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# Billettes and the economic viability of pin-making in 1700

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## ***Abstract :***

The activity of pin-making became well-known in economic theory thanks to Adam Smith's certainly because it was the only manufacturing process for which he had the necessary data to calculate productivity. One may ask for what reason French encyclopaedists collected and published information on pin-making work-rates, but not for other (crafts ?)trades. The purpose of this paper is to show across the early works of Billettes and then of Perronnet, how the economic relexion about pin-making activity emerged. The study is based on the only two traces of this first scholarly work on pin-making: a plate from 1702 and a handwritten document. More than 60 years later, once these descriptions had been published, Adam Smith used this example to illustrate his law concerning the division of labour. Pin-making was the backdrop for a cumulative process of data collection and their use in answering questions which were completely new at the time.

***Keywords :*** *Pin-making, Adam Smith, encyclopaedist, Division of Labour, Billettes, Wage, productivity*

## **Résumé :**

La fabrication des épingles est bien connue dans l'histoire de la pensée économique parce que sur cette production Adam Smith a fondé son raisonnement sur la division du travail. Il s'est inspiré des publications des encyclopédistes français qui avaient collecté des données détaillées sur cette production et avaient notamment indiqué les cadences de travail à chacun des postes. Cela permettait de calculer la productivité. Cette industrie était la seule sur laquelle on disposait des données de productivité. La réflexion académique au sujet de cette production a commencé au début du 18<sup>ème</sup> siècle et dès cette époque Billettes s'interrogeait sur la viabilité économique de cette activité. Le présent article commente deux documents de cette première réflexion, un manuscrit conservé aux archives de l'Académie des Sciences à Paris et la planche réalisée à cette époque. Les interrogations ont suscité d'autres recueils d'informations qui ont débouché sur les publications dont Adam Smith s'est inspiré.

**Mots clés :** *épingles, Adam Smith, encyclopédie, Division du travail, Billettes, salaires, productivité*

The pin-making became well-known in economic theory thanks to Adam Smith's work on the division of labour. "To take an example, therefore, from a very trifling manufacture ; but one in which the division of labour has been very often taken notice of, the trade of the pin-maker"<sup>1</sup>. Ever since 1776, there has been debate as to why he chose this example rather than another manufacturing context. We know that he made use of various French publications which dealt with pin-making, and which appeared in contemporary reference works, so his choice was dictated by the available documentation. Further, the work-rates of each post in the production process had already been published. The *Encyclopédie* had also already described a great many (crafts ?)trades, but all these descriptions lacked information about work-rates. Adam Smith chose pin-making because it was the only manufacturing process for which he had the necessary data to calculate productivity.

One may ask for what reason French encyclopaedists collected and published information on pin-making work-rates, but not for other trades. This article shows that Parisian thinkers were taking interest in this industry from the beginning of the 18<sup>th</sup> Century. The data collected at the time had not been properly thought out, leading to requests for extra information which was provided later, and which thus gave an economic view of this trade, to complete the technical treatment which already existed for this and other trades.

The pin-making industry was therefore the subject of three management science investigations during the 18<sup>th</sup> Century, by Adam Smith, by Perronet and by Billettes. The works by Rodolphe Perronet in 1761 and 1765 present all the economic and technical data necessary to work out the cost price and profit, as a function of pin size. This text corresponds to a handwritten document dating from 1740. The present paper shows that forty years earlier, Billettes, a member of the Paris Academy of Sciences, already possessed part of this manufacturing data and had tried to apply management reasoning to it.

This attempt was unsuccessful, and did not get beyond the stage of posing questions : no conclusions were reached. However, this uncompleted work was the catalyst for a drive to collect new information. The works of Perronet and later Adam Smith, which both successfully reached conclusions, were undoubtedly linked to this first, failed, investigation. Thus, a theoretical path dealing with the technical and economic aspects of pin-making was laid during the 18<sup>th</sup> Century, comprised of three parts, the last of which is universally known.

## 1. The Royal Academy of Sciences and the Description of 'Arts and Trades'

Louis XIV created the Royal Academy of Sciences in 1666, and in 1675, Colbert asked the Academy to describe the 'Arts and (Crafts ?)Trades'. This work was carried out extremely slowly, and was only published in 1761, because of competition from Diderot's *Encyclopédie*.

As from 1693, the Abbot (Father?) Bignon, who was president of the Academy of Sciences, started to bring some workers together with the same aim. Among them was Abbot (Father?) Gilles Filleau des Billettes (1634-1720), who joined the Academy in 1699 as a 'mechanic'<sup>2</sup>. Although he presented works to his peers in the Academy on average once a

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<sup>1</sup> Adam Smith, 1776, *Inquiry into the nature and causes of the Wealth of Nations*. London : Straham & Cadell. Book I Chapter 1.

<sup>2</sup> « mécanicien »..

year, these were not published, contrary to usual practice. His first presentation concerned an existing lock across the Seine river which featured cylindrical gates, such that the load was borne along the gates' axes<sup>3</sup>. Billettes did nothing more than draw the lock and make comments about the design, without explaining its advantages over other types of lock gates. The text is dull and the description appears completely redundant. In a second text which was equally dull, Billettes described a paddle wheel with buckets which opened to release the water<sup>4</sup>, and was capable of lifting more than 5000 muids of water per hour<sup>5</sup>.

Subsequently, Billettes, with the help of Jaugeon, presented a text to his colleagues once a year: '*the description of everything concerning Printing was continued by Messieurs Billettes and Jaugeon*'<sup>6</sup>; '*Messieurs Billettes and Jaugeon continued their descriptions of the Art of Printing and related Arts*'<sup>7</sup>; '*Mr. des Billettes described the Art of Engraving*'<sup>8</sup>; '*Mr. des Billettes, while continuing the Art of Printing, described the Press followed by the particular cases of printing Church Books, Signs, Sentences, etc. He then went on to the Art of Engaving with small characters*'<sup>9</sup>. After 1705, he moved on to other subjects: '*Mr. des Billettes gave a description of the art of making gunpowder*'<sup>10</sup>, followed by papermaking (1706), book gilding (1707), the sugar industry (1708 and 1709), and leather tanning (1708, 1709 and 1712).

Other descriptions of 'Arts and (Crafts ?) Trades' were given to the Academy by Carré, Jaugeon, la Hire, Saulmon, Lémery, and Réaumur up to 1725, but we do not have any record of these works. We do, however, know that the illustrations (engraved plates) were sent to Diderot for the *Encyclopédie* and were published in part in the series by Duhamel after 1761. On his death, all the files that Billettes had accumulated were given to Réaumur (1683-1757), who devoted a decade to them<sup>11</sup>. On his death, the 138 files which he left were passed on to Duhamel, but many of these were lost. Those which survived were considered of very poor quality by those who carried on studying the subject.

Billettes' third paper concerned pins. In 1700, '*Mr. des Billettes read a precise description of the Art of the Pin-Maker*'<sup>12</sup>. It was given in the *Journal des Sçavants* ('The Scientists' Journal') under the title 'The Art of Pin-Making involving ingenious and delicate practices'<sup>13</sup>, but this text has disappeared. It is possible that the paper was only given verbally. Today we only have two traces of this first scholarly work on pin-making: a plate from 1702 and a handwritten document. The plate was the sixth published by Duhamel in '*The Art of the Pin-Maker*'<sup>14</sup>. These two documents are given below.

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<sup>3</sup> Billettes, '*Description d'une nouvelle manière de porte d'écluse qu'on a pratiquée dans l'entreprise de la navigation de la Seyne*', ('Description of a new type of lock used for navigating the Seine river'), read at the Academy by Mr. des Billettes, *Histoire de l'Académie Royale des Sciences*, 2 May 1699, pp. 63-68.

<sup>4</sup> Billettes, '*Deux manières de roues à épuiser l'eau*', ('Two types of paddle wheel used to raise water'), *Histoire de l'Académie Royale des Sciences*, 9 December 1699, pp. 184-206.

<sup>5</sup> 1300 cubic metres per hour.

<sup>6</sup> *Histoire de l'Académie Royale des Sciences*, 1701, p. 141.

<sup>7</sup> *Histoire de l'Académie Royale des Sciences*, 1702, p. 136.

<sup>8</sup> *Histoire de l'Académie Royale des Sciences*, 1703, p. 135.

<sup>9</sup> *Histoire de l'Académie Royale des Sciences*, 1704, p. 123.

<sup>10</sup> *Histoire de l'Académie Royale des Sciences*, 1705, p. 137.

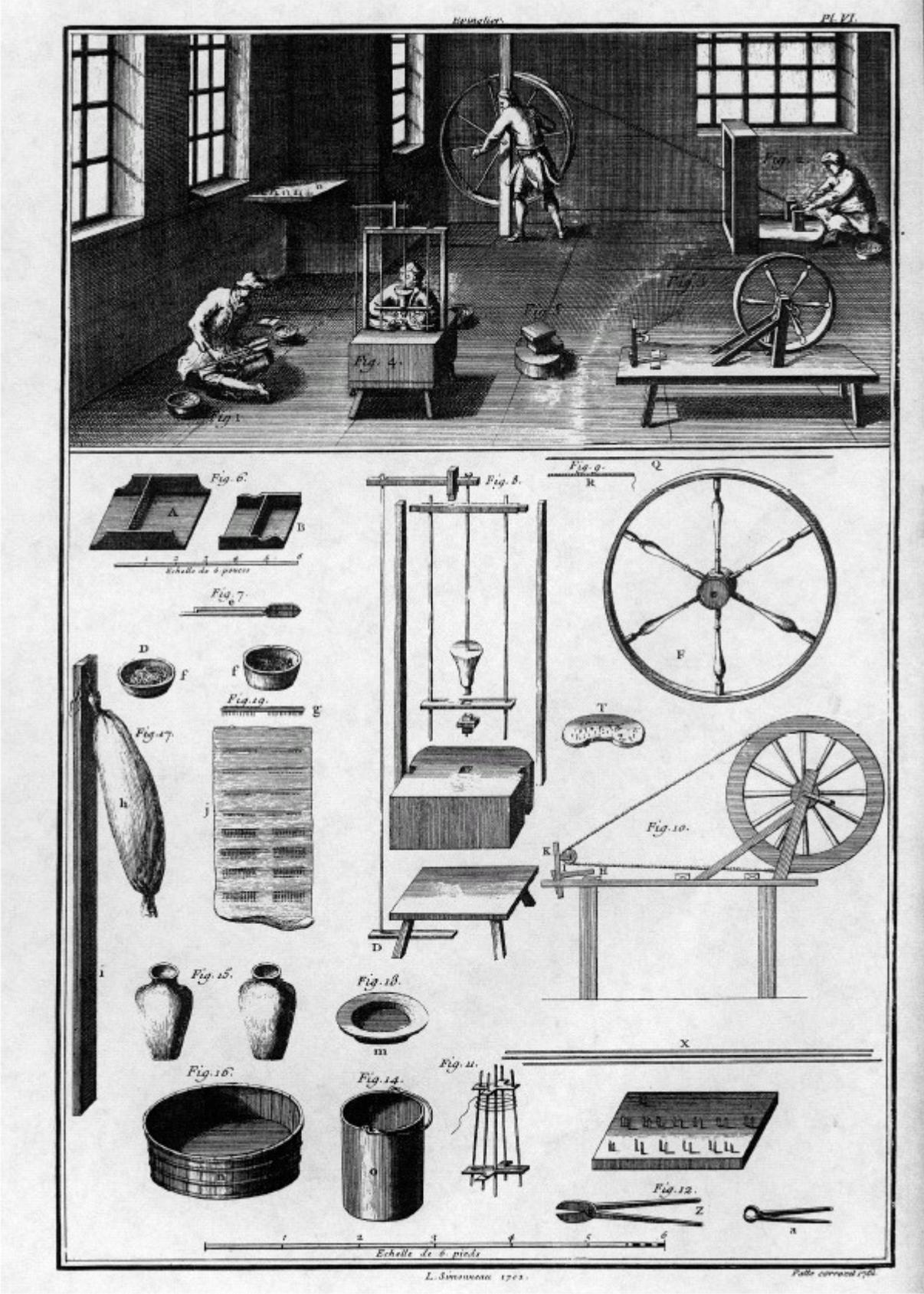
<sup>11</sup> 1717 *L'Art du Tireur d'or*, in 1715 *Les Arts qui regardent les pierres précieuses*, in 1723 *L'art de convertir le fer forgé en acier* and *L'Art d'adoucir le fer fondu*, les ancrs (1723), le fer blanc (1725), la porcelaine (1727), le thermomètre (1730).

<sup>12</sup> Billettes, *Histoire de l'Académie Royale des Sciences*, 1700 p. 382.

<sup>13</sup> « L'art de faire des épingles avec des pratiques ingénieuses et délicates », *Journal des Sçavants*, 1703, Volume 1, p. 623.

<sup>14</sup> Henri Louis Duhamel du Monceau, Réaumur and Perronet, 1761, *Art de l'épinglier*. Paris : Saillant et Noyon.

2. The plate from 1702



This plate was the first to show pin-making pictorially, and dates from 1702. It was produced by Simonneau, the draughtsman at the Academy of Sciences, and is made up of two parts. The upper part shows the workmen in position, at work with their tools. The lower part focuses on the tools and shows them in plan and profile. Each figure carries a number so that they can be referred to in the following explanations.

The plate shows the main stages involved in pin-making: the putting the head on, the pointing and the cutting the wire. Four workmen are involved. In the background there is a turning and sharpening machine (fig. 2), and in the foreground the head-maker (fig. 4). On the left is a cutter (fig. 1), and the wheel for turning the heads is shown in detail (figs. 3 and 10). The bag of bran (fig. 17) for drying the pins illustrates an old manufacturing process, pre-dating the rubbing machine. The hot tin-plating pot (fig. 15) was specifically used for making iron pins. In the upper left corner and in the bottom right one can see the device used to straighten the pin-wire.

	<b>Delaire's operations, 1755</b>		<b>Billettes operations</b>	<b>Figures</b>
1	Yellowing	Jaunir		
2	Drawing out the wire	Tirer à la bobille	Wire-drawing	
3	Straightening the wire	Dresser le fil	Straightening	11 and top left
4	Cutting the sections	Couper les tronçons	Making the sections	1, 6 and 12
5	Sharpening	Empointer	Refining (pointing)	
6	Grinding	Repasser		
7	Cutting the shanks	Couper les hanches	Slicing shorter	1, 6 and 12
8	Turning the heads	Tourner les têtes	'I shall not speak of drawing the test wire, of moulding or of cutting'	3, 9 and 10
9	Cutting the heads	Couper les têtes		7
10	Softening the heads	Ramollir les têtes		
11	Making the heads	Entêter	heading	4 and 8
12	Yellowing	Jaunir	Yellowing, whitening And drying	
13	Whitening	Blanchir		14 et 15
14	Extinguishing	Éteindre		16
15	Drying	Sécher		17
16	Winnowiing	Vanner		
17	Piercing the papers	Piquer les papiers		Piercing and putting in paper
18	Putting the pins in paper	Bouter les épingles	19	

Table 1 The steps involved in pin-making

We can study this plate with reference to the traditional description of pin-making in the *Encyclopédie* of 1755<sup>15</sup> (see Table 1). The initial wire-drawing (steps 1 and 2) is missing. The pins are not ground - the grinding wheels, equivalent to those for sharpening, are not duplicated. Some steps (10, 12, 14, 16 and 17) do not appear – they do not involve any particular instrument which would require an explanation. Overall, the process is the same as that described half a century later.

The plate was modified by Pierre Patte in 1761, and although we do not know in which respects, careful study of the drawing suggests that it concerns the wheel in the upper part of the plate, which was apparently added to complement the detailed drawing in the lower part.

This plate featured in the Academy of Sciences' file, and was published in 1761 by Duhamel<sup>16</sup> who added comments to the 19 figures. It does not look out of place beside the other plates which were made about 15 or 60 years later. The style is typical of all the later plates which show 18<sup>th</sup> Century 'Arts and (Crafts ?)Trades' given by the *Encyclopédie* or by the Academy of Sciences.

### 3. The handwritten document

The handwritten document measures 12 cm by 22 cm, is written on both sides of the paper, and can be found in the 'Billetes' file in the Archives of the Academy of Sciences. It is a rough draft with the title 'plan', and was probably an memorandum for an oral presentation. To understand this document, one must first decipher the handwriting. Although some of the words are illegible, this does not prevent one from understanding the text as a whole. Tables 2 and 3 are a transcription of the document, and to facilitate our commentary we have added the line numbers in the left column.

1		plan	
2	par jour ... affiner	per day.....pointing	220 thousand
3	bouter et frapper	heading	14 thousand
4	tirer à la filière à 3 toises pour 216 hanches et une minute pour les 3 toises, ou 180 toises par heure	Drawing 3 toises for 216 shanks and one minute for the 3 toises, or 180 toises per hour	
5	Je compte la hanse à 1 pouce dont la toise en fait 72 dont 3 toises en font 216	I measure the shanks at one inch for which 6 feet gives 72 so that 3 toises gives 216.	
6	je compte qu'un xxx tire par minute 3 toises donc par heure 180 toises qui font 12960, et on compte le jour xxxx 10 heures, on tire à la filière par jour la valeur de	I count that only one xxx draws per minute 3 toises and so per hour 180 toises giving 129600, and we count the day as 10 hours , so we draw per day the value of	129600 shanks
7	pour les dresser par jour	For the straightener per day	129 600
8	pour faire les tronçons de 500 à chaque coup, par jour	To make the sections by 500 at each cut, per day	300 000
9	pour les affiner par jour	To refine them per day (to point)	220 000
10	trancher à la courte par jour	Slicing shorter per day	300 000

<sup>15</sup> Article 'Epingle' in the *Encyclopédie* by Diderot, Volume 5, 1755.

<sup>16</sup> Duhamel du Monceau, 1761, *Art de l'épinglier*, Planche VI.

11	bouter et frapper par jour	putting the head per day	14000
12	jaunir blanchir et sécher	Yellowing, whitening and drying	300 000
13	piquer et mettre en papier par jour	Piercing and putting in paper per day	20000
14	Réduisons le tout à	Round the total down to	220 thousand
15	cela revient environ	Which gives roughly	
16	pour fileter et redresser à	to thread and straighten up	2 ¾ days
17	pour affiner à	to refine	1 day
18	pour trancher, longuement et courte, jaunir et blanchir	to slice, long or short, to yellow and whiten	2 ¼ days
19	pour bouter et frapper	to head	15 days
20	pour piquer et mettre en papier	to pierce and put in paper	11 days
21			<u>32 days</u>

Table 2 Transcription of Billettes' document on pins, front page

Note : xxx for illegible words (line 6)

22	Divisant 220 milliers par 32 jours, c'est par jour environ 7 milliers où entrerait de la matière pour 28 sols	Dividing 220 thousand by 32 days, gives about seven thousand per day where the raw material would cost 28 <i>sols</i>
23	Et les 7 milliers ne se vendroient qu'environ 45 sols 6 deniers,	And the seven thousand would sell for about 45 <i>sols</i> 6 <i>deniers</i> ,
24	auquel cas ce ne serait pour la journée que 16 sols 6 deniers,	Which would make [a profit of] only 16 <i>sols</i> 6 <i>deniers</i> for the day,
25	Il faut que j'estime beaucoup trop le temps de piquer et mettre en papier, ou qu'on estime fort peu le travail qui se fait pour cela, comme n'estant que pour des femmes et des petits enfants	I must be over-estimating the time spent on piercing and putting into paper, or else we under-estimate the work required for that, as being only for women and small children.
26	Et comme on y a compté pour 11 jours, les réduisant à des journées de 5 sols 6 deniers l'un portant l'autre il reviendrait £6 11 sols à régaler sur 11 autres journées d'homme à 16 sols 6 deniers ce qui ferait 27 sols 6 deniers	And as we counted 11 days for it, reducing them to days paid at 5 <i>sols</i> 6 <i>deniers</i> all in all we would be left with £6 11 <i>sols</i> to pay 11 man-days at 16 <i>sols</i> 6 <i>deniers</i> making 27 <i>sols</i> 6 <i>deniers</i>
27	Et réduisant les 11 jours de piquer etc. au mieux ce sera seulement 7	Reducing the 11 days for piercing etc. at best it would be only seven
28	Et ainsy au lieu de 32, il n'en faut compter que 28 par quoi on divise 220	And thus instead of 32, we should only count 28 by which we divide 220
29	ce qui fera environ 8 milliers	Which makes about eight thousand
30	à 6 sols 6 deniers, ils valent 52 sols	at 6 <i>sols</i> 6 <i>deniers</i> , they are worth 52 <i>sols</i>
31	Et il y entre de matière pour 32 sols reste pour la journée 20 sols	And 32 <i>sols</i> ' worth of raw material come in leaving 20 <i>sols</i> for the day
32	Fil de laiton 36 livres la botte	Brass wire 36 pounds the roll

33	Mlle Saunier chez Madame Colbert	Miss Saunier at Mrs. Colbert's
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Table 3 Transcription of Billettes' document on pins, back page

Billetes was trying to use the figures to investigate the economic viability of pin-making. By studying his comments, one can see six stages in his reasoning.

### 1. The raw data (lines 2 to 4 and 32)

Billetes gives the daily production for pointing and the heading . For the drawing, he bases his calculations on the rate of 6 yards drawn per minute. For an inch long pin and ten hours work per day, this gives 129,600 pins per day<sup>17</sup>.

In the last line (line 32) some more raw data is given, the price of brass, 36 french pounds per roll of 28 weight pounds, i.e. .

### 2. The daily production per operation (lines 5 to 13)

Billetes begins calculating production by looking at each post. In lines 5 and 6 he repeats the raw data given in line 4. The wiredrawing is performed on 129,600 pins per day, and the straightening at the same rate. The cutting is done at the rate of one scissor cut per minute, giving 500 pins each time. From this Billetes deduces the daily production for ten hours' work. For the pointing, the production is given in line 2. For the second cutting ('slicing shorter'), Billetes takes the same production as for the first. For making the pin-heads, the production is given in line 3. For 'yellowing, whitening and drying' Billetes uses the data for the cutting. For 'piercing and putting in the papers', he uses new production datas.

This means that Billetes distinguishes 8 operations: drawing, straightening, first cut, pointing, second cut, heading, whitening and the last putting into the paper. He indicates production rates for each of these 8 operations.

### 3. The time taken to produce 220,000 pins (lines 14 to 21)

To combine the production figures from each position, it is necessary to build in the production times. Billetes calculates the times for an arbitrary number of 220,000 pins. The number of operations should not vary, but he only has five left: straightening, pointing, cutting, heading, and putting in the paper. By adding up the number of days worked for each operation on 220,000 pins, Billetes found the total time, 32 days. He can thus find the productivity, the number of pins divided by the number of days, for all the operations which were performed consecutively.

### 4. The maximum wage (lines 22 to 24)

Billetes calculated the productivity for 7000 pins per day/per person, i.e. the ratio of the two preceding numbers. Straightaway he includes the value of the brass for this production of 7000 pins and the sale price. The difference is the **value added per day and per person**, which is the maximum wage, 16.5 *sols*<sup>18</sup>.

<sup>17</sup> A 'toise', equal to six feet of twelve inches each, this gives  $3 \cdot 60 \cdot 10 \cdot 6 \cdot 12 = 129\,600$

<sup>18</sup> One pound was worth 20 "sols" (shilling) of 12 "deniers" (old penny).

### **5. The hypothesis concerning women's work (lines 25 and 26)**

This result does not satisfy Billettes, because a Parisian workman's salary was higher, at least 20 *sols* per day. He suggests two possible sources of error: either he allowed too much time for the last stage, or else women's work was involved. His source told him that women took care of putting the pin-heads, and so he looks into this possibility. He imagines that over the 11 days of putting pin-heads the women were paid 5.5 *sols*, 11 *sols* less. This allows him to pay the men 11 *sols* extra over the 11 days, or 27.5 *sols* per day. This new higher salary is acceptable.

### **6. The hypothesis of higher productivity (lines 27 to 31)**

Billettes' alternative hypothesis involves increasing the productivity. He increases the rate of 'piercing the papers' by 57%, which increases the overall productivity to 8000 pins per person and per day. We are given the sale price of these 8000 pins and the value of the raw material; the difference is the wage per person, 20 *sols* per day, which was probably an acceptable solution for Billettes.

### **7. The address**

The address 'Miss Saunier at Mrs. Colbert's' shows that the paper was originally to be sent to some living quarters, but was used as rough paper. This address has no importance for the economic analysis of pin-making.

The overall reasoning is thus as follows : knowing the work-rate for each operation (as daily production datas), Billettes can transform them into times to produce a given quantity of pins. He sums these times and by division he can calculate a productivity, that is the number of pins produced per day and per person. Then he calculates the cost of raw-material and the selling price of this quantity of pins. From this he finds the value added per day and per person, which is taken as the daily wage. The method of calculation is correct, and the profit for the master pin-maker can be included in the price for the raw materials or in the sale prices. The tools belong to the workmen, and his wage covers both the work and the upkeep of his tools.

The problem for Billettes was that the wage he calculated was too low for mens working in Paris. He needs change his data and his method of calculation to give reasonable worker's wages, for that period in Paris. However, he had no information to justify this manipulation of his raw data. He could have made his own enquiries *in situ* at Laigle. He took advantage of the change in government in 1715 to have new data collected for him, which led to a comprehensive text, hand-written by Guérault<sup>19</sup>, who was one of the sources for the description of pin-making used by French encyclopaedists.

## **4. Billettes' errors of calculation**

Although his method was correct, Billettes made several errors in his calculations, his reasoning and his raw data.

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<sup>19</sup> Guérault, 1717, « Description générale de la fabrique d'épingles de latton et de fer de la manière dont elles se font à Laigle, Généralité d'Alençon ». handwritten at the library of the Ecole Nationale des Ponts et Chaussées, at Marne La Vallée (France), number 333 MS 2385..

To begin with, Billettes is not very good at subtracting. For 7,000 pins, if the brass wire cost 28 *sols*, and the pins are sold for 45.5 *sols*, the value added is 17.5 *sols* (and not 16.5). Billettes also made mistakes in his divisions. He calculated 32 days of work to produce 220,000 pins, with a resultant overall productivity of 6,875 pins per day/per person, which Billettes rounded to 7,000. But with the daily production datas that he gives, the production time for 220,000 pins is shorter by almost two days. The productivity would then be 7,298 instead of 7,000 per day/per person (see table 4).

Operation	Production figures per operation (pins per day)	Number of days to produce 220,000 pins		
		Billettes	Exact calculation over 5 operations	Exact calculation over 8 operations
drawing	129,600			1.70
straightening	129,600	2 $\frac{3}{4}$ days	1.70	1.70
cutting	300,000			0.73
pointing	220,000	1 day	1.00	1.00
cutting	300,000	2 $\frac{1}{4}$ days	0.73	0.73
yellowing, whitening, drying	300,000		0.73	
heading	14,000	15 days	15.71	15.71
putting in paper	20,000	11 days	11.00	11.00
	Total	32 days	30.15	33.31
	Productivity pins /man /day	7,000	7,298	6,605
	Added value /man /day	16.5 <i>sols</i>	17.5	16.5

Table 4 Calculation of the overall productivity using Billettes' datas

These calculation errors are not of any great importance, and everyone used to make them at the time. We found too mistakes in the reasoning. For the daily production figures, Billettes had 8 work posts, 3 of which he deleted in order to find the overall productivity. If one includes all the original 8 operations, the productivity drops to only 6,600 pins per day/per person. With the same buying and selling prices, 26.4 *sols* of raw material are brought in and 42.9 *sols* are earned from the sale, giving a value added of 16.5 *sols*! After correcting the calculation errors and the omissions, we therefore find the daily wage given by Billettes! This is perhaps a coincidence, as it is quite possible that he had previously correctly performed the calculations, and then copied the intermediary figures which seemed easier to justify.

The third source of error comes from the raw data. To check the production figures given by Billettes, one must consult the detailed treatise on pin-making given 40 years later by Perronet<sup>20</sup>, who gives the daily production for each operation. Table 5 gives these figures.

<sup>20</sup> Jean-Rodolphe Perronet, 18 November 1739, 'Explanation of how one draws brass wire of various thicknesses, in the town of Laigle in Normandy, using a thread to make pins and other works', « Explication de la façon dont on tire le fil de leton à différentes grosseurs, dans la ville de Laigle en Normandie par le moyen de

One can see that overall they resemble Billettes' own figures, with relatively small positive or negative discrepancies.

	<b>Operations (Delaire 1755)</b>	<b>Production / day (Perronet 1740-1765)</b>	<b>Billettes' operations</b>	<b>Production / day (Billettes)</b>
1	Yellowing			
2	Drawing the wire		drawing the wire	129,600
3	Straightening the wire	96,000 to 120,000	straightening	129,600
4	Cutting the sections		making the sections	300,000
5	Pointing	180 000	Pointing	220,000
6	Grinding	180 000		
7	Cutting the shanks	360,000 to 480,000	slicing shorter	300,000
8	Turning the heads	144,000	'I shall not speak of drawing the test wire, of moulding or of cutting'	
9	Cutting the heads			
10	Softening the heads			
11	Heading	10,000 to 12,000	heading	14,000
12	Yellowing		yellowing, whitening and drying	300,000
13	Whitening			
14	Extinguishing			
15	Drying			
16	Winnowing			
17	Piercing the papers	24,000 to 48,000	piercing and putting in the papers	20,000
18	Putting the pins in paper			

Table 5 Comparison of work-rates according to Billettes and Perronet

Billettes calculated his rate for the wiredrawing using a thread speed of 6 yards per minute, which he probably found in the report he had. This calculation corresponds to a single run, but the wiredrawing was carried out in 6 or 9 runs. The exact calculation should take into account the lengthening over each run, but Perronet did not attempt this, preferring to use an overall measurement based on observation.

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la filière pour en faire des épingles et différents autres ouvrages ». Paris : Bibliothèque de l'ENPC, manuscrit cote MS 2383. Jean-Rodolphe Perronet, 7 janvier 1740, « Description de la façon dont on fait les épingles à Laigle en Normandie ». Paris : Bibliothèque de l'ENPC, manuscrit cote 333 MS 2385. Jean-Rodolphe Perronet, 1765, Encyclopédie, article « Epinglier ».. Jean-Rodolphe Perronet, 1765, *Encyclopédie*, article 'Epinglier' ('pin-maker').

Cutting is performed twice, before pointing (operation 4) and afterwards (operation 7). In fact, each pin requires a single cut with the scissors, but Billettes counts the operation twice as if each pin were cut twice.

In pointing, Billettes forgot to include the wheel turner, and to duplicate the operation for the grinding. Most probably, his source did not stress this operation, which the pin points more .

The yellowing, whitening and drying operations were performed on large batches of several hundreds of thousands of pins at a time, and were far from occupying one workman for an entire day. In fact this length of time is neglected by Perronet.

These details do not detract from the plausibility of the overall figures, which are good approximations. Perronet arrived at a productivity of between 4,500 and 5000 pins per day and per person, which are the figures used by Adam Smith. “Each person [...] might be considered as making four thousand eight hundred pins in a day”<sup>21</sup>. Billettes’ productivity is higher because he neglected some of the stages and because he supposed that the workmen worked at the same rate all day.

As far as the price of the brass wire is concerned, there is agreement. Billettes estimated that the raw material cost 28 *sols* for a weight pound, as did Perronet forty years later<sup>22</sup>. Likewise, Billettes’ and Perronet’s sale prices are the same.

The difference is essentially due to the wages. Billettes did not know how much the workmen in Laigle were paid, and so he supposed that they were equivalent to Parisian wages. This, however, was a serious mistake, as their daily wages varied from 4 *sols* (for those putting the pins in papers) to 15 *sols* (for cutters)<sup>23</sup>. All these wages were lower than those paid in Paris at the time. The average wage paid in this industry was 10 *sols* per day.

<b>Function</b>	<b>Daily wage</b>
straightener	8 to 10 <i>sols</i>
pointer	18 <i>sols</i>
turner	7.5 <i>sols</i>
grinder	7.5 <i>sols</i>
turner	7.5 <i>sols</i>
cutter	17 <i>sols</i>
head preparer	7.5 <i>sols</i>
head putter	11 <i>sols</i>
putter into paper	4 to 5 <i>sols</i>
weighted average wage	10 <i>sols</i>

Table 6 Work-rates and wages in the 18<sup>th</sup> Century, according to Perronet.

<sup>21</sup> Adam Smith, *Wealth of Nations*, Book I Chapter 1. Adam Smith had read the French publications on pins.

<sup>22</sup> These pins, which were 3cm long, were Perronet’s ‘number VI’, weighing 0.134 pounds per thousand. From this we can calculate the price at roughly 30 *sols* per pound. Perronet had a drawn wire at 30.8 *sols* per pound. However, in 1700 brass should have been cheaper, because the price of raw wire had gone up by 40% over 40 years, according to Jean Vidalenc, 1946, *La petite métallurgie rurale en Haute Normandie sous l'ancien régime*. (‘Small scale rural metal-working in Upper Normandy under the Ancien Regime’) Paris : Domat-Montchrestien.

<sup>23</sup> The workmen were paid for piece-work. The daily wage was not the product of the maximum work-rate with the remuneration per piece because this rate was not maintained all day.

Billettes had access to quite a good description of the process and fairly precise work-rates. He represented the pin-making manufacture in a simplified way, omitting certain stages, which led to an over-estimation of the productivity. His main error was to suppose that the wages were similar to in Paris, whereas in reality the manufacture was carried out in the country and partly at home by women (putting out). It will be useful to understand why Parisian thinkers believed that all workmen's wages were equal.

## 5. A household's subsistence wage

The idea that workmen's wages at this time were all the same is known today as 'subsistence wage theory'. The workers were only given just enough to allow them to subsist. "The lowest class of labourers, therefore, notwithstanding their scanty subsistence, must some way or another make shift to continue their race so far as to keep up their usual numbers"<sup>24</sup>. This theory results in equal wages for all.

Nevertheless, in reality there were differences between wages in the 18<sup>th</sup> Century, and wages in the country were lower than those in the capital. "Wages in a large town and its suburbs are often.....between 20 to 25 percent higher than a few miles away"<sup>25</sup>. These differences are explained by the differences in the cost of living. Supplies in town cost more because of transport costs and various taxes, and housing is more expensive. Some french encyclopaedists were aware of this. "As the production takes place in a small provincial town, and is to a large extent spread throughout the surrounding countryside, where foodstuffs are cheap, one can find low cost labour more easily, because the workers are often determined to work, as long as one pays them enough for subsistence"<sup>26</sup>.

These differences in wages between the capital and the provinces do not contradict the subsistence wage theory. The wages vary according to location as a function of the cost of living. Differences between individuals are also compatible with the theory if we relate the family's income to its expenses. The wages of each member of the same household were put in the same pot. Men were better paid than women, but the latter's wages were considered to be a supplementary income. The contributions from husband, wife, children and even the elder generation were all combined to ensure the household's subsistence; each member could have a different wage.

Another source of differences was the location of the work. At that time, putting out was common in these early countryside industries. An entrepreneur brought the raw materials and the orders and returned with the finished product. He organised the communication between the widely spread homes, and was able to offer very low remuneration because no other work was available. In the pin-making industry, the drawing and heading were done at home<sup>27</sup>.

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<sup>24</sup> Adam Smith, *Wealth of Nations*, Book I Chapter 8.

<sup>25</sup> Adam Smith, *Wealth of Nations*, Book I Chapter 8.

<sup>26</sup> « Comme la manufacture est établie dans une petite ville de province, & qu'elle est même en grande partie répandue dans les campagnes voisines, où les denrées qui servent à la nourriture sont à bon marché ; on peut plus aisément y mettre la main d'œuvre à bas prix ; car les ouvriers se déterminent souvent à travailler, pourvu qu'on leur donne une récompense qui puisse les faire subsister », Chalouziere in Henri Louis Duhamel du Monceau, Réaumur et Perronet, 1761, *Art de l'épinglier*, Paris : Saillant and Noyon, p. 46.

<sup>27</sup> Peaucelle J-L 2006, *Adam Smith, la division du travail et la fabrication des épingles*, ('Adam Smith, the division of labour and pin-making'), Chapter 5.

Therefore, the low wages in the country and the differences between labourers do not contradict the subsistence wage theory. Billettes' main error was simply to be unaware that the differences existed. Out of the 16.6 *sols* of value added, he could easily have paid provincial wages. With a low productivity of 4,000 pins per day/per person, the value added per person is 10 *sols*, sufficient to remunerate workmen and workwomen in Normandy. Pin-making was thus economic because of the very low wages paid in the French countryside in the 18<sup>th</sup> Century.

Finally, let us note that the subsistence wage was paid for a day's work, irrespective of the work performed; it was not piece-work. However, part of the work (straightening, heading) was done at home, and the resultant remuneration was paid piece-rate, according to Perronet. This remuneration was converted into a daily wage by using standard work rates and durations, which were often taken as ten hours.

## 6. Rediscovering the original data

The information provided by Billettes allows us recreate the contents of the report on which he based his work. This report had probably been written at Alençon at the end of the 17<sup>th</sup> Century. "From the year 1692, the Commerce inspectors were ordered to send to the Court statements concerning their departments"<sup>28</sup>. The report from 1692 has been lost, but we will try to recreate its contents, from which Billettes calculated the daily production figures as if each individual operation took place consecutively over ten hours.

He worked out the speeds of the thread and the straightening (129,600 pins per day) from the speed of the wire, 3 *toises* (6 yards) per minute<sup>29</sup>. The raw data was thus **3 toises per minute** (360 m/hour).

He based the cutting rate on the information **one scissor cut per minute** and **500 wires** per cut. This gives 300,000 pins per day.

To make the points, the workman held **60 pins** in pincers and sharpened them in **10 seconds**. This gives a daily production of 216,000 pins per day for 10 hours' work, rounded to 220,000.

To produce the heads, Billettes probably had a time of **3 seconds** per pin. We can therefore calculate 12,000 pins per day for 10 hours' work, and 14,000 if they worked for nearly 12 hours.

To put the pins into the papers, the production of 20,000 corresponds to a row of **25 pins** placed in **¾ of a minute** over 10 hours.

For the yellowing, whitening and drying, 300,000 seems to be an approximation because in 1717 the Academy asked for more information about how many pins were put into the whitening pot.

Billettes, therefore, had some basic information about the duration of some individual operations (**3 toises** per minute, one cut per minute for 500 wires, 60 pins sharpened in 10

<sup>28</sup> Jacques Savary des Brûlons, 1723, *Dictionnaire de Commerce*. Paris : Estienne. Preface, page XIX.

<sup>29</sup> Perronet gives 3.5 *toises* (Jean-Rodolphe Perronet, 18 November 1739, 'Explication de la façon dont on tire le fil de laiton à différentes grosseurs, dans la ville de Laigle en Normandie par le moyen de la filière pour en faire des épingles et différents autres ouvrages', ("Explanation of how one draws brass wire of various thicknesses, in the town of Laigle in Normandy, using a thread to make pins and other works.")). Paris : Bibliothèque de l'ENPC, manuscrit cote MS 2383.

seconds, 3 seconds per pin-head, a row of 25 pins in 45 seconds). This information is equivalent to a time and motion study, but is inaccurate because (chronometers ?) stopwatches were not available at the time. He had, in addition, the prices of brass and of pins. Such information was certainly available from Parisian businessmen. He also knew what wages were paid at the time, and was able to combine data from ‘the field’ with data collected in Paris.

## 7. Later documents about pin-making

Billettes had thus begun an economic analysis, based on technical productivity data about some operations. His problem however was that the buying and selling prices and the Parisian wages were incompatible with the work-rates. His reaction was to request supplementary information, through the Royal Administration. In 1717, he asked the local Intendant for a more detailed description of pin-making. We possess a copy of the response<sup>30</sup>. The questions concerned details of the technical operations and their rate, but the question of wages was not asked. This new investigation did not allow Billettes to solve his puzzle. In fact, the extra detail gave more stages in the production process and the overall productivity dropped down. The answer was not to be found with more precise description of this work.

Guérout’s text was received by the Academy of Sciences and Réaumur, who had assisted Billettes, used it to produce a new text on pin-making in which the economic aspects had been removed<sup>31</sup>.

The report to the Academy was conserved at the archives of the Intendant of Alençon and, twenty years later, Perronet, a young engineer from the french Roads Administration, understood the technical-economic aspect of the Parisian Academician’s investigations. He restarted the inquiry in the workshops at Laigle in Normandy and noted the wages for each operation and the work-rate. He brought together the diverse economic data by calculating the cost price and the profit , for each pin size<sup>32</sup>. The contradictions were dispelled: this industry was economic because of the low wages in the provinces, and the work of women. Perronet had found the answer to Billettes’ problem. It was the third study, and it had reached a conclusion partly because of Billettes’ unanswered question, and partly because the person collecting the data ‘in the field’ was the same who processed them and applied the correct theoretical framework (the concept of **cost price**).

These were internal investigations in the Administration and the Academy. They would not have been known without the later publications; Guérout’s observations from 1717 and Perronet’s from 1740 would have disappeared like the handwritten document of 1692. The information was made public thanks to a happy combination of circumstances. First, there was Diderot’s *Encyclopédie*, in which there were technical articles on the ‘Arts and (Crafts ?) Trades’, and an article ‘*Épingles*’ (‘Pins’) which brought together all the relevant

<sup>30</sup> Guérout, 1717, ‘*Description générale de la fabrique d’épingles de laiton et de fer de la manière dont elles se font à Laigle, Généralité d’Alençon*’, (“General description of brass and iron pin-making as done in Laigle, Généralité d’Alençon.”). Paris : Bibliothèque de l’ENPC, cote 333 MS 2385.

<sup>31</sup> Réaumur in Henri Louis Duhamel du Monceau, Réaumur et Perronet, 1761, *Art de l’épinglier*.

<sup>32</sup> Jean-Rodolphe Perronet, 7 January 1740, ‘*Description de la façon dont on fait les épingles à Laigle en Normandie*’, (‘Description of how pins are made at Laigle in Normandy’). Paris : Bibliothèque de l’ENPC, manuscrit cote 333 MS 2385.

existing works in Paris<sup>33</sup>. This very famous article was the first to appear on pin-making and it popularised the idea that 18 consecutive operations were employed. However, no economic ideas were included.

The second great publication was Duhamel's in 1761, for the Academy of Sciences, which was giving structure to its documentation on Arts and (Crafts ?)Trades<sup>34</sup>. It was based on the same texts but they are interwoven, regrouped by stage in the production process. Only Perronet had any interest in the economics, and Duhamel, who provided a commentary for the texts was evidently unaware of the originality of the approach. This publication also turns up in several scientific reviews with fraternal connections to the Academy, and the portable dictionaries also used it.

The third publication was a repetition. Perronet insisted with Diderot that his text should be published in its entirety<sup>35</sup> in order to make sure proper attention was paid to the cost price, as in 1755 the *Encyclopédie* had removed this aspect and in 1761 Duhamel had failed to highlight it.

All these publications were inspired by the same sources, but few noticed that they were different to the other descriptions in the Arts and (Crafts ?)Trades because of their technical-economic approach, visible in Perronet's text and those inspired by him. Adam Smith had access to some of these texts<sup>36</sup>, and he understood the value of these figures on work-rates. From them, he deduced a productivity of 4,800 pins per day/per person. This was the basis for the illustration of his theory, an illustration which greatly helped to convince his readers.

The unknown observer in 1692 who provided a little information about work-rates was thus the catalyst for an intellectual process. In 1700, Billettes was frustrated, but his tenacity drew the attention of others to a point normally neglected. His insistence led to further observations to check the work-rates. Perronet introduced coherence through carrying out his own observations and understanding which concept to apply, the cost price. More than 60 years later, these descriptions had been published, Adam Smith saw the originality of their technical-economic reasoning and used this example to illustrate his law concerning the division of labour. Pin-making was the backdrop for a cumulative process of data collection and their use in answering economic questions which were completely new at the time.

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<sup>33</sup> Jean-Louis Peaucelle, Christian Dave, 2005, 'Les sources de l'article 'épingles' de l'Encyclopédie Diderot', ('The sources for the article 'pins' in Diderot's *Encyclopédie*', *14èmes Rencontres Histoire et Gestion*, Toulouse, November.

<sup>34</sup> Henri Louis Duhamel du Monceau, Réaumur and Perronet, 1761, *Art de l'épinglier*. Paris : Saillant et Noyon.

<sup>35</sup> Jean-Rodolphe Perronet, 1765, *Encyclopédie*, article 'Epinglier'.

<sup>36</sup> Jean-Louis Peaucelle, 2006, "Adam Smith's use of multiple references for his pin making example", *The European Journal of the History of Economic Thought*, Vol 13:4, Winter.

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