheid uit de eerste helft der 19de eeuw. Martinus Nijhoff, 's Gravenhage.
- Brugmans IJ (1969) Paardenkracht en mensenkracht: sociaal-economische geschiedenis van Nederland, 1795 - 1940. Nijhoff, Den Haag.
- Buyst E (2009) Reversal of fortune in a small, open economy: regional GDP in Belgium, 1896 - 2000. *Vives Discussion Papers* 8:1-27.
- Clark G (2005) The condition of the working class in England, 1209-2003. *Journal of Political Economy*, 113:1307-1340.
- Crafts NFR (1996) The first industrial revolution: a guided tour for growth economists. *American Economic Review Papers and Proceedings* 86:197-201.
- Dansma D, De Meere JMM, Noordegraaf L (1979) Statistieken van de Nederlandse nijverheid der eerste helft der 19de eeuw. Supplement. Martinus Nijhoff, 's Gravenhage.
- Dansma D, Noordegraaf L (1982) Een vergeten plattelands nijverheid. Vlasarbeid, bevolkingsgroei en proto-industrialisatie in zuid-west Nederland 1700 - 1900. *Economisch en Sociaal Historisch Jaarboek* 44:145-154.
- De Brabander GL (1983) Regionale structuur en werkgelegenheid: een economische en geografische studie over de Belgische lange-termijn-ontwikkeling. Koninklijke Academie voor Wetenschappen, Letteren en Schone Kunsten van België, Brussel.
- De Jonge JA (1968) De industrialisatie in Nederland tussen 1850 en 1914. Scheltema & Holkema NV, Amsterdam.
- De la Croix D, Vandenbergh V (2004) Human capital as a factor of growth and employment at the regional level: the case of Belgium. *Department of Economics Working Papers of the Catholic University of Louvain*:1-67.
- De Pleijt AM, Weisdorf JL (2015) Human capital formation from occupations: the 'deskilling hypothesis' revisited. *Warwick Working Paper Series* 225:1-47.
- De Pleijt AM (2015) Human capital and long run economic growth: evidence from the stock of human capital in England, 1300-1900. *Competitive Advantage in the Global Economy Working Papers* 229:1-30.
- Feldman NE, Van Der Beek K (2016) Skill choice and skill complementarity in eighteenth century England. *Explorations in Economic History* 59:94-113.
- Franck R, Galor O (2015) Is industrialization conducive to long-run prosperity? *CESifo Working Papers* 5354:1-79.
- Franck R, Galor O (2016) Technology-skill complementarity in the early phase of industrialization. *IZA Discussion Paper Series* 9758:1-64.
- Galor O (2005) From stagnation to growth: unified growth theory. In: Aghion P, Durlauf S. *Handbook of economic growth*. Elsevier, Amsterdam, 171-293.
- Galor O (2011) *Unified growth theory*. Princeton University Press, Princeton.
- Garnier JG (1828) *Correspondance mathématique et physique*, publiée par A. Quetelet. Hayez Imprimeur de l'Academie Royale, Brussels.
- Goldin C and Katz LF (1998) The origins of technology-skill complementarity. *Quarterly Journal of Economics* 113:693-732.
- Goldin C, Sokoloff K (1982) Women, children, and industrialization in the early republic: evidence from the manufacturing censuses. *The Journal of Economic History* 42:741-774.
- Griffiths RT (1979) Industrial retardation in the Netherlands 1830 - 1850. Martinus Nijhoff, Den Haag.
- Hemels JMJJ (1969) De Nederlandse pers voor en na de afschaffing van het dagbladzegel in 1869. Van Gorcum, Assen.
- Humphries J, Schneider B (2016) Spinning the industrial revolution. *Discussion Papers in Economic and Social History* 145:1-53.
- Jansen M (1999) De industriële ontwikkeling in Nederland, 1800 - 1850. *Nederlands Economisch Historisch Archief*, Amsterdam.
- Kelejjan HH and Prucha I (1998) A generalized spatial two stage least squares procedures for estimating a spatial autoregressive model with autoregressive disturbances. *Journal of Real Estate Finance and Economics* 17:99-121.
- Lintsen H and Steenaard R (1991) Steam and polders. *Belgium and the Netherlands, 1790 - 1850. Yearbook for History of Science, Medicine, Technology and Mathematics* 3:121-147.
- Lintsen HW (1995) *Geschiedenis van de techniek in Nederland. De wording van een moderne samenleving 1800 - 1890*. Walburg Pers, Zutphen.
- Malou JB (1843) *Notice statistique sur les journaux Belges (1830 - 1842)*. Hayez Imprimerie de la Commission Centrale de Statistique, Brussels.
- Mandemakers CA (1996) *Gymnasiaal en middelbaar onderwijs: ontwikkeling, structuur, sociale achtergrond en schoolprestaties, Nederland, ca. 1800 - 1968*. Erasmus Universiteit, Rotterdam.

- Manski C (1993) Identification of Endogenous Social Effects: The Reflection Problem. *The Review of Economic Studies* 60:531-542.
- Martin R (1988) The political economy of Britain's North-South divide. *Transactions of the Institute of British Geographers* 13:389-418.
- Meisenzahl R, Mokyr J (2012) The rate and direction of invention in the British industrial revolution: incentives and institutions. In: Lerner J, Ster S. *The rate and direction of incentives and institutions*. University of Chicago Press, Chicago, 433-479.
- Mitch D (1993) The role of human capital in the first industrial revolution. In: Mokyr J. *The British industrial revolution: an economic perspective*. Westview press, Boulder, 267-307.
- Mokyr J (2005) Long-term economic growth and the history of technology. In: Aghion P, Durlauf S. *The handbook of economic growth*. Elsevier, Amsterdam, 1113-1180.
- Mokyr J, Voth HJ (2009) Understanding growth in Europe, 1700 - 1870: theory and evidence. In: Broadberry S, O'Rourke KH. *The Cambridge economic history of modern Europe. volume 1: 1700 - 1870*. Cambridge University Press, Cambridge, 7-43.
- Muldrew C (2012) "Th'ancient distaff" and "whirling spindle": measuring the contribution of spinning to household earnings and the national economy in England, 1550 – 1770. *Economic History Review* 65:498-526.
- Nicholas SJ, Nicholas JM (1992) Male literacy, 'deskilling' and the industrial revolution. *Journal of Interdisciplinary History* 23:1-18.
- Quetelet A (1827) *Recherches sur la population, les naissances, les décès, les prisons, les dépôts de mendicité etc. dans le Royaume des Pays-Bas*. Libraire Tarlier, Brussels.
- Pluymers B (1992) *De Belgische industriële productie 1811 – 1846, reconstructie van een databank van de fysieke productie en de toegevoegde waarde*. Centrum voor Economische studiën, Leuven.
- Roodman D (2007) A short note on the theme of too many instruments. *Center for Global Development Working Papers* 125:1-32.
- Roodman D (2009) A note on the theme of too many instruments. *Oxford Bulletin of Economics and Statistics* 71:135-158.
- Rostow WW (1960) *The stages of economic growth: a non-communist manifesto*. Cambridge University Press, Cambridge.
- Squicciarini MP, Voigtländer N (2015) Human capital and industrialization: evidence from the age of enlightenment. *Quarterly Journal of Economics* 130:1825-1883.
- Steenard R (1989) *Stoom en stoomwezen, 1824 – 1850*. Doctoraatsverhandeling Erasmus Universiteit van Rotterdam.
- Vandenbroeke C (1979) Sociale en conjuncturele facetten van de linnennijverheid in Vlaanderen (late 14e - midden 19e eeuw). *Handelingen der Maatschappij voor Geschiedenis en Oudheidkunde te Gent* 33:117-174.
- Van Der Wee H (1984) De industriële ontwikkeling in de Nederlanden tijdens de 17de - 18de eeuw. Enkele kritische bemerkingen naar aanleiding van het debat over de proto-industrie en poging tot aanvulling van het synthese-model. *Mededelingen van de Koninklijke Academie voor Wetenschappen, Letteren en Schone Kunsten van België* 46:57-77.
- Van der Woude AM (1980) De Alfabetisering. In: *Algemene Geschiedenis der Nederlanden*. Fibula-van Dishoeck, Haarlem, 257-264.
- Vanhaute E (1994) De meest moordende van alle industrieën: de huisnijverheid in België omstreeks 1900. *Tijdschrift voor Sociale Geschiedenis* 20:461-484.
- Van Neck A (1979) *Les débuts de la machine à vapeur dans l'industrie Belge 1800 – 1850*. Palais des Académies, Brussels.