STEAM AND POLDERS
BELGIUM AND THE NETHERLANDS
1790-1850

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In the first half of the nineteenth century a dramatic gap opened up between the Netherlands and Belgium. Belgium was the first country on the continent to follow in the footsteps of the industrial revolution in England and consequently may rightly be given the title of 'Second Industrial Nation of the World'. As in England mining, textiles and metal were the key sectors in economic growth. The factory system, large-scale operations and mass production characterized the changes that took place in these sectors. Little of this could be found in the Netherlands until late in the nineteenth century. Contemporaries and historians have marveled at this divergent development. How could two countries that bordered on each other, differed little in surface area and population size, shared to a certain extent a linguistic community and historical ties undergo such a different process of industrialization? How was it possible that a relatively poor country like Belgium could generate the energy to accomplish such a radical metamorphosis, while a rich country like the Netherlands with its tradition of commercial capitalism could not make the transition to industrial capitalism? In what way did the circumstances[1] in Belgium and the Netherlands

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* Translated by G.T. Moran.

[1] The study by J. Mokyr is explicitly concerned with the issue of the difference in industrialization between the Netherlands and Belgium in the first half of the nineteenth century. See: J. Mokyr, *The industrialization in the low countries 1795-1850* (New Haven, 1976).
In addition, there are numerous books and articles that take the industrialization of both countries as their theme. For the Netherlands the period covered in this article is rarely treated as a separate unit. We cite here only: R.T. Griffiths, *Industrial retardation in the Netherlands 1830-1850* (Den Haag, 1979), and "Ambacht en nijverheid in de Noordelijke Nederlanden 1770-1844," in *Algemene Geschiedenis der Nederlanden (AGN)*, vol. 10 (Haarlem, 1981), pp. 219-252.
It is not so surprising that no period of Belgian economic history has been so thoroughly studied as

differ, therefore leading to their own peculiar pattern of industrialization? This problem can be posed in various ways. We shall approach it by highlighting one aspect, namely the utilization of the steam engine in both countries. Steam power is regarded as a key innovation in the process of industrialization in the nineteenth century. Data on steam power in the Netherlands and Belgium afford us the possibility of studying in detail its introduction and diffusion. The progress of steam power in different branches of industry can be followed with great precision (see Tables 1 and 2). The picture reveals indeed striking differences between the Netherlands and Belgium.

In the middle of the nineteenth century Belgian industry[2] counted approximately 2000 steam engines and Dutch fewer than 300. Expressed in horsepower (h.p.), the differences are even more considerable: about 50,000 h.p. compared with 4000 h.p.[3] Belgium had at its disposal at least twelve times the steam capacity deployed in Dutch industry. To put it another way, Belgian

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the years 1790-1850. We cite just: P. Lebrun, M. Bruwier, J. Dhondt and G. Hansotte, *Essai sur la révolution industrielle en Belgique, 1770-1847* (Brussel, 1979); H. van der Wee, "De industriële revolutie in België," in *Historische aspecten van de economische groei* (Antwerpen/Utrecht, 1972), pp. 162-208; K. Veraghtert, "Ambacht en nijverheid in de Zuidelijke Nederlanden 1790-1844," in *AGN*, vol. 10 (Haarlem, 1981), pp. 253-288.

[2] For Belgium it suffices to cite the monumental work of A. van Neck, "Les débuts de la machine à vapeur dans l'industrie Belge 1800-1850," in *Histoire quantitative et développement de la Belgique*, Tome II, vol. 2 (Bruxelles, 1979).
For the Netherlands we refer to the master's thesis of R. Steenaard, *Stoom en stoomwezen, 1824-1850* (Erasmus Universiteit Rotterdam, 1989). In the appendix of this thesis Steenaard gives an inventory of all steam plant and equipment between 1824 and 1850, for which a file has survived in the archives of the Ministry of Internal Affairs (Ministerie van Binnenlandse Zaken, Nijverheid (Industry) and predecessors, 1817-1877, Algemeen Rijksarchief (ARA)). The file contains, among other things, an inspection report made by the inspectors for steam engineering pursuant to the Royal Decrees of 6 Mey 1824 (*Staatsblad* no. 32) and 26 September 1833 (*Staatsblad* no. 58). Through a comparison with other sources it appears that this research has uncovered half of all the steam installations from the period 1824-1850. This inventory supplemented by the surveys of steam plant in the Netherlands in 1851 compiled by the provincial governors forms the basis for the investigation of the quantitative development of steam power in the Netherlands between 1800 and 1850 described in this article. For the 1851 surveys of the provinces we refer to the following sources:

Drente	ARA Nationale Nijverheid	7-3-1851	No. 66
Friesland	ARA Nationale Nijverheid	24-3-1851	No. 122
Gelderland	ARA Nationale Nijverheid	31-3-1851	No. 95
Groningen	ARA Nationale Nijverheid	24-3-1851	No. 13
Limburg	ARA Nationale Nijverheid	22-8-1851	No. 130
Noord-Brabant	ARA Nationale Nijverheid	15-4-1851	No. 67
Noord-Holland	ARA Nationale Nijverheid	16-4-1851	No. 75
Overijssel	ARA Nationale Nijverheid	5-4-1851	No. 103
Utrecht	ARA Nationale Nijverheid	8-3-1851	No. 102
Zeeland	ARA Nationale Nijverheid	17-4-1851	No. 63
Zuid-Holland	ARA Nationale Nijverheid	25-3-1851	No. 60

[3] For the sources, see note 2.

industry had available 11.3 h.p. for every 1000 inhabitants, while the Dutch only had 1.4 h.p.

Closer examination shows that the three sectors cited above – mining, metal and textiles – were the chief beneficiaries of this development. Around 1850 they together accounted for 68% of the number of steam engines and as much as 87% of the steam capacity of Belgian industry. Without these sectors the difference between Belgium and the Netherlands would be less significant, varying at most by a factor of four. Moreover, in that case smaller numbers and much less capacity are involved. In this article we will subject these sectors to examination making use of general economic-historical literature complemented by specific literature on mining, metal and textiles. Data on the size, the geographical diffusion, the structure, product assortment, raw materials and the market already offer us good insights into our problem. From a comparative analysis of the industrial sectors of Belgium and the Netherlands a satisfactory explanation can be found for much of the difference in the utilization of steam power in both countries.

Nevertheless the analysis will still fall short on a number of points, which leads us to descend to the level of the individual firm, where we can draw on a tradition of economic and technical research inaugurated in the Netherlands by publications of Mokyr[4], Griffiths,[5] Bos[6] and Fischer.[7] These authors have argued for an explanation of the tempo of innovation in the Netherlands based on a cost analysis of the factors of production. According to them, the costs of capital, labor, raw materials and additives play a crucial role in the decisions of entrepreneurs to invest in steam engines and modern labor-saving machines. The point of departure is the entrepreneur trying to make a profit, in other words seeing to it that his proceeds will be greater than his costs. The method of production with the highest profit will be given preference, assuming that the entrepreneur would rather have a higher than a lower profit. At issue therefore is in the first place a cost-benefit analysis of the different methods of production.

Such analyses must be conducted on a micro- and a meso-level, in other words per industrial sector, firm and region. The circumstances determining the cost of factors can differ very widely per sector, firm and region. The absence of innovation can therefore have different causes. The great advantage of this approach, according to Fischer, is that various background factors such as

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[4] Mokyr (n. 1), *Industrialization in the low countries*.

[5] Griffiths (n. 1), *Industrial retardation*.

[6] R.W.J.M. Bos, "Factorprijzen, technologie en marktstructuur; de groei van de Nederlandse volkshuishouding 1815-1914," *AAG-Bijdragen* 22, 1979.

[7] E.J. Fischer, *Fabriqueurs en fabrikanten, Twente, Borne en de katoennijverheid 1800-1930* (Utrecht, 1983).

legislation, excises taxes and transportation costs can in the first instance be left out of consideration, since they are expressed in the different costs of the production factors.[8]

Such research has now been performed for a number of Dutch industrial sectors and we will present the results in this article. The conclusions would have been more valuable if a comparison with Belgium had been possible, but the necessary data are unfortunately lacking.

But before we begin our sector and factor-cost analysis, we will first give the reader some historical information on Belgium and the Netherlands relevant to our theme.

The un-unitable Netherlands[9]

The Netherlands and Belgium may, superficially seen, display a number of similarities, but the two territories had grown irrevocably apart since the sixteenth century. Around the middle of that century the Netherlands still belonged to the empire of Charles V. But while the overwhelmingly Catholic southern Netherlands remained loyal to the Spanish king in that period, the semi-Protestant north rose in revolt and separated from the kingdom, marking the beginning of a separate history that brought about such political, cultural and economic differences that the reunification of both countries under one crown between 1815 and 1830 could only amount to a brief intermezzo.

The Netherlands had developed in the seventeenth century into an island of wealth at the cross-roads of shipping routes, based on the role of Holland as a staple market. The basis of its economic power disintegrated in the following century for among other reasons the decreasing need for an entrepot as direct exchange of goods between trading countries grew. But the Netherlands remained relatively prosperous with great strength in currency trade and commission business.

Agriculture had also developed into a strong economic sector. In the coastal provinces specialized farming with high productivity was practiced, exporting dairy products, madder, rapeseed and vegetables. Industry, however, languished due to changed economic relations or was outstripped by competition from abroad, especially England and France. In terms of its political structure the

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[8] *Ibid.*, p. 20.

[9] See among others: E.H. Kossmann, *The low countries 1780-1940* (Oxford, 1978); C. Vandenbroeke, "Landbouw in de Zuidelijke Nederlanden 1650-1815," in *AGN*, vol. 8 (Haarlem, 1979), pp. 73-101; H. Hasquin, "Nijverheid in de Zuidelijke Nederlanden 1650-1795," in *AGN*, vol. 8 (Haarlem, 1979), pp. 124-159.

Netherlands, which until 1795 was known as the Republic of the United Provinces, formed a unique configuration. There was no crowned head and the central authority was no stronger than the multitude of regional and local elites. The Netherlands was a republic without a center.

Belgium remained part of the Habsburg dominions until 1795. Its economy, which had been so flourishing in the sixteenth century, suffered greatly from the many wars fought on Belgian territory, from the exodus of Protestant craftsman and other skilled labor to the north and from the closing of Antwerp's harbor to international trade. The eighteenth century brought a period of slow recovery. The population was able to grow rapidly thanks to the celebrated Flemish agriculture based on intensive exploitation of the soil by small farming units. Furthermore, agricultural production underwent a partial reorientation, in which the spread of potato cultivation was the most important element, along with the expanded production of industrial and commercial crops such as flax, rapeseed, tobacco and hops. At the same time, an extensive cottage industry developed in the Belgian countryside, in particular for linen in Flanders, wool in Verviers and metal in Liege, Namur and Hainault.

The French period was disastrous for both countries. Following their victory at Fleurus in 1794, the French annexed Belgium outright and began to plunder the country. Belgian industry declined, commerce was cut off for a good part from its traditional outlets and farmers experienced hard times. But some sectors did manage to benefit from the changed circumstances, for example, the textile industry in Verviers and Ghent, and we will return to them later in this article.

In the Netherlands the French intervention in 1795 brought about the fall of the old republic and the establishment of a state based on the unity of citizenship, government, policy-making and law. A turbulent period ensued marked by a series of coups in the new republic, its transformation into the Kingdom of Holland in 1806 and finally by French annexation in 1810. The French interlude exacerbated the economic problems that the Netherlands had already been facing. The sectors dependent on shipping, international trade, and the import/export of raw materials by sea all suffered greatly and some went under. Foreign markets were hard to reach or were completely inaccessible as a result of among other things the French Continental System.

After Napoleon's defeat the allies united the two Netherlands in 1815 in one kingdom to serve as a bulwark against France. This experiment in unity was not doomed to fail from the start in spite of a century and a half of separate development. The constitution stipulated the complete equality of north and south and King William I regarded it as his life's work to shape this union. His government actually succeeded in formulating a reasonably consistent policy in the areas of the economy, social welfare, education and the colonies that applied

to both territories and brought them together. But the political and cultural contrasts were such that the common basis remained weak. Liberal opposition to the paternalistic, mercantilistic system of William I combined with virulent anti-Holland feelings among the Belgian Catholic common people ultimately led to the split in 1830. The cause of this separation can also be sought in the difference in economic structure: the industrializing south versus the commercial and wealthy north. Yet this does not seem accurate for the king had attempted, not without success, to unify the economic interests of both halves. He made abundant credit available for promoting modern industry in the south, through which northern trade could only reap advantages. For Netherlands manufactures would be financed by Netherlands capital and find their way in Netherlands ships to the colonies and other markets from which other valuable products would be transported back to the Amsterdam, Rotterdam and Antwerp staple markets. Nation-building, economic and colonial policy thus complemented one another. It was in any case a course that gained the most support in Belgium from a group of enterprising industrialists.

For this reason the economic-technical development of Belgium followed another pattern than in the Netherlands. It is to this theme that we will now turn, in which as we posited earlier, steam power occupies central stage. Around 1800 there were only a limited number of steam engines in both Belgian and Dutch industry, 67 and fewer than five respectively. In the period to 1850, their number grew exponentially in Belgium, while in the Netherlands there was barely any change until 1830 and thereafter only slow growth. In order to understand this difference we will look more closely at both industrial sectors.

Raw materials in Belgium and the Netherlands

Mining furnishes a first explanation for Dutch backwardness, for Belgium possessed economically exploitable minerals, while the Netherlands hardly had any. Coal was mined in Liege, Charleroi and the Borinage district; lead ore could be found around Namur; zinc ore near Altenberg and iron ore in the regions Tussen Sambre-en-Maas, Landroz and Lorraine. Stone quarries were located in among other places Hainault. The history of Belgian mining is very old, the first coal mines in the Liege region date from the twelfth century and iron mining began there in the fifteenth century. Initially the ore was extracted from open-pit mines and from galleries dug to shallow depths, but later the development of pumps and blowers made deeper excavation possible.

In the eighteenth century steam engines served especially to pump ground

water out of the mines and quarries,[10] but subsequently they were also put to use to help transport miners and ore through the main shafts and for ventilation. As in England coal mining was the first area where steam power was utilized, with steam engines in place as early as 1720. These engines were of the Newcomen type, in other words beam machines operating exclusively through atmospheric pressure and condensation in the cylinder. This initial generation of steam engines would remain in use in Belgium until late in the nineteenth century alongside more modern types such as those of Watt, Hornblower and Cornwall. Among these were gigantic engines of 150 h.p. and more. In 1850 the average h.p. was 43 in the mining sector, but only 23 h.p. in metalworking, 16 h.p. in the textile branch, and in the food and other sectors as low as 10 h.p. In the whole period under consideration therefore mining dominated the use of the steam engine in Belgium, of the 67 steam engines in use in 1800 there were 61 in mines. Half a century later 36% of the steam engines and 61% of all steam capacity were still deployed in mining. At that time the Netherlands had two steam engines with a total of 144 h.p. in the State Mine in Kerkrade.

These state mines were located in a region that formed a remote corner of the French empire between 1794 and 1814 and thereafter a remote corner of the Kingdom of the Netherlands.[11] Due to their geographical position they could hardly profit from the demand for coal in urban and industrial centers. The 'natural' market for the state mines, and in general for those near Aachen, remained limited to the immediate region until 1890, due to geography and the weak infrastructure. In contrast to the Belgian mines near Liege, Charleroi and in the Borinage, the mines at Kerkrade were of little economic importance. Their development was also hindered by lack of money and by flooding. In the 1820s new plans for exploitation led to the installation of a big steam pump and two steam engines for raising the coal. Given the geological and geographic situation, however, mining in the Netherlands could never play the pioneering role it did in Belgium and England.

It was not only mining that provided raw materials for industry and export. Agriculture also had a quite important function to perform in this respect in our period. Was there perhaps a pioneer's part to be played by Dutch agriculture in economic development, mechanization and the use of steam power?

Domestic and colonial agriculture produced numerous products. The Dutch East Indies, for example, supplied among others raw cane sugar, coffee, cacao and tobacco, while Dutch domestic fields produced grain, especially rye, and also

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[10] Van Neck (n. 2), "Les débuts de la machine à vapeur," pp. 77-98 and pp. 510-557.

[11] B.P.A. Gales, "De weg naar het hemelrijck is geplaveid met goede voornemens; schachten en steenkoolwinning in Limburg tussen 1750-1850," *Jaarboek voor de Geschiedenis van Bedrijf en Techniek (JbGBT)* 5, 1988, pp. 317-320.

oats, wheat, buckwheat and barley.[12] In addition, potatoes, oilseed and beans took up a substantial part of cultivated land and commercial crops such as madder, flax, rapeseed and hops were also raised. The rest of the cultivated area was used for garden farming and especially for keeping livestock.

The essential point here is that Dutch agriculture in the first half of the nineteenth century did not mechanize, yet nevertheless was able to make a real contribution to the economy.[13] As early as the seventeenth and eighteenth centuries, the Netherlands succeeded in achieving a very high level of productivity, in particular on the drained polderland in the coastal provinces. In the first half of the nineteenth century, however, while production continued to increase by and large, productivity declined under the influence of increased population growth and the growing supply of labor, with the exception of the province of Groningen.[14] Nonetheless the agricultural sector was the most important pillar of the Dutch economy in terms of employment and its contribution to national income. In this period as well, the balance of agricultural trade was positive.

In Zealand, for example, madder root was cultivated extensively, which after processing in ovens yielded the dye that was used in textiles both domestically and abroad. The many peat bogs and clay-soil areas along the coast with high ground-water levels were ideally suited for pasturage. The numerous livestock grazing there supplied the dairy products for which England was the most important foreign customer. Dairy products were among the most important exports and around mid-century were only equaled by cane sugar and other colonial crops.

Agriculture remained of excessive importance for Dutch economic development, while in Belgium it underwent a relative decline.[15] Moreover, several

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[12] For the development of Dutch agriculture from 1800 to 1850, see among others: J.L. van Zanden, *De economische ontwikkeling van de Nederlandse landbouw in de negentiende eeuw 1800-1914* (Wageningen, 1985); J.G.M. van der Poel, "Landbouw in de Noordelijke Nederlanden 1770-1840," in *AGN*, vol. 10 (Haarlem, 1981), pp. 159-182; J.A. de Jonge, "Het economische leven in Nederland 1844-1873, agrarisch bedrijf," in *AGN*, vol. 12 (Haarlem, 1977), pp. 59-61.

[13] J.M.M. de Meere, *Economische ontwikkeling en levensstandaard in Nederland gedurende de eerste helft van de negentiende eeuw* ('s-Gravenhage, 1982), pp. 5-19; R.T. Griffiths, *Achterlijk, Achter of Anders?* (Amsterdam, 1980); J.L. van Zanden, "De mythe van de achterlijkheid van de Nederlandse economie in de 19e eeuw," *Spiegel Historiael*, 1989, pp. 163-167.

[14] Van Zanden (n. 12), *De Nederlandse landbouw*, pp. 204-219.

[15] For the development of Belgian agriculture from 1800 to 1850, see among others: C. Vandenbroeke and W. Vanderpijpen, "Landbouw en platteland in de Zuidelijke Nederlanden 1770-1844," in *AGN*, vol. 10 (Haarlem, 1981), pp. 183-209; J. Craeyebeckx, "Het economische leven in België 1844-1973, agrarisch bedrijf," in *AGN*, vol. 12 (Haarlem, 1977), pp. 20-33. For East Flanders in particular, see: Ph. Kint, *Prometheus aangevuurd door Demeter. De economische ontwikkeling van de landbouw in Oost-Vlaanderen 1815-1850* (Amsterdam, 1989). In the early nineteenth century Belgian agriculture also reached a high level, especially in Flanders. Numerous crops were

sectors of Belgian agriculture entered a structural crisis around mid-century in which in particular the cultivation and processing of flax for the traditional linen industry suffered heavily from foreign competition and the rise of cotton. Pauperization in the Flemish countryside reached dramatic proportions and an important export product disappeared.

Based on the literature we can cautiously conclude that economic development in the Netherlands was based on agriculture among others and in Belgium on mining. This situation had far-reaching consequences for the utilization of steam power in both countries and thus also for the metal industry.

Machine making and the iron industry

Around 1850 the metal industry was second to mining in Belgium in the use of steam power, with 322 engines (approximately 16% of the total number in industry) with a capacity of 7659 h.p. (ca. 15%). The metal industry consisted of diverse activities. The majority of the steam engines were installed in the many machine workshops and factories.[16] They were used to run steam hammers, lathes and machines for grinding, cutting, drilling and such. A substantial number were also put to use in blast furnaces and foundries to power the bellows. In addition steam was employed in the metal-processing business, in particular for the rolling machines and steam hammers used in the manufacture of nails. Finally, there were some ten steam engines at work in the Belgian armaments industry and in cannon foundries.

In the first half of the nineteenth century the Belgian iron- and machine-building industries had experienced powerful growth with the exception of a short period after the breakup of the Kingdom of the Netherlands in 1830, which had a disastrous effect on investment and production.[17] The momentum was directly related to the modernization of mining and the mechanization of the textile industry. The iron industry as supplier of raw materials and the machine-building industry as supplier of capital goods were indissolubly tied to

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cultivated: grains, potatoes, legumes, tuberous plants, cattle feed and commercial crops. Among the most important of the latter were flax, rapeseed and other oil-producing plants. Livestock played less of a role compared with the Netherlands. Precise data on the contribution of agriculture to Belgian economic development are not available. Kint posits that agricultural productivity experienced strong general growth in the period 1815-1850 in East Flanders and provided a stimulus to industrialization (p. 427). But the quality of his statistical data has been questioned by J. Bieleman in a review of Kint's research (*NEHA-Bulletin* 3, 1989, no. 2, pp. 124-126). The discussion on this topic and also on the role of agriculture in the Netherlands in comparison with Belgium has certainly not been closed.

[16] Van Neck (n. 2), "Les débuts de la machine à vapeur," pp. 98-100, 559-562.

[17] See among others: Veraghtert (n. 1), "Ambacht en nijverheid," pp. 262-263, 268-270.

the use of steam engines and iron machines.

In the Netherlands a limited modernization and mechanization of industry took place. There was therefore no expansion in the metal industry and the backwardness in this sector in the use of steam engines can thus easily be explained.[18]

In 1850 Dutch industry possessed 49 steam engines, which were employed especially in blast furnaces, iron foundries and machine building. Blast furnaces were found in the Netherlands starting in the eighteenth century and were located in the Achterhoek region and along the Ijssel river, where the ore itself was excavated. From the start of the nineteenth century on, iron foundries could also be found spread around the country, which used pig iron (iron that has already been smelted in a blast furnace and cast in oblong masses called pigs) and scrap iron. In this period a small nucleus of machine factories also appeared, numbering ten companies in 1850.

It is astonishing that an industrial sector of this nature was able to survive in the Netherlands at all, but its relationship to shipbuilding helps explain its continued existence. The two biggest machine factories in mid-century – the Maatschappij voor Scheeps- en Werktuigbouw Feyenoord in Rotterdam and the Koninklijke Fabriek van Stoom- en andere Werktuigen in Amsterdam, both founded in 1825 – were connected to steamship companies and had an important shipbuilding division. They did not work exclusively for their own shipping companies, however, and also built and repaired steamers, steam engines and machines for third parties at home and abroad. Another company, the Leidsche Grofsmederij, set up in 1838, carved out a niche with the manufacture of anchors and other heavy rolling-mill products for ships. These three companies accounted for approximately one-third of the total steam capacity in Dutch industry in mid-century. They managed to maintain themselves reasonably well despite international competition, weak domestic demand and the lack of local iron and coal reserves.

The textile industry

One of the reasons for the insignificant development of the Dutch metal and machine industry was the weak market for their products in the textile sector in contrast to the situation in Belgium, where machine factories and workshops delivered numerous machines and steam engines to textile manufacturers.

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[18] See among others: Griffiths (n. 1), *Industrial retardation*, pp. 116-135 and G. van Hooff, *In het rijk van de Nederlandse vulcanus. De Nederlandse machinenijverheid in de periode 1825-1914. Een bedrijfstakverkenning* (Amsterdam, 1990).

Between 1830 and 1850 there were four to five times more steam engines in this branch than in the Netherlands. To arrive at an explanation for this situation we will probe more deeply into the mechanization of the wool and cotton industry.

Verviers was the center of the Belgian wool industry.[19] As early as the eighteenth century a whole series of technical innovations had been carried out there to varying degrees of success. In the French period the industry also underwent radical change and mechanization continued at a fast pace. New tools and machines for carding, spinning, shearing and various other processes were introduced extensively and resulted in an improvement in the productivity of labor by a factor of two to three. In weaving productivity doubled with the introduction of the shuttle. On the whole, however, it remained handwork, mechanization of this branch only being achieved around the middle of the nineteenth century.

Technical innovations also brought organizational change to the wool industry. Originally more than 100 firms produced woven cloths in Verviers whereby the various stages of production were integrated in a single company. Thus the purchase of the wool in Spain, France or Germany, its preparation (scouring, washing and carding), the spinning, weaving, and finishing (dressing, fulling and pressing), the dyeing and the selling were all performed by the same enterprise. Spinning and weaving were mainly done by peasant families in the countryside. This cottage industry had to make way to some extent for factories due to mechanization, but the two methods of production persisted side by side in Verviers for a considerable time to come. In 1810 only six of the 114 cloth manufacturers in this region owned a complete machine park with the exception of weaving. But these six accounted for more than half the production. Centralization occurred in the branch and a shift from the countryside to the city. The increased production found outlets domestically and was also exported to France, Italy, Switzerland and the Scandinavian countries.

Originally the mechanization of the Belgian wool industry proceeded without the use of steam. The availability of cheap water power was an obstacle to a breakthrough of steam power. The first steam engines were introduced in 1816 and by 1825 the wool business counted 36, more than half the number of steam engines in the textile industry. In 1850 there were 152 engines, which was a bit less than half the total in the textile industry.[20]

In the Netherlands the wool industry partially relocated from the coastal provinces inland in the course of the eighteenth century. The two most impor-

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[19] P. Lebrun, *L'industrie de la laine à Verviers pendant le XVIIIième et le début du XIXième siècle. Contribution à l'étude des origines de la révolution industrielle* (Luik, 1948). See further for the Belgian wool industry, the survey works cited in note 1.

[20] Van Neck (n. 2), "Les débuts de la machine à vapeur," pp. 492-493.

tant centers were Leiden and Tilburg. In the French period the Tilburg wool industry benefited from French orders and the northward shift of the customs border through which a large domestic market was created. For that reason Tilburg enjoyed a favorable competitive position when the Kingdom of the Netherlands was formed, while Leiden suffered a steep decline.

As in Verviers spinning and weaving were performed in Tilburg by home workers in farms and weavers' houses, and additionally also in so-called factory houses. The factory houses grouped workers together for certain operations in the wool processing. Among others the wool was made ready there for spinning and the woven cloth was sheared and dyed. The cloth manufacturer organized and integrated all stages of production. He was the owner and financier of the factory houses, the raw materials, and the intermediate and finished products.

It is noteworthy that the modernization of the Tilburg wool industry commenced shortly after that in Verviers.[21] After a great number of changes had been introduced in the eighteenth century, the mechanization of production began about 1810. The manufacturers began to acquire various sorts of textile machines such as picking mills, wool openers, and carding, spinning and finishing machines. The machine factory of Cockerill in Liege supplied many machines, just as it had done to the Belgian wool manufacturers. The shuttle appeared somewhat later, but had been largely introduced by 1825. As in Verviers, the power loom only achieved importance in Tilburg after 1850.

Just as in Verviers the process of mechanization in Tilburg also got underway without steam power. In Tilburg, however, it was not water power that played a role but rather the horse, the wind and of course human beings who drove machines with their hands and feet. The first steam engine was in operation in 1827, sixteen years later than in Verviers. In mid-century there were 20 steam engines in 18 factories in Tilburg. During the same period the city counted approximately 2100 home workers and more than 40 wool factories without power machinery, which means that all the machines were still hand- and foot-operated. It seems that different methods of production could coexist. In Verviers factory production and the machine held sway. Nearly all companies had one or more steam engines. Production too was significantly higher, between five and ten times the number of pieces of woollen cloth were produced than in Tilburg.

The conclusion is justified that innovations were introduced in Tilburg just a few years later than in Verviers, but the rate of diffusion and the degree of mechanization were clearly lower. This situation was related to among other

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[21] For the history of the Tilburg wool industry: P.J.M. van Gorp, *Tilburg, eens de wolstad van Nederland. Bloei en ondergang van de Tilburgse wollenstoffenindustrie* (Eindhoven, 1987). See further for the Dutch wool industry, the survey works cited in note 1 and also: P.J.M. van Gorp, *Wollenstoffen. De industriële revolutie in Nederland* (n.p., n.d.).

things the differences in finished products and markets, which entailed differences in production methods. Tilburg produced above all heavy, dark cloths such as baizes and duffels that were in great demand in the countryside. Verviers made the finer cloths such as flannels and dometts that were sold in the cities and on the international market. For that reason Tilburg and Verviers hardly competed with each other, as is demonstrated by the fact that the Tilburg cloths were sold in abundance in the lion's den itself, the southern Netherlands forming an important market for the Tilburg wool industry before the separation of Belgium from the kingdom.

It was predictable that the Belgian secession would bring hard times to the Tilburg wool industry. The loss of the Belgian market could have been compensated by conquering the market in the northern Netherlands. But there the finer sorts of material were involved and Tilburg could not make the adjustment, with the result that the English penetrated this market. The question can be asked why the Tilburg manufacturers failed to take up this challenge and did not turn to the production of the finer materials that allowed for higher value added and generated such considerable profits for the southern neighbors. Did they forego opportunities in the utilization of the technical and labor potential of the time?

Whatever the case it was true that the Dutch companies that operated on the same markets as the Belgians and the English experienced more difficulties. The

the successive phases of the manufacturing process – spinning, weaving and printing – under one roof.

Lieven Bauwens, who had given the stimulus to this spectacular development, did not come originally from a textile background. He descended from a well-known family of tanners, had become acquainted in England with the revolutionary possibilities of new techniques and had managed in 1798 to smuggle part of a power-driven cotton-spinning mill to the continent. He set up his first spinning mill near Paris and the second in Ghent. His initiative led to euphoria among the entrepreneurs of Ghent. The cotton industry developed by fits and starts, alternately confronting a surfeit and then a paucity of productive capacity. Bauwens himself finally fell victim to this development and went bankrupt in 1814.

Although it was the technologically most advanced on the European continent, the Belgian cotton industry needed protection of its domestic market until 1823 in order not to succumb in the fierce competitive struggle with the English. Protection was provided among other ways by the trade blockade of England organized by Napoleon, and by tariff laws in effect during the period of the Kingdom of the Netherlands. Starting in 1824 orders placed by the Netherlands Trading Company for the colonies ushered in a flourishing period that was abruptly cut off in 1830 by the separation of Belgium. The ensuing stagnation lasted into the 1840s.

During this whole period, however, there was no question of stagnation in technical developments. From the very beginning spinning was mechanized to a great extent. The first steam engine was installed by Bauwens in 1799 in his cotton-spinning mill in Ghent. During the French period another five steam engines were added, probably all destined for spinning mills. The number of steam engines increased to 30 in 1825 for the Belgian cotton industry as a whole and to 106 in 1838. From that year until mid-century an additional 10% growth occurred.[23]

Steam was not only used in spinning, but also in the processes of cleaning, carding, weaving, shearing and others. To be sure mechanization did not proceed at the same rate for all these processes. Machines for carding and spinning were developed first and put to use on a large scale. It proved more difficult to design power-driven machines for weaving and shearing and their mechanization hence proceeded more slowly. The power loom became profitable in England in the 1820s and the shearing machine in the 1850s.[24] But handwork persisted alongside these mechanical inventions for quite some time.

One of the first mechanical cotton-weaving mills was established in Ghent in

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[23] Van Neck (n. 2), "Les débuts de la machine à vapeur," pp. 492-493.

[24] S.D. Chapman, *The cotton industry in the industrial revolution* (second edition; London, 1987).

1821 with 100 looms. In 1830 Ghent had 700 looms, a modest number compared with various regions in England, but trend-setting as far as the continent was concerned.

Until the separation of Belgium the cotton industry producing for distant markets was of little significance in the northern Netherlands.[25] By contrast there was an extensive home industry that produced mainly for local or regional use. Spinning was done on the spinning wheel or in workshops using spinning machines that elsewhere were considered obsolete. Weaving was still done on the old hand loom. The shuttle, invented in 1733, was still unknown there. The cloths were made of linen, half-linen and cotton. They belonged to the coarser sorts that experienced little competition from abroad. The mechanization of the cotton industry in the first three decades of the nineteenth century completely by-passed the northern Netherlands. Economically speaking, mechanization was an impossibility. Just as in Belgium thirty years earlier, the cotton industry producing for export arose in the Netherlands in a relatively short period of time. In ten years's time cotton was spun, woven, bleached and printed on a large scale, especially for the colonies. This change admits of a simple explanation. Belgium had seceded and the Netherlands wished to keep its colonial market for its own industry. The Netherlands Trading Company was given the opportunity through stringent protectionist measures against foreign competition, in particular from England and Belgium. Since the production apparatus had been located in the southern Netherlands, it was imperative now to search for new possibilities for production and these were found in Twente.

The production apparatus differed in a number of important aspects, however, from that in Belgium and England. We will limit ourselves to weaving and spinning. Weaving remained handwork. Except for a few machines in one insolvent factory, there were no power looms in use. According to a contemporary source, hand weaving was the cheapest method of production for Twente.[26] The Netherlands Trading Company therefore focussed its efforts completely on introducing the hand loom with shuttle, including setting up weaving schools to train the necessary labor power. Around 1840 the Maatschappij's orders for calico cloth reached 600,000 pieces worth two million guilders, theoretically enough to keep 6000 weavers working uninterruptedly.

Although handwork was the cheapest method of production in the given circumstances in the Netherlands, it was unable to withstand a hard confron-

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[25] For the history of the Dutch cotton industry, in particular for Twente, see: E.J. Fischer (n. 7), *Fabriqueurs en fabrikanten*; J.A.P.G. Boot, *De Twentsche katoennijverheid 1830-1873* (Amsterdam, 1935); J.A.P.G. Boot en A. Blank, *Van smiet tot snelspoel* (Hengelo, 1975). See further for the Dutch cotton industry, the survey works cited in note 1.

[26] Mokyr (n. 1), *Industrialization in the low countries*, p. 102.

tation with foreign competition as the 1840s revealed. The collapse of the East Indian market and the elimination of government subsidies, both the result of the trade crisis of 1839-1842, forced the Netherlands Trading Company to reduce its orders and introduce a more competitive system. The measures had to be carried out gradually, however, for otherwise the cottage industry in Twente would have gone under. By the 1850s the cotton industry had adjusted to the new situation and started to change the weaving process radically. Mechanization of weaving began in these years, stimulated by improvements in the infrastructure that made transporting coal easier and cheaper.

The situation of the spinning mills was problematical during the entire period 1830-1850. They had to get by with less protection than the other sectors of the textile industry and were hard pressed by English competition. There were four spinning mills in the 1830s, all mechanized and steam operated. Two of them had been founded by former Belgian entrepreneurs and another was managed by an English technical expert. They all – some more than others – led a difficult existence. Only one company, the Enschede Katoen Spinnerij, survived the crisis years in the textile branch, in part thanks to a reorientation toward the coarser threads for the domestic market.

Textiles, metal and mining were crucial for the industrial revolution and steam power in Belgium and England. In the Netherlands, however, they did not play this pioneer's role. Is this a sufficient explanation for the backwardness of industrialization and steam power? Certainly not! For that would mean accepting that the Belgian and English pattern was the only one possible. Why could not other sectors in the Netherlands play the pioneer's role? The retardation in the use of the steam engine requires further analysis. In particular production costs demand our attention: what is the relation of the costs of steam energy to those of traditional techniques? There is no general answer to this question since the production processes and costs vary too much by sector, region and date. Our analysis shall treat a few cases and is meant as an exploratory approach to the problem. Based on its results we try to demonstrate that a pioneering role in the use of steam would most likely have been problematical for most sectors in the Netherlands.

Production costs

Thanks to historical research we have more detailed information for the Netherlands on the costs of several mechanized production processes using steam compared with the existing classical production methods. Unfortunately there is very little of this sort of data available for Belgium. A comparative factor-cost analysis is therefore not possible. Such an analysis would have

certainly been worthwhile and could have furnished insights into the international competitive relations between both countries. In the section that follows we will necessarily have to restrict our discussion to the Netherlands.

If we first compare the energy sources only and consider them to be completely interchangeable in the production process, then around 1825 water power[27] and wind power[28] were the most inexpensive, followed by steam (based on an engine of 15 h.p.)[29] and finally the labor of horse and human (Table 3).[30] Steam represented a saving on labor costs compared with human, horse or wind power. Only the use of water power seems more favorable in this regard. It is noteworthy that steam produced economies in interest costs, depreciation and maintenance compared to wind and water power. Interest and depreciation costs are determined by investments and steam is an expensive capital good. A steam installation of 15 h.p. cost approximately 22,000 guilders around 1825, including the building and foundation. But the investment in the traditional technology, in particular, wind power, should also not be underestimated. A typical industrial windmill easily cost 15,000 guilders (in the western part of the country.) The capacity it provided on average throughout the year

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[27] The purchase of a water mill (of about 5 h.p.) probably did not require an investment larger than about 5000 guilders. See: S.W. Verstegen en A. Kragten, "De Veluwse kopermolens in de negentiende eeuw; een raadsel voor historiografen?," *JbGBT* 1, 1984, pp. 172-178. In the tables an interest rate of 3.5% has also been assumed. Water mills were usually not depreciated. The mill could remain standing for decades, but this required a lot of maintenance, on average 630 guilders per year (information from Verstegen). In a previous article by one of the present authors, these costs were not included, which explains the discrepancy with the figures given there, see: H. Lintsen, "Stoom als symbool van de industriële revolutie," *JbGBT* 5, 1988, pp. 337-353. Water millers also had to pay considerable sums for leasing water rights. This item is included here under fuel and fixed at 500 guilders per annum. Finally, the wages for operating the water mill. Since operation was simple and did not require much time, this cost is fixed at 65 guilders per annum, which is a rather arbitrary amount.

[28] We assume an industrial mill worth 15,000 guilders with an average yearly capacity of 6 h.p. No account has been taken of depreciation; windmills also could be used for years. The maintenance, however, cost about 400 guilders a year. See also: H. Lintsen, *Molenbedrijf en meelfabriek in Nederland in de negentiende eeuw* (Den Haag, 1990), pp. 53-54. Operating the windmill required a lot of experience and the cost has been fixed at a miller's salary of 700 guilders per annum. There are significant differences with figures reported previously that stem principally from the capacity used to make the calculations. In Lintsen, "Stoom als symbool" (n. 27) a maximum capacity of 15 h.p. was assumed for a windmill. Here we have based ourselves on an average capacity of 6 h.p. throughout the year. This second point of view seems to us more accurate.

[29] We have assumed a steam installation of 15 h.p. valued at 22,000 guilders (including the building). Interest, depreciation and maintenance have been fixed at 5%. The yearly wages of the fireman/engineer were set at 700 guilders and the fuel costs at 4980 guilders. These figures are in general agreement with those given in Lintsen, "Stoom als symbool."

[30] A horse-driven treadmill of one-half horsepower cost approximately 500 guilders; yearly maintenance 30 guilders and horse feed 300 guilders. Operation was simple and has been fixed at 65 guilders a year. See: Lintsen, "Stoom als symbool" (n. 27).

can be estimated at 5 to 8 h.p. The relative investment costs per horsepower would therefore be considerably higher with wind power than with steam. For water mills the investment costs were relatively lower, but the maintenance costs of the structure on the other hand represented a stiff entry in the annual accounts.

In the figures given in Table 3, coal accounts for the most important expense of steam. One source of energy was more expensive, namely the horse. A horse needed a minimum of 300 guilders a year worth of oats, hay and other feed. If food for humans is also considered as fuel, then wages went largely for it and in that regard the human being was the most expensive source of energy.

Human labor power is an expensive energy source, but the human being is usually more than just a source of energy in the process of production. He is at the same time skilled in the use of tools and simple machines, so that a comparison must also include the machines. The horse also often performed different tasks in a business, in particular in production and transportation. For these reasons, both sources of energy could compete with steam. In Table 3 steam is inferior to wind and water power.

Nevertheless further analysis of the production process as a whole is necessary in order to gain more insight into the operating costs of the various sources of energy. We will look more closely at weaving, milling grain, paper making and rolling copper.

For grinding grain the steam-driven grain mill was probably more expensive than the windmill during the entire first half of the nineteenth century (Table 4).[31] The same is true for mechanical weaving as opposed to hand weaving (Table 5).[32] Around 1850, both weaving techniques were evenly matched in terms of their operating costs, at least in some places in Overijssel. For rolling copper the middle of the century also appears as a turning point in the preference for steam, but this was dependent on the annual production in rolled copper (Table 6).[33] It is only in paper making that steam energy in the form of the paper machine was probably competitive with the traditional production

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[31] Lintsen (n. 28), *Molenbedrijf en meelfabriek*, p. 22.

[32] On this see: Fischer (n. 7), *Fabriqueurs en fabrikanten*, pp. 272-273. We have assumed that one piece required 4.6 kilograms of yarn.

[33] The figures were obligingly made available by W. Verstegen. The coppermills in the Veluwe have been exhaustively studied in the first *Jaarboek voor de Geschiedenis van Bedrijf en Techniek*, see: Verstegen and Kragten (n. 27), "De Veluwse kopermolens." The publication of this article prompted an extensive discussion between W. Terwel and W. Verstegen on the question of whether there actually was a steam engine in the Amsterdam Mill in Vaassen. The discussion took place in *Mededelingen Ampt Epe* 1985-1988. Although no mention of the steam engine has been found in the archives, there are sufficient grounds for supposing that a steam engine was in use in the Amsterdam Mill.

methods at an earlier date (Table 7).[34] In all cases the use of steam energy represented a relative saving in labor costs. As far as the costs of interest, depreciation, maintenance and fuel were concerned, the situation was not so unambiguous.

The use of steam energy necessitated significant investment. A steam-operated weaving mill with 100 power looms and the necessary ancillary machinery demanded an investment of some 50,000 guilders (around 1850). In the cottage industry the investment in hand looms for the same level of production would have been at most 20,000 guilders. To give another example, a paper factory in the 1840s required about 100,000 guilders in investment, while a comparable production unit using paper mills and handmade paper cost about 50,000 guilders. The example of the grain mill shows, however, that the classical technique also needed relatively big investments. A wind-driven grain mill with a production of 500,000 kilograms of grain cost approximately 15,000 guilders; to be sure a steam-operated mill required 23,000 guilders to set up but had a capacity two and half times higher.

The consumption of coal was in nearly all cases the other important expense. If we only consider the relationship among the costs of depreciation, interest, maintenance and fuel, then fuel represented 14% of the costs in paper making, 25% in weaving and 53% in milling grain. In rolling copper, the percentage depended on the production and fluctuated between 32% and 57%. It is worth noting the relatively high fuel costs of the classical technique using water power, 57% (in 1824). Fuel was needed in copper rolling to fire the boilers when steam was used and the furnaces in which the copper was heated before being beaten with hammers. By using steam the hammers could attain more power, meaning that the copper did not have to be heated as much, thus saving energy.

In the Netherlands, peat was an alternative to coal, but it had the disadvantage of a low concentration of energy. Depending on its quality, peat produced only approximately 60% the heat of coal per kilogram, while a kilogram of peat took up three times the volume of a kilo of coal. It was thus necessary to have a larger storage area (not a point to be ignored in the city centers where many steam engines were installed) and a larger boiler (which meant a larger cooling surface). Moreover, transportation costs were higher for peat. As a result, peat was only used as fuel for steam engines in the immediate vicinity of the peat bogs. It had to yield mainly to coal due to price, storage and quality considerations.

The figures presented here must be seen as an indication and nothing more.

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[34] A.R.J. Callewaert, "Keuze van technologie: een onderzoek naar de invoering van de eerste papiermachine in Nederland bij Van Gelder, Schouten en Compagnie," *JbGBT* 7, 1990, pp. 83-101; O. de Wit, *Papierfabricage in Nederland in de negentiende eeuw. Van molen naar fabriek* (Den Haag, 1990).

Various factors bring about shifts and uncertainties in the calculations and temper to some extent the importance of the factor-cost analysis. We cite a few.

The figures are estimates due to both practical and theoretical causes. The practical problems stem from the insufficient availability and accessibility of archival material. The theoretical concern the complexity of the material. Thus, for example, an apparently straightforward comparison between a windmill and a steam engine causes big problems. How for example should the productive capacity of a windmill be determined, which is so strongly dependent on unpredictable and changeable (weather) conditions? Can, and if so how, the constant capacity of a steam engine be compared with the variable capacity of a windmill?

The disposition of the figures is closely related to the region. We can take fuel costs as an example. In 1843 in Rotterdam coal cost 11 guilders a ton, in North Brabant on the other hand, 15.50 per ton.[35] Transportation costs are largely responsible for the differences between places in the Netherlands. Transport took place by boat on the waterways and where that was not possible by cart over the rare paved roads. The coastal provinces possessed a good infrastructure of rivers and canals, but this could not be said of the rest of the country. Many rivers in the east were not navigable in the summer due to low water level and in the winter due to dangerous currents. Road transportation was then necessary, but also expensive. Shipping goods by wagon in 1836 between Zwolle and Enschede, for example, cost as much as 18 guilders a ton.[36] As a consequence large price differences could occur between places that were barely more than a few dozen kilometers apart. Not only did coal prices vary greatly from one region to another, but also taxes and wages.[37]

Another factor of importance was the size of the market. Purchase and operating costs of a technology requiring steam were especially sensitive to the scale on which production was carried out. Increasing the scale and the production reduced the fixed costs of the steam engine and the coal consumption per unit of product considerably. But expanding the scale of production was only feasible where a large market lay within reach of the entrepreneur. The situation and the perspectives varied greatly per sector in this regard. In the paper industry for example, a large part of the foreign market had been lost, but machine production offered the opportunity of reconquering the lost ground.[38] In the grain-milling business on the other hand, legislation, a strongly segmented market and numerous forms of cooperation between local entrepreneurs blocked

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[35] Griffiths (n. 1), *Industrial retardation* p. 75.

[36] Fischer (n. 7), *Fabriqueurs en fabrikanten*, p. 50.

[37] *Ibid.*, p. 18-21.

[38] De Wit (n. 34), *Papierfabricage*, p. 18.

large-scale production until the middle of the nineteenth century.[39]

Another factor that should be taken into account is the mutual comparability of production techniques, especially as far as the finished product is concerned. In many cases different production processes resulted in different finished products, each with its own market segment. For this reason a comparative cost-benefit analysis falters. We saw a good example in the wool industry, where the Tilburg manufacturers concentrated on the coarser yarns and cloths for the domestic market, while those in Verviers focused on the finer-quality products for the international market. The Tilburgers pursued another strategy of mechanization and possibly also the best strategy for survival given the international competitive relationships.

Nevertheless our impression remains that none of the arguments cited above undermines the conclusion of the earlier analysis: the costs of the factors of production form in the first half of the nineteenth century the decisive explanation for the marginal use of steam power in industry. The arguments do play a role in the period after 1850. It appears that an economic cost-benefit analysis is insufficient to explain the breakthrough of the steam engine in the second half of the nineteenth century.[40]

Coal versus agriculture

We can now review once again the difference between Belgium and the Netherlands in the use of the steam engine in the first half of the nineteenth century. First of all it is necessary to distinguish the production of goods in general and the mechanization of the production of specific goods.

As far as the latter is concerned we have shown for various production processes that in the Netherlands the prices of the production factors capital, labor and raw materials (in particular fuel) were unfavorable for the utilization of steam power. The traditional methods of production were usually more profitable. To be sure a cost analysis varies greatly from one region to another, but the different pieces of the mechanization puzzle did not fit well together anywhere in the Netherlands. Where labor was cheap, in the interior provinces, the costs of among other things fuel and capital ran high because of transportation. Due to their inadequate infrastructure these provinces were relatively isolated, which likewise influenced the shipping of products to the outside. Only

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[39] Lintsen (n. 28), *Molenbedrijf en meelfabriek*, p. 45; J.L. van Zanden, "De introductie van stoom in de Amsterdamse meelfabricage 1825-1855; over de rol van marktstructuren, ondernemersgedrag en de overheid," *JbGBT* 8, 1991, pp. 63-80.

[40] H. Lintsen a.o., "Industrialiseren en innoveren in de 19e eeuw," *JbGBT* 5, 1988, pp. 327-336.

Limburg enjoyed a fuel-cost advantage thanks to its favored position with respect to the Liege coal fields. Together with North Brabant, where the wool industry was partially mechanized, Limburg had the largest number of steam engines in the interior in mid-century (see Table 8).[41] The opposite is true for the coastal provinces. There the fuel and capital costs were lower, but wages were considerably higher. Only in those places where capital, fuel, raw materials and labor were all relatively cheap did steam have a good chance. Such places were quite scarce in the Netherlands. Lack of data makes it difficult to say what the situation in Belgium was.

If we compare the production of goods in general we encounter important differences between the Netherlands and Belgium that the gap in steam capacity explains to a large extent. Belgium possessed rich ore deposits and used approximately 61% of its industrial capacity in steam engines to exploit them . Furthermore, part of steam capacity in the metal industry was needed to manufacture, service and repair mining machinery. In addition, Belgium had an extensive textile sector in which steam was used on a large scale. The Netherlands did not have that wealth of minerals, produced fewer textile goods and made these mostly by hand in view of the prices of the production factors.

Steam power in the first half of the nineteenth century remained, viewed internationally, for the most part limited to specific sectors: mining, metal and textiles. For Belgium these sectors played a key role in industrialization and economic development. The economic development of the Netherlands in this period was based on completely different sectors. Thus agriculture played there an important role. Production was achieved on the farm not in the factory. In Belgium the riches lay under the ground, in the Netherlands on it. Steam and coal were therefore in competition with the reclaimed polderland.

[41] For the sources, see note 2.

Summary

In the first half of the nineteenth century a techno-economic gap opened up between the Netherlands and Belgium. The present paper surveys one aspect of this gap, namely the utilization of the steam engine which took place on a much larger scale in Belgium than in the Netherlands. A satisfactory explanation for this difference can be found in a comparative analysis of three industrial sectors: mining, metal and textile. Nevertheless, further research is necessary on the costs of several mechanized production processes using steam production methods. Unfortunately the discussion in the article has to be restricted to the Netherlands because there is very little information available on Belgium. It appears that an economic cost-benefit analysis is sufficient to explain the marginal use of steam power in Dutch industry.

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Table 1. Number of steam engines in industry in the Netherlands and Belgium, 1800-1850

	Neth	Belgium		Neth	Belgium		Neth	Belgium		Neth
	Belgium 1800	1802/04		1829	1825/26		1839	1838	1851	1850
Mining	-	61	4	190	4	416	3	720		
Metal	-	4	12	35	24	163	49	332		
Textile	-	1	12	68	58	219	68	326		
Others	<5	1	10	26	66	246	173	635		
Total	<5	67	38	319	152	1044	293	2013		

Table 2. Steam engines by number and capacity in industry in the Netherlands and Belgium, c.1850

	Netherlands (1851)			Belgium (1850)		
	Number N	Capacity C (in h.p.)	C/N	Number	Capacity C (in h.p.)	C/N
Mining	3	144	72	720	30.969	43
Metal	49	784	16	332	7.659	23
Textile	68	973	14	326	5.269	16
Others	173	2.189	13	635	6.539	10
Total	293	4.090	14	2.013	50.436	25
Population	$3{,}1.10^6$			$4{,}4.10^6$		
h.p./1.000 inhabitants	1,3			11,5		

Table 3. The costs of depreciation, interest, maintenance, labor and fuel of various sources of energy, c.1825 (in guilders per horsepower per workday)

Place/region	Overijssel	Gelderland	Amsterdam	Amsterdam	Amsterdam
Technique	Manpower	Water power	Wind power	Steam	Horsepower
Depreciation, interest and maintenance		0,45	0,42	0,20	0,26
Wages	5,00	0,04	0,32	0,13	0,36
Fuel		0,27 *		1,24	1,54
Total	*f* 5,00	*f* 0,76	*f* 0,74	*f* 1,57	*f* 2,26

* Cost of leasing the water rights (see note 27)

Table 4. Production costs in guilders of 1000 kilograms of grain in Amsterdam from a wind- and a steam-operated mill

Annual production	500.000 kg	1.225.000 kg
Year	1840	1830
Technique	windmill	steammill
Depreciation, interest and maintenance	1,8	1,0
Wages	3,4	2,6
Fuel		4,0
Total (*f*/1.000 kg)	*f* 5,2	*f* 7,6

Table 5. Production costs of hand weaving and mechanical weaving of cotton fabrics in Overijssel, c. 1850 (in guilders per piece)

Annual production	c.100 pieces	c.15.000 pieces
Year	c.1850	c.1850
Technique	Hand weaving	Mechanical weaving
Depreciation, interest and maintenance	0,06	0,50
Wages	1,60	0,74
Fuel		0,41
Total (ƒ/piece)	ƒ 1,66	ƒ 1,65

Table 6. Production costs of 100 kilograms of rolled copper from the Amsterdam Mill in Vaassen (Eastern Veluwe) (in guilders)

Annual production	43.000 kg	120.000 kg	33.000 kg	50.000 kg
Year	1824	1855	1859	1860
Technique	Hammering with water	Rolling with steam	Rolling with steam	Rolling with steam
Depreciation, interest and maintenance	2,30	2,19	6,70	4,40
Wages	4,27	2,15	5,75	3,12
Fuel	8,79	2,94	5,92	5,02
Total (ƒ/100 kg)	ƒ 15,36	ƒ 7,28	ƒ 18,37	ƒ 12,54

Table 7. Production costs of hand-dipped and machine-made paper in the Zaan region, 1840-1850 (in guilders per ream)

Annual production	6.300 ream	21.600 ream
Year	1840-1850	1840-1850
Technique	Hand	Paper machine
Depreciation, interest and maintenance	0,28	0,55
Wages	1,00	0,54
Fuel		0,18
Total (*f*/ream)	1,28	1,27

Table 8. Steam engines by province in numbers and percentage, 1851

	Number	Percentage
North Holland	83	28
South Holland	65	22
North Brabant	41	14
Limburg	40	14
Overijssel	18	6
Other provinces	46	16
Total	293	100