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Knowledge and Technology Transfer during the Industrial Enlightenment

Swiss Visitors to the Soho Manufactory, Birmingham, circa 1765–1820

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The impact of the "knowledge economy"[1] on 18th-century Switzerland is an area in which little research has been undertaken. Whilst Jean Trembley, René Sigrist, David Bickerton[2] and others have extended our knowledge of the involvement of Swiss *savants* in the pan-European Enlightenment, the picture we have remains rather superficial and unbalanced. The contributions of Geneva and the westerly French-speaking cantons have been analysed in some depth, but developments taking place in the German-speaking territories during this period are known only to specialists. The Genevan city-state, it is clear, played a mediating role in brokering intellectual currents emanating from Britain and France. Yet the extent to which Basel, Bern or Zurich performed a similar role with regard to the German lands is harder to determine. The focus on mega-savants such as Albrecht von Haller or the Bernoullis casts everyone else into the shade.

The Swiss Confederation lay astride the commercial cross-roads of 18th-century Europe and it is not unreasonable to suppose that all her cities' elites participated in the long-distance "conversations" between natural philosophers that were taking place in the second half of the century. How far these conversations, that is to say opportunities for knowledge exchange, actually bore fruit in the form of transformative technologies is not an easy question to answer, however. The acquisition of natural knowledge, or science, is usually considered to be the *sine qua non* for effective technology transfer, but it was only the first stage. In the case of the Swiss in the period before the Second Industrialisation there are grounds for believing that the process was neither linear nor even in its effects. Useful knowledge and craft skills, unlike modern technology, did not lend themselves to easy transmission and reproduction. Much depended on circumstance and context, not to mention entrepreneurship, capital availability and cost factors.

In the case of Geneva and the arc of territory extending from Lake Léman which forms the main focus of this article, the issue of technology transfer presents something of a paradox. No other place in Switzerland enjoyed better access to the two principal knowledge-generating economies of 18th-century Europe, Britain and France, yet Geneva and its hinterland would not become a primary

site of mechanised industry. If a significant amount of knowledge exchange took place as most certainly it did, the Genevan natural philosophers and publicists must have played a rather different role, therefore: that of relay-station for onward transmission to districts and localities where conditions conducive to the exploitation of useful knowledge were altogether more promising. The image of the relay-station is apt for we must guard against the habit of supposing that the flow of useful knowledge and "know-how" was bound to move in one direction only. Whilst the term "transfer" conveys a sense of agency, it risks obscuring the fact that the 18th-century knowledge economy tended to function in a manner that was more circular than linear. Even as Geneva's native *philosophes* were customising the information they had acquired from elsewhere, her highly trained craftsmen were on route to employment in the expanding consumer and fashion industries of Paris, London, Saint-Petersburg and Birmingham. Artisan migration, it should be pointed out, did not usually require a preliminary transfer of natural knowledge for the skills in question were largely embedded, or tacit. It is important to bear in mind too that, with a few notable exceptions, much of what passed for new technology in the phase of Industrial Enlightenment was nothing of the sort. As David Edgerton[3] points out, most was shared across national borders. It follows that the essence of what was being transferred or exchanged was more akin to "know-how"; in other words "skill". Although entrepreneurs and the projectors who clung to their coat-tails routinely spoke of "innovation" and "invention", the main currency of 18th and early 19th-century technology transfer was much less dramatic. It can be better described as "imitation" and "improvement". To be sure, the overseas visitors to the Soho Manufactory whose evidence provides the basic data-set for this article were drawn to Birmingham by the prospect of viewing James Watt's new steam engine in action. However, most of the machinery they actually encountered whilst exploring the workshops of Soho would have been broadly familiar to them because it was already in widespread use on the continent of Europe. It was the proficiency of construction and the skill levels of the workers who operated these machines which excited wonder and activated the process of technology transfer.

The Soho Manufactory and its Visitors

Matthew Boulton's Soho Manufactory was built between 1761 and 1765 in a rural setting on the outskirts of Birmingham. Until the advent of multi-storey, iron-framed spinning mills at the turn of the century, it was probably the largest single-site factory in England. By the 1770s it employed nearly a 1000 workers in the production of fashionable metal wares or "toys". When Boulton contracted

Fig. 1: *Soho Manufactory, Handsworth, circa 1800.*

a partnership with the Scots mechanic James Watt, in 1774, heavy engineering yards were added in order to develop and market the famous steam engine that would become the symbol of the Industrial Revolution.

Visitors made their way to Soho from all over Europe, and it is largely thanks to the records they left behind (letter correspondence and travel diaries) that it has been possible to construct this case study of knowledge and technology transfer as practised in the late 18th and the early 19th centuries. How many individuals in total applied to tour the Soho industrial complex will never be known precisely. However, it has proved possible to identify by name and by geographical origin between 1500 and 2000 of the men and women who set off for Birmingham over the 40-year period between 1765 and Boulton's death in 1809.

Although the Swiss visitors to Soho were not particularly large in number (tables 1 and 2, page 40 f.), they represent a significant cohort when the data are weighted to take account of the demographic profile of *ancien-régime* Europe. In proportion to population, only the emissaries from Denmark-Norway were more numerous than those from the Swiss Confederation. 18th-century Denmark-Norway was a state located on the margins of Europe and the Danish crown pursued a deliberate and effective policy of technology transfer. By contrast, the intercourse between Britain and Switzerland obeyed rather different

Tab. 1: *Swiss Visitors to the Soho Manufactory, circa 1765–1820*

Names, with dates	Profession, origin
Achard, Jacques, 1747–1828	*négociant,* Geneva
Ador, Jean-Jacques	entrepreneur, Geneva
Argand, F.-P.-A. dit Ami, 1750–1803	savant, Pays de Gex/Geneva
Autran, Jean-François	*maître-bijoutier,* Geneva
Baumgartner, Jean-Louis, 1730–95	merchant/banker, Geneva
Bodmer, Johann-Georg, 1786–1864	engineer, Zurich
Bourdieu, James, 1714–1804	merchant/banker, Geneva/London
Bréguet, Abraham-Louis, 1747–1823	*horloger,* Neuchâtel/Paris
Bréguet, Antoine-Louis, 1776–1858	*horloger,* Neuchâtel/Paris
Chappuis, Charles	merchant, Geneva
Clais, Johann-Sebastian, 1742–1809	metallurgist Zurich/Winterthur
Chollet, Samuel, 1732–1802	*négociant*/banker, Pays de Vaud
Delessert, Benjamin, 1773–1847	banker, Paris/Pays de Vaud
Delessert, François, 1780–1868	banker, Paris/Pays de Vaud
Deluc, Jean-André, 1727–1817	savant, Geneva/London
Droz, Jean-Pierre, 1746–1823	engraver, Paris/La Chaux de Fonds
Dumont, Pierre-Etienne-Louis, 1759–1829	savant/*publiciste,* Geneva
Du Roveray, Jacques-Antoine, 1747–1814	*avocat,* Geneva
Escher, Hans-Caspar, 1775–1859	industrialist, Zurich
Fischer, Johann-Conrad, 1773–1854	metallurgist, Schaffhausen
Fueter, Christian, 1752–1844	engraver/mint master, Bern
Gautier, Etienne	Pays de Gex/Geneva
Guyot, Abraham, 1743–1794	tutor/savant, Neuchâtel
Méchel, Christian de, 1737–1817	engraver, Basel
Moilliet, Jean-Louis, 1770–1845	merchant, Geneva/Birmingham
Necker de Saussure, Jacques, 1757–1825	botanist, Geneva
Pasteur, Louis [?]	*notaire,* Geneva
Perret-Gentil, Jean-Jacques	*horloger,* Paris/La Chaux de Fonds
Pictet, Marc-Auguste, 1752–1825	savant/journalist, Geneva
Pictet, Charles-René, 1787–1856	savant/journalist, Geneva
Preponier, Paul	entrepreneur, Geneva
Prévost, René, 1749–1816	*notaire,* Geneva
Prévost-Dassier, A.-F.	*négociant*/banker, Geneva
Rey, Stéphane-Rey-Marcet	Geneva
Saussure, Horace-Bénédict de, 1740–1799	savant, Geneva
Studer, Samuel Emanuel, 1757–1834 [?]	Winterthur
Sylvestre, Dr P.	Geneva
Trembley, Jean-Charles, 1764–1846	Geneva
Valtravers, Jean-Rodophe, 1723–1800	Bern/London

Tab. 2: *Foreign Visitors to the Soho Manufactory by Origin, circa 1765–1820*

Country	Number	Percentage
France	124	21.57
Russian Empire	64	11.13
Italian States	62	10.78
German States (excluding Brandenburg-Prussia and Hamburg)	59	10.26
Swiss Confederation	39	6.77
Sweden (including Finland)	34	5.91
Brandenburg-Prussia	30	5.22
America	30	5.22
Denmark-Norway	25	4.35
Habsburg Empire (including Austrian Netherlands)	24	4.17
Spain	19	3.30
Dutch Provinces	18	3.13
Hamburg	16	2.78
Portugal	12	2.09
Canada	2	0.35
Ottoman Empire	2	0.35
[Unidentified	15	2.61]
Total	575	99.99

imperatives as we shall see. In this connection we are fortunate to possess the travel diaries or note books of several extremely able Swiss publicists, *savants* and technologists. Those of Marc-Auguste Pictet (1752–1825) of Geneva, Johann-Georg Bodmer (1786–1864) and Hans-Caspar Escher (1775–1859) of Zurich, and Johann-Conrad Fischer (1773–1854) of Schaffhausen are documents of quite exceptional quality for students of technology transfer. We can extract relevant information, too, from the published correspondence of node figures of the European Enlightenment in its Swiss dimension such as Leonhard Euler (1707–1783) and Albrecht von Haller (1708–1777).

Historians of science and technology tend to neglect the correspondence networks of the 18th-century Republic of Letters – on the ground that participant members of these *réseaux* only ever discussed themes drawn from the realms of pedagogy, philosophy and religion, or else socio-political issues of topical interest. Yet the correspondence of the *philosophes* contains much of value to researchers interested in the diffusion of technical knowledge. Equally, it should not be supposed that entrepreneurs like Matthew Boulton (1728–1809) confined their correspondence to matters of business. The second half of the

18th century defined an age in which cultivation of the sciences was fast becoming a cultural hallmark of gentlemanly status, and nowhere more so than in Hanoverian Britain. By the 1780s, moreover, the focus was shifting decisively in the direction of *experimental* science with *useful* applications. This empirical outlook would particularly aid the process of communication between British and Swiss natural philosophers as David Bickerton[4] has noted. It would serve as one of the factors that helped to smooth the passage of technological knowledge between the two countries.

As one of the few Birmingham manufacturers to trade directly with London houses and even with merchants on the continent of Europe, Boulton's first contacts with the Swiss were confined to commercial transactions. In the early days much of his continental business was handled by the firm Baumgartner & Hofstetter. Jean-Louis Baumgartner (1730–1795) hailed from Geneva where his family traded in silks.[5] After a peripatetic existence he set up in London as an import-export merchant before moving to Birmingham, probably in the early 1750s. There is a suggestion that his travels were those of a political dissident. The turbulent politics of the Calvinist city-state would provide an important channel for technology transfer in the second half of the century. At any event, Baumgartner initially prospered and he completed his migration by marrying into Birmingham's mercantile elite. Another Geneva–Birmingham commercial connection was forged when his nephew, Jean-Louis Moilliet (1770–1845), also moved to Birmingham and, in 1789, established his own export business with the assistance of Matthew Boulton. Moilliet, in his turn, would marry into the family of James Keir (1735–1820), the Tipton chemist and industrialist who was one of the first to devise and commercialise a fully synthetic process for alkali production. We know the names of 39 visitors to Soho from the Swiss Confederation. Although a few of these individuals arrived on business of an official nature, the majority were independent travellers, that is to say free-lance entrepreneurs, skilled craftsmen or touring *savants* in pursuit of natural knowledge. Entrepreneurs (Jean-Jacques Ador of Geneva, Christian Fueter of Bern, Johann-Sebastian Clais of Winterthur, Ami Argand, Fischer, Bodmer, et cetera) often came to Soho with business propositions, or else to recruit specialised metal-workers in a neighbourhood noted for its highly skilled labour force. Swiss precision craftsmen (clock and watchmakers, instrument makers, engravers, chasers, modellers), by contrast, were all in heavy demand in Britain's industrial centres. When Matthew Boulton launched his mint venture in 1787, he issued a call for engravers and die-sinkers that echoed across Europe from Stockholm to Naples. The talented Swiss engraver Jean-Pierre Droz (1746–1823) was induced to come to Soho (by way of France), and was remunerated handsomely in return for bringing with him his engine lathe and other items of equipment which Boulton had seen de-

monstrated at the Hôtel de la Monnaie in Paris the previous year. Yet he would later grumble that Droz's stay at Soho served chiefly to transfer competence in steam-powered coining to France rather than *vice versa*.

Natural philosophers formed the largest contingent of Swiss visitors, however. As we shall see, their presence attests both to the vitality of science culture in 18th-century Geneva – albeit detached from a technological base – and to the emergence of Soho in the final quarter of the 18th century as a node point in the knowledge circuits of the Republic of Letters.

What vectors of knowledge and technology transfer can be identified when Britain and Switzerland are juxtaposed? A number of links invite investigation: epistolary exchanges between *savants,* grand tourism, entrepreneurship and trade, artisan migration, and politics. These themes will be familiar enough to historians with an interest in science and technology, of course. There was nothing characteristically "Swiss" about the correspondence networks of the Industrial Enlightenment. Nor were the business relationships between Soho and Swiss-born entrepreneurs fundamentally different in character from those between Soho and French, or Dutch entrepreneurs and projectors. On the other hand, Switzerland would come to occupy a somewhat unusual position in the pan-European circuits of grand tourism – particularly with the development of "glacier tourism" at the turn of the 18th and 19th centuries. As for politics, the city-state of Geneva was commonly regarded as the cockpit of political revolution in the years before 1789. Civil strife is not an obvious vector of technology transfer, but it produced considerable frictional movement of men and ideas.

Helpful though it is to distinguish the categories proposed above for analytical purposes, it should be remembered that knowledge exchange rarely took place in such a schematic fashion. On the evidence of the visitor records of the Soho Manufactory, links forged in the epistolary "cyberspace" of the Republic of Letters often led to person-to-person contacts which could lead in turn to fruitful commercial relationships, or technology transfer, or both. Equally, Swiss refugees who found themselves in involuntary exile in London, Edinburgh or Birmingham often became conduits for the diffusion of British experimental science and its derivatives in the form of technologically useful knowledge.

Correspondence Networks

In the 18th-century a great deal of natural knowledge circulated by means of the letter. In the interval between the end of the Seven Years War and the Wars of the Revolution (1763–1792), the velocity of knowledge transfer by this method reached levels never before seen in Europe. The great mercantile and capital

cities were now all linked by efficient postal services and it took only five days to send a letter from Birmingham to Paris, whether a business letter or one transmitting the latest scientific news. Only in the most formal sense can this epistolary exchange be described as private correspondence. The *savants* of the Enlightenment were men committed firmly to public knowledge dissemination, and a loosely configured infrastructure[6] of societies, academies and freemason lodges was emerging to facilitate the process of diffusion.

It is true, however, that scientific knowledge travelled more easily than technological "know-how". In part this was a problem of inscription for only at the very end of the century is it possible to detect the presence of an explicitly technological literature as opposed to an undifferentiated science literature disseminated in periodical form. Indeed, Swiss publicists and amateur experimentalists such as the Pictet brothers played an important role in encouraging this development. The encoding of knowledge to make it more portable and therefore transmissible was not the only problem, though. It is apparent from the Soho Manufactory archives that industrialists and engineers such as Boulton and Watt drew a rough and ready distinction between discoveries in natural philosophy (to use their term) which were, or should be, made "public", and knowledge with commercial or industrial potential which should be "protected" by means of patents and *privilèges*. It was this tension at the heart of the Enlightenment knowledge project that gave rise to alternative mechanisms of technology transfer such industrial espionage.

Two of the most prominent figures in the *réseau* distributing information between Britain and Switzerland in the second half of the 18th and the early 19th centuries were Jean-André Deluc (1727–1817) and Marc-Auguste Pictet (1752–1825). Businessman by vocation, natural philosopher and author by inclination, Deluc hailed from an "ingenious" craft background (his father had been a watchmaker). He arrived in London from Geneva in 1773 and obtained the post of Reader to Queen Charlotte, a post that provided considerable opportunities for patronage. He carried out experiments with Joseph Priestley (1733–1804) and James Watt (1736–1819) in the early 1780s, and would make significant contributions in the fields of geology and atmospheric physics. In the context of this article, however, it is his role as contact point for a whole generation of Swiss travellers to Britain and as a two-way conduit for knowledge and "know-how" exchange which is the most important. It was Deluc, for instance, who provided Ami Argand (1750–1803) with a letter of introduction to the firm of Boulton & Watt when the Swiss inventor arrived in London in search of backers and manufacturers for his tubular wick oil lamp in 1784, and when Jean-Charles Trembley (1764–1846), son of Abraham, the Genevan naturalist, called on Watt in the summer of 1789. It is perhaps not surprising to find that men of a similar background and outlook

tended to have known one another from an early age. The socially fluid environment which enabled entrepreneurs, natural philosophers and skilled artisans to mix on terms of familiarity if not quite equality in London, Birmingham or Glasgow could be found in Geneva to some degree as well. London's Society of Arts, which had been founded in 1754 to promote enterprise, innovation and emulation, spawned several similar initiatives, the most successful of which appears to have been the Société pour l'Encouragement des Arts of Geneva. The product of collaboration between the most illustrious of the Republic's *savants,* the botanist Horace-Bénédict de Saussure (1740–1799), and the clockmaker Louis Faizan in 1776, it established a bridge between the patriciate and a petite bourgeoisie of talented artisans.[7]

Like Saussure before him, Marc-Auguste Pictet made a number of trips to Britain. In 1775/76 he toured the sights of London in the company of his fellow Genevan the astronomer Alexandre Aubert (1730–1805), a well integrated member of the capital's Swiss expatriate community. He was in England again in 1787 and secured access to Matthew Boulton and the Soho Manufactory on production of a letter of recommendation signed by Abraham Guyot (1743–94) of Neuchâtel. Guyot was another peripatetic Swiss who combined the role of travelling natural philosophy tutor with that of *colporteur technique*. The suspension of hostilities in Europe made it possible for Pictet to make further extensive tours of the British Isles in 1801/02 and these were extensively reported in the *Bibliothèque britannique*. We know, too, that he visited the elderly James Watt senior in Birmingham in 1819 – the year of the latter's death.

Having suffered losses as a result of the outbreak of the revolution in France, Pictet made a virtue out of necessity and turned his energies in the direction of journalism. For three decades he was the most energetic and effective populariser of scientific and technological knowledge between Switzerland and Britain, a role which was formalised with the launch of the *Bibliothèque britannique*. This widely read periodical appeared seven times a year between 1796 and 1815, with Marc-Auguste editing the sciences and arts section and his younger brother Charles covering literature and agriculture. In practice the brothers filled the journal with hefty chunks of material translated from English in which the emphasis was placed firmly on the concrete applications of scientific knowledge. During the period of the Continental System (1806–1814) when even the letter post had largely broken down as a vector for information exchange between Britain and the Continent, the *Bibliothèque britannique* remained one of the few accessible sources of information in continental Europe. Pictet's extensive correspondence it should be said was very much of a piece with his journal: a miscellaneous bringing together of the scientific, the pedagogic and the industrial ranging from reports of weather phenomena to reports of English inventions such as the "water closet".

Grand Tourism and Commercial Exchange

As can be seen, the movements of men are scarcely to be separated from the movements of ideas within the Republic of Letters. If we set aside for a moment the occupationally-driven mobility of skilled artisans, it is probable that a contingent of at least 40,000 English tourists, together with servants, could be found on the continent of Europe by the summer of 1785. At least this is the figure reported to the historian Edward Gibbon – himself a resident of Lausanne between 1783 and 1787.[8] Yet as other contemporaries would acknowledge, the Grand Tour was losing some of its social cachet in the 1780s; or rather it was metamorphosing like the Enlightenment itself into something more focused and utilitarian. The popularity of industrial sites such as Matthew Boulton's Soho Manufactory bears witness to this transition. The "classic" Grand Tour was being supplemented by a discrete cultural practice which we may label technological tourism.

By the time the phenomenon of overseas travel resumed in the late summer of 1801 this new development had become even more pronounced. Leisured travellers with no particular objective other than sight-seeing still traversed the Channel, in both directions, but the emphasis was increasingly laid upon the investigative. Whilst English tourists whose apprehensions of nature now betrayed a pre-romantic outlook flocked to Switzerland in order to contemplate the glaciers,[9] the flow in the opposite direction seems to have been altogether more business-like. Nearly half of the passports issued in Paris by the British ambassador for onward travel to London were requested by entrepreneurs, manufacturers, tradesmen and craftsmen.[10]

Swiss technologists and businessmen did not wait upon the uneasy Peace of Amiens (1802/03) to come to Soho, of course. In fact the partners concluded quite early on that some of their overseas visitors were using the resumption of intercourse as a cover for technological knowledge collection. It was difficult after all to control access to a particular technology if the applicant appeared in the guise of a customer who was proposing to pay ready money for it (one of the improved steam engines for instance). Ami Argand incurred this suspicion until the partners were able to satisfy themselves that he was both a first-rate practical scientist *and* an entrepreneur. Christian Fueter is another case in point. A member of the city council of Bern, he arrived at the gates of Soho in 1791with a request that he be permitted to visit the works. Fueter, too, had a business transaction on his mind. As Director of the Bern Mint he was engaged on a Europe-wide tour of inspection of facilities for the striking of coin. Matthew Boulton needed no encouragement to try and interest him in his new steam-powered coining presses, but the coining needs of a Swiss canton scarcely justified the introduction of

rapid-strike machines and flow production. Boulton therefore changed tack and offered to sell Fueter the tailings, or scrap produced by Soho's Sheffield Plate operation – together with the "know-how" to separate the silver from the copper. When the noted Schaffhausen industrialist Johann-Conrad Fischer crossed the Channel for the first time in 1794, it was the quest for metallurgical knowledge that spurred him on. Within a decade he would become Director of Mines for the canton of Schaffhausen and begin experimental production of cast steel at Mühlental. Apart from the sight of the extraordinary quantities of cast iron employed as a constructional material in Britain, what chiefly attracted his attention were the exceptionally high skill levels on display in workshops. Having proved his competence as a metallurgist to James Watt junior during a visit to Soho in 1814, he recorded in his diary a sense of amazement on beholding the skill which the Soho smiths lavished on the construction of a humble chisel. Like others before him, he drew the conclusion that it was not so much the "hardware" (that is machines) that provided the key to successful technology transfer as human resources. By the 1820s Fischer's prowess in low-carbon smelting would enable his company to break the British monopoly of crucible cast steel production.

Artisan Exchange

We know that considerable numbers of skilled workmen moved around Europe, transferring skills as they went during the second half of the 18th and the early decades of the 19th centuries. Some estimates put the figure as high as 200,000.[11] What we know much less about, however, are their identities and their occupational trajectories. As a result the story of knowledge and technology transfer in this period has an in-built bias in favour of entrepreneurs and industrialists; in other words in favour of those whose names appear in the historical record. We can document, for example, the movements of a William Wilkinson or a William Cockerill or, in the Swiss case, those of a Fischer or a Johann-Georg Bodmer, but the artisans and craftsmen who also moved from employer to employer in what was fast developing into a market economy for technological competence pass largely unnoticed.[12] The fact that the government of Great Britain[13] sought repeatedly to prevent the expatriation of artisans and the export of many types of machine tools until the second quarter of the 19th century nonetheless testifies indirectly to the efficacy of artisanal transfer. When the legal ban on the emigration of British artisans was lifted in 1825, the toolmaker Henry Maudslay (1771–1831) remarked that skilled workmen "have gone in flocks" to Europe.[14] In the case of Matthew Boulton we do know a little about the skilled craftsmen

that he brought over from Switzerland and elsewhere to work at Soho, and rather more about the movements of his engine erectors. These latter were sent out to supervise the installation of static steam engines purchased by customers, and they occupied an intermediate niche between the craft-based artisan and the technician. Several spent long periods on the Continent, erecting engines for French, Dutch and Spanish entrepreneurs, and a few would go on to become engineers in their own right. As physical embodiments of a skill-set that was but poorly encoded before the 1820s, they were frequently poached by rival employers.

There are no instances of engine erectors working in the Swiss cantons and territories during the period covered by this article, however. In the late 1780s Ami Argand, acting on behalf of the Société pour l'Encouragement des Arts, contacted James Watt with a view to purchasing an auxiliary steam engine to back up a pumping station on the Rhône. Aware of developments in corn-milling technology in London and Paris, he stipulated that the engine should also be capable of turning two mill stones. No doubt the enquiry was prompted by the flour shortage which Geneva had faced during the severe winter frosts of 1788/89. It does not seem, however, that the political will for works of *utilité* existed in the Republic at this time.

In any case Watt questioned whether Switzerland possessed the socio-economic infrastructure to domesticate successfully his invention. When Pictet asked Jean-André Deluc to sound out the Birmingham engineer on the subject of steam technology, he was rather dismissive. In the light of their discussion, Deluc reported, "il en est résulté que tout ce qu'il [Watt] vous communiquerait ne saurait vous servir à rien. La théorie à cet égard ne sert pas plus à la pratique qu'un ouvrage d'horlogerie ne servirait à faire des montres à Otahiti. Après la description la plus exacte et la plus circonstanciée, il faudrait avoir des fourneaux de fonte, et les raffineries qu'on a dans ce pays-ci, tous les divers ateliers et le nombre des machines que l'expérience a accumulés à Soho, et tous les ouvriers que Messrs Watt & Boulton ont éduqués."[15]

This seems a rather sweeping and definitive judgement – even when applied to cutting-edge steam technology. After all, by the 1800s Prussia was well on the way to establishing in Upper Silesia a heavy-engineering capability that had been built up more or less from scratch. Nevertheless, it is important to keep in view the wider picture of artisanal exchange and skill transfer operating at more mundane levels. Matthew Boulton's quest for gold and silversmiths, gilders, chasers and engravers has already been mentioned, and he routinely employed recruiting agents such as Johann-Sebastian Clais (1742–1809) to funnel talented craftsmen from Europe in the direction of his workshops.[16] By the same token, he also found himself the target of enticement activities by rival industrialists who were just setting up.

A case in point is the visit to Soho in 1766 of two Swiss entrepreneurs Jean-Jacques Ador and Paul Preponier. Having been entrusted with the extension of the Pforzheim metal-wares and jewellery factory established with the support of Margrave Karl Friedrich of Baden-Durlach, they came to Birmingham in search of the expertise involved in the manufacture of steel "toys". In effect, they planned to establish a south German replica of the Soho Manufactory and they seem to have succeeded in recruiting a multi-skilled English workforce for this purpose. So much so, indeed, that four years later the directors of the firm wrote to Boulton to propose a business merger on the ground that their English-trained native workforce could now turn out goods that were every bit as competitive as those manufactured in Soho. In fact, the partners informed Boulton that they would be glad to send home their English operatives on the ground that their skills in the cutting and polishing of metals had now been successfully transferred.[17]

The Politics of Knowledge Transfer

Jacques Trembley has remarked that 18th-century Geneva was a veritable "laboratory of revolutions".[18] Prior to the obliteration of the Republic in 1798, there had been repeated episodes of crisis and internal revolt against its political system (in the 1710s, 1730s, 1760s and 1782), although the *ancien régime* would not be toppled finally until 1798. Each of these civil commotions produced a consignment of political refugees, and it is apparent that exile and even incarceration as a prisoner-of-war, or as a civilian hostage, also facilitated the movement around Europe of knowledge and "know-how". Boulton &Watt received a steady stream of wandering Swiss natural philosophers who had either quit, or been forced to leave their country.

The best known Genevan expatriate was of course Jean-André Deluc. Although it is not absolutely clear whether political antagonisms or business failures were the main reason for his relocation in 1773, he stayed in Britain for most of the rest of his life and would follow events in his homeland with passion and not a little anguish. By the late 1790s we find him combining the role of natural philosopher with that of intelligence gatherer for the British government, a combination which also applied in the case of Marc-Auguste Pictet. Another Swiss "patriot" who fled Geneva following the conservative riposte to the revolution of 1782 was Jacques-Antoine Du Roveray (1747–1814). In November 1785 James Watt complained to his partner that the "scoundrel" Du Roveray had been seen "snooping" around the Soho Manufactory. Yet this less than flattering description would not deter Boulton from using Du

Roveray as a business intermediary several years later when he was trying to secure a contract to sell copper to the Paris Mint. Despite Watt labelling him a scoundrel, he was clearly a man of parts. By 1798 we find him back in London. Now on his third marriage and living in straitened circumstances, he wrote to Matthew Boulton with a proposal to travel to Paris and gather intelligence on the advances being made in the cut-steel "toy" trade.

The common denominator in the politics of technology transfer was France as will be apparent; a France which since the appointment of Charles-Alexandre de Calonne as Contrôleur-Général in 1783 had started to put considerable resources behind its commercial and industrial policies. When Ami Argand moved from Paris to London and subsequently Birmingham early in 1784, it was because the necessary manufacturing skills, together with the high quality flint glass needed for his lamp, could not easily be found in the French capital. After a less than fruitful business relationship with Matthew Boulton, a subsidy obtained by Calonne persuaded him to build a manufacturing plant of his own at Versoix in the Pays de Gex, just on the French side of the border with Geneva. Yet he would confide to Boulton that the choice of location was intended principally to ensure ready access to components smuggled overland from England. This was not at all what the Contrôleur-Général had intended when arranging for seed capital to be provided: "[M]y secret reason I did not tell him [Calonne] as you think, which is that I may get there [to Versoix] through Ostende all the lamps & parts of the lamps which will be more convenient to be made in England, especially the *plated* [lamps]."[19]

Clearly the complex politics of border control could also play a role in technology transfer, as indeed could war. We know, for instance, that at the height of the Terror in France agents of the Comité de Salut Public routinely interrogated British prisoners-of-war in the hope of obtaining information about machine-tool design and steel-making technologies. Yet it must not be forgotten that Britain also adopted a protectionist stance at this time; a time when arguments for freedom of trade and industry were only just beginning to have an impact in government circles. On the outbreak of the war against revolutionary France in 1793, an Alien Act was passed to enable supervision of the movements of foreigners. Those who were suspected of being industrial spies were often forced to remain within a narrow radius of the Channel ports. However, when the sea lanes re-opened in the autumn of 1801, the focus switched to surveillance of *out-going* artisans and manufacturers. In February 1802 a secret circular from the Alien Office urged customs officers at Dover, Gravesend and Harwich not to deliver passports for France or Holland to anyone suspected of "conveying away machines employed in manufacturing certain staple commodities of this country".[20]

Conclusion

In the light of his study of the introduction of steam power to Sweden, Svante Lindqvist remarks that "scientific discoveries are quickly published in detail, for the satisfaction and prestige of priority. In technology, on the other hand, innovations are kept secret for as long as possible for reasons of commercial or military competition."[21] Evidence drawn from the archives of the Soho Manufactory seems to bear out this dictum. Yet what must strike anyone who pauses to investigate the history of technology transfer in the late 18th century is how unsuccessful were the attempts to prevent the movement of human capital from one national context to another. Perhaps this helps to explain why governments largely abandoned their efforts to prevent competitor states from gaining access to endogenous "know-how" from the 1820s. However, it is at least as likely that key political decision-takers had come to the conclusion that "improvement" passed by way of "emulation" [imitation]; in other words that invention and innovation were more likely to be nurtured in an environment in which knowledge and "know-how" were permitted to flow freely – albeit competitively – in whatever direction they were needed.

It is of course true that natural knowledge did not translate in any neat fashion into "know-how". Knowledge did not automatically empower. Many stages were required before information encoded in the *Encyclopédie* and similar Enlightenment advice manuals could be embedded in craft practices. In the case of Switzerland, it is noticeable that most of Matthew Boulton's contacts were drawn from Geneva, often by way of France. Yet Geneva and the French-speaking cantons offered little scope for sustained industrial development. Only at the turn of the century did the profile of the Swiss visitor to Soho start to alter so as to embrace entrepreneurs and industrialists drawn from the more northerly German-speaking cities. Johann-Conrad Fischer's repeated journeys to Birmingham are a case in point, as are the peregrinations of the Zurich engineer Johann-Georg Bodmer who first came to Birmingham in 1816 in hopes of selling his gun-lock and cannon technology.

The most successful of the Swiss industrial visitors was probably Hans-Caspar Escher, though. Like so many of his compatriots he took the opportunity afforded by the peace treaties of 1814 to travel and spent a few days visiting Birmingham's workshops among many others. Although the re-opening of the European market rapidly eclipsed his initial cotton spinning venture, the Neumühle site would give birth to the Swiss Confederation's biggest machine-building enterprise. From modest beginnings Escher, Wyss & Co. became a company with 400 employees by 1835 – the year in which it launched its first iron steam ship. 19 more would be launched over the following decade.

Even the metallurgist Johann-Sebastian Clais, whose career is much less well documented, would use "know-how" collected during his travels in England and France to establish between 1777 and 1781 a major chemical works.[22] It produced vitriol employing the lead-chamber process pioneered in Birmingham as well as other products for the use of the textile manufacturers and calico printers of the town of Winterthur.

Notes

1 The term is borrowed from Joel Mokyr, *The Gifts of Athena,* Princeton 2004, as is the concept of "Industrial Enlightenment" employed in the title of this article.
2 See JeanTrembley (ed.), *Les savants genevois dans l'Europe intellectuelle au XVIIIe siècle,* Geneva 1987; David Bickerton, René Sigrist (ed.), *Marc-Auguste Pictet, 1752–1825: correspondance: science et techniques,* 3 vol., Geneva 1996–2000.
3 Conference intervention.
4 David Bickerton, David Sigrist, *Marc-Auguste Pictet, 1752–1825*, tome iii: *Les correspondants britanniques,* Geneva 2000.
5 Olivier Perroux, "Tradition, vocation et progrès: les élites bourgeoises de Genève (1814–1914)", PhD thesis, University of Geneva 2006, 276–291.
6 See David Lux, Harold Cook, "Closed Circuits or Open Networks? Communicating at a Distance during the Scientific Revolution", *History of Science* 36 (1998), 179–211.
7 On craft milieux in western Switzerland, see Roger Smith, "The Swiss Connection: International Networks in some Eighteenth Century Luxury Trades", *Journal of Design History* 17 (2004), 123–139.
8 See Jane Norton (ed.), *The Letters of Edward Gibbon,* vol. 3: *1784–1794,* London 1956, 33, E. Gibbon to Lord Sheffield, 1 October 1785.
9 "[Les anglais] vont aux glaciers *at the rate* de 50 par jour". Bickerton/Sigrist (cf. note 4), 356 (M.-A. Pictet to A. Marcet, 30 June 1802).
10 See Renaud Morieux, "'An Inundation from our Shores'. Travelling across the Channel around the Peace of Amiens", *http://www.politics.ox.ac.uk/philp/text/Papers/Morieux_Paper.pdf.*
11 See Poul Stromstad, "Artisan Travel and Technology Transfer to Denmark, 1750–1900", in Kristine Bruland (ed.), *Technology Transfer and Scandinavian Industrialization,* New York 1991, 136.
12 But see R. Smith, "The Swiss Connection: International Networks in some Eighteenth-Century Luxury Trades", *Journal of Design History* 17 (2004), 123–139.
13 See David Jeremy, "Damming the Flood: British Government Efforts to Check the Outflow of Technicians and Machinery", *The Business History Review* 51 (1977), 1–24.
14 William Henderson, *Britain and Industrial Europe, 1750–1870: Studies in British Influence on the Industrial Revolution in Western Europe,* Liverpool 1954, 122.
15 Bickerton/Sigrist (cf. note 4), 248.
16 See *"Der curieuse Passagier". Deutsche Englandreisende des achzehnten Jahrhunderts als Vermittler kultureller und technologischer Anregungen,* Heidelberg 1983, 69.
17 See: Werner von Kroker, *Wege zur Verbreitung technologischer Kenntnisse zwischen England und Deutschland in der zweiten Hälfte des 18 Jahrhunderts,* Berlin 1971, 171; Birmingham Central Library, MS 3147, Autran and Ador *fils* to M. Boulton, Pforzheim, 8 June 1770.
18 Trembley (cf. note 2), 11.

19 Birmingham Central Library, MS 3782/12/30, A. Argand to M. Boulton, Paris, 4 August 1785.
20 Morieux (cf. note 10), 13.
21 Svante Lindqvist, *Technology on Trial. The Introduction of Steam Power Technology into Sweden, 1715–1736*, Uppsala 1984, 116.
22 On 11 November 2009 this "Laboratorium" was granted Chemical Landmark status, officially acknowledging it to have been the first purpose-built chemical factory in Switzerland.

Zusammenfassung

Wissens- und Technologietransfer während der industriellen Aufklärung. Schweizer Besucher in der Soho Manufaktur, Birmingham (circa 1765–1820)

Dieser Artikel untersucht Wissens- und Technologietransfers zwischen Grossbritannien und der Schweiz während der paneuropäischen Aufklärung. Die Fallstudie basiert auf der Auswertung von schweizerischen Reiseberichten über die Vorbildsmanufaktur von Matthew Boulton in Soho, in der Nähe von Birmingham zwischen 1765 und 1820. Die Mehrheit dieser Fabrikbesucher kam zuerst aus der französischsprachigen Westschweiz, die meisten unter ihnen waren daran interessiert, technologisches Wissen zu erlangen, welches dann diskutiert und weitergegeben wurde; dabei war Genf in einer Relaisfunktion. Die Rolle der *Respublica literaria* in der Vermittlung von technologischem und naturwissenschaftlichem Wissen wird hier genauso untersucht wie die Berufsmobilität als Transmissionsriemen. Aufgezeigt wird ebenfalls, wie die politische Instabilität in Genf den Wissens- und Technologietransfer beeinflusste. Erst an der Jahrhundertwende begaben sich auch Unternehmer aus Deutschweizer Kantonen auf die Wissenstour nach Birmingham und in die West Midlands.

(Übersetzung: Michael Jucker)