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► **To cite this version:**

Aleksandra Kobiljski, Sarah Teasley. Making raw materials: innovation and imported technology in Meiji Japan. *History and Technology*, 2022, 10.1080/07341512.2022.2100970 . hal-03902981

HAL Id: hal-03902981

<https://hal.science/hal-03902981>

Submitted on 16 Dec 2022

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Making raw materials: innovation and imported technology in Meiji Japan

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Abstract

This article explores coal and wood manufacturing in late nineteenth- and early twentieth-century Japan as the empirical sites for understanding the material gaps between industrial inputs available locally and the affordances of imported technology. Using hitherto unexplored archival materials, it demonstrates how the process of making coking coals for steel smelting and wooden boards for furniture-making challenge a conceptual framework that assumes that raw materials exist on one side of a binary and manufactured goods on the other.

Instead, this article foregrounds the creative ways in which actors approached, redesigned and manufactured raw materials locally, to make them comply with the constraints of imported technologies. In doing so, the article provides a useful counterbalance to scholarly explorations that anchor modern Japan in notions of technology transfer and appropriation, thus failing to recognize the creative labour necessary to making imported technologies work on local ground. By focussing on the labour of matching materials to hardware, this article restores to the historical record the creativity and innovation that formed the fabric of the first wave of Japan's industrialisation and nuances our understanding of raw materials in the history of technology in general.

Keywords: modern Japan, raw materials, innovation, natural resources, coal, timber

Introduction

The idea that Meiji Japan's industrialization was built on imported technologies is a common trope in the accounts of contemporaries and company histories (shashi 社史), as well as in strands of economic history that build on these accounts.¹ In principle, there is a scholarly consensus that very little technology travels without some thought and adaptation required at the point of landing, both in general and in the specific case of modern Japan.² More recently, scholars have sought to reclaim concepts such as tinkering and creativity to provide a more nuanced understanding of the histories of making in early modern and modern East Asia.³ However, much remains to be done to foreground the creative labour involved in Asia's first experience of industrialization.⁴

The reasons for the elision are both structural and archival. Attempts to expand thinking in the history of technology to include more than the experience of certain parts of the world over relatively short periods of time can involve significant cognitive stress for historians working with European and North American materials. One site where this stress manifests clearly is in accounts of how technology travels. Although powerfully criticized as the framework for apprehending how technology circulates in the European context, diffusionist logic is unstated and alive in the available framings of the global industrial past, despite best intentions and much effort to deprovincialize technology stories.⁵ The exclusion of questions and actors from epistemologies beyond those grounded in Enlightenment models remains a structural feature of the historiography and a source of structural stress in the production of knowledge.⁶ Recent scholarship has provided effective critiques of diffusionist logic and accounts of technology's use that are more attuned to notions of adaptation, tinkering and circulation of technical knowledge.⁷ However, the framework of innovation, including critiques that emphasise tinkering, makes it

difficult to account for the great breadth of experiences that arise when technologies are imported into a new context under political and economic pressure, as was the case of Meiji Japan. The stories historians of Japan have told to date, as precious as they are, tend to focus on the eventful but ultimately successful travel of technology from one context to another (telegraph, railway, steam shipping).⁸ As David Edgerton has persuasively argued, histories of technology that focus on what are de facto exceptions yield a distorted picture of the technology in the human past.⁹ Neither do they leave space for reckoning with the fact that imitation vs. innovation, and adoption vs. adaptation, are not always the most relevant questions to ask of the historical record. What we need is to piece together stories that do justice to the creative work of those who matched a priori mismatched incoming technologies with the available resources.

Building on existing critiques of the framing of the modern history of technology outside the European and North American context as ‘imported magic’, this article foregrounds the creative ways that historical actors approached, conceptualized, and (ultimately) manufactured raw material. Morris Low notes ‘... much of the history of technology is in fact about ideas, information, and know-how, and how they are applied and used. Successful technology transfer in Meiji Japan was arguably more about careful on-the-job training and adaptation of Western techniques rather than mere importation of the relevant piece of equipment.’¹⁰ On the contrary, we argue that assumptions built into technology’s original design often stacked the odds against any local adaptation of imported technologies. As a result, actors sometimes modified industrial inputs, rather than the technologies themselves. In bringing to light this process, this article suggests that the concept of technology transfer is too blunt of an analytical tool. Instead, it models a way of understanding the fine mechanics of the creative labour of matchmaking which

enables technologies to travel. Coal and wood manufacturing in Meiji era Japan provide the empirical moorings and sites for us to explore the gaps between materials available locally and the affordances of imported technology that framed such tinkering.

Paying attention to the materiality of materials allows us to argue that raw materials can themselves be manufactured goods.¹¹ Available archives indicate that the physical properties and varieties of a material framed the margin of manoeuvre and set the limits of the socio-technical realm. Adaptation is not an indefinite and boundless thing, so this materiality was an important parameter setting the contours of the socio-technical imaginary. What emerges is the following working hypothesis: if much of your industrial technology has been designed elsewhere and takes for granted the kinds of local raw materials that are available, the result can be creative manufacturing of materials rather than an adaptation of industrial technologies.

Focusing on the labour of those in charge of making the imported “magic” work enables us to restore to the historical record the creativity and innovation that was the fabric of the first wave of Japan's industrialization. In so doing, we seek to nuance the understanding of raw materials in the history of technology broadly speaking. Equally, we aim to restore creativity to the history of Japan's early industrial efforts, as a counterpoint to the still-prevalent idea that Japan succeeded in becoming the first Asian industrial power because of a national capacity to be careful copiers of technological innovations made elsewhere.¹² Finally, alongside the articles by Hyungsub Choi and Hyeok Hweon Kang in this special issue, we call for more nuance and texture in understanding the nature of making in histories of East Asia.

Couture coals

The archive

Over a decade ago, in the archive of Kyoto's oldest university, I – Aleksandra – discovered a big black rock inside a box of paper files. It was a lump of coke, the kind of carbon fuel indispensable for industrial-scale production of steel, the stuff of railways, machine tools, and gun boats – thus the coke in the box was the bedrock of the modern nation-state.¹³ The rock and the box containing it were amongst some 27 boxes of uncatalogued private papers of a chemist, Shimomura Kôtarô 下村孝太郎 (1863–1937), the Chief Engineer of Osaka Chemical Works (today Osaka Gas, the single largest purveyor of domestic gas in western Japan).¹⁴ It is not unusual for a historian to encounter unsolicited material unrelated to ongoing research. To be a historian is to be unwilling and unable to resist the temptation of looking into this material nevertheless. Over the decade that followed, as I was trying to finish a book about early Meiji intellectual networks, the files from the boxes kept pulling me back, promising a material counter vantage-point on the same period. The coke in this box and its accompanying documents told ‘the making of’ Japan’s industrialization story, leading me to interrogate the meaning of ‘raw material’.

The files documented how some technologies travelled less well than others, because of a material gap between the kinds of natural resources required and those that were available locally. It is important to highlight that this was a mismatch in quality, not a problem of pure penury. Coke manufacturing for the steel industry is one case in point. At the end of the nineteenth century, industrial coking ovens were built with a particular range of coal in mind. As a result, they worked poorly with the coals available in Japan, which contained more volatile

elements than their European counterparts. In much of Europe and most of North America the types of coals suitable for coking were widely available. While Japan did not lack coal in absolute terms, the types of coals available had to be substantially doctored before they could qualify as raw materials suitable for coking using existing technologies.¹⁵ Hence, in the context of Meiji anxiety about energy sourcing, a supposedly raw material or natural resource (coking coals) had to be designed and manufactured in ways not dissimilar to any other consumer product in order for imported technology to work. In short, it was up to those at the point of landing to bridge the gap by attempting to bend their resources to fit the imported technologies. The black lump in the box was a monument to a successfully-developed technique for manufacturing metallurgical-grade coke out of the coal extracted in Japan's home islands. It was a powerful reminder of the ingenuity and persistence of technicians working against the grain of the Western technological consensus.

The glitch

The “making of” the black rock story, in the personal archives of one of the key production actors, Shimomura Kôtarô, is a story of an enterprise of modest size and sizable ambition. Initially a professor at Harris School of Science at Dôshisha 同志社 (today Dôshisha University), Shimomura was hired in 1895 by Toyama Shūzō 外山脩造 (1842–1916), a now obscure Osaka entrepreneur. This active, if relatively minor, Meiji businessman of samurai origin established the Osaka Chemical Works in 1894–95, seemingly with the aim of producing coke to satisfy the needs of the newly-developing machine-tools manufacturing industries clustering in Osaka.¹⁶ Shimomura had presented an appealing pitch to Toyama: manufacture metallurgical-grade coke using technology that not only can feed on domestic coals but also recover and sell

by-products of the process. By-product recovery was the key aspect of the pitch. What had previously been emissions and effluvia generated in the standard coke manufacturing process could now be captured and turned into saleable products such as coal tar (for wood preservation and briquetting) and ammonia (for fertilizer). At first glance this looked like making money out of waste and thin air. Toyama agreed to give it a shot. Yet there was a significant glitch in the pitch: the discrepancy between the composition of types of coals in Europe and Japan.

To pursue the project, the Osaka Chemical Works imported a cluster of top-of-the-line coking ovens from the Solvay Company in Belgium, using funding Toyama secured through his regional network. These ovens were designed and built in Belgium to work with mostly continental coal types, which had on average fewer volatile elements than the coal available in Japan. Solvay coking ovens were designed to work with metallurgical grade coal, which contains 15 to 18 percent volatile matter. According to company records, no Solvay oven at the time was required to coke coals with more than 22 percent volatile matter.¹⁷ Mines in Japan and Manchuria however, had on average between 38 to 40 percent volatile matter, more than double the baseline amount.¹⁸ This dramatic mismatch between the quality of input technology required and the quality of resources intended or available for the input presented a major challenge. Although the local grade of coal was suitable for simple combustion and to power steam engines, significant problems ensued if it was used to produce metallurgical-grade coke. The higher the volatile matter in the coal, the lower the quality of coke obtained, and thus the lower the chance that what came out of the coking oven would be usable for iron and steel production. In short, the glitch in Shimomura's pitch to Toyama was that the ovens imported from Belgium would not properly coke because the assumptions hardwired into their design could not be reconciled with the actual

properties of the raw material available in Japan. What helped overcome the glitch was that Toyama was able to make a profit by selling the by-products of coke manufacturing, even if strictly speaking the manufacture of the main product – coke – was a failure. Even if coke obtained in the research and development phase was not of metallurgical grade, it could be marketed as domestic coal. This allowed Shimomura and his research associates to quite literally buy the time to figure out how to devise a coking protocol that would allow them to make hard coke from suboptimal coals.

The solution

To achieve this, either the raw material or the oven technology had to yield. Shimomura and his team of technicians started by altering the raw materials themselves and endeavoured to tailor Japanese coals to suit the Belgian coking ovens they had installed. This had never been done before, and many obstacles, both material and ideological, beset their project. First, there was no existing technical literature on the subject because the attempt was unprecedented. Second, the foreign technical experts they consulted for advice and input met their proposal with scepticism, or refused outright to cooperate. When Shimomura tried to discuss aspects of his plan with sales technicians at the Hardy Patent Pick Co. Ltd. in Sheffield, for instance, they called the plan ‘suicidal’ and refused to assist him.¹⁹ To stress their disapproval of Shimomura’s plan, the sales technicians sold their equipment to the Osaka Chemical Works, but would not provide an installation blueprint, thereby making it harder for Japanese technicians to work out a successful modification of the machinery. Third, Japan had a five decades-long history of struggle in figuring out a durable fuel solution for coking. The record of things tried and failed, the sharing of experience on what had worked and what had not, would have been of help to the Osaka team.

Yet because of competing interests and distrust within Japan, the Osaka Chemical Works could not count on the advice of those who had tried before them. For example, Ôshima Takatô 大島高任 (1826–1901) was Japan's most experienced blast furnace engineer at the time. He had an impressive record of building over a dozen blast furnaces in the last years of the Tokugawa and the first years of the Meiji periods, and was also involved in the emblematic Kamaishi Iron Works project in the 1870s.²⁰ At the time when Osaka Chemical could have reached out to Ôshima Takatô, his son Michitarô was the Director-Engineer of the second emblematic Meiji iron and steel project, the Yawata Steel Works, and was ill-disposed to cooperate with the upstart Osaka company. As a letter from Shimomura to the Solvay company attests, Ôshima 'was always an obstacle' to their efforts 'to get the coke business of the Steel Works into [their] hands'.²¹ Hence, no exchange of experience within Japan was available to the Osaka Chemical Works.

By and large, the technicians at Osaka Chemical were on their own. During the four-year period between 1898 and 1902 they developed a three-stage assaying protocol, aiming to: 1) comprehensively evaluate the chemical makeup of their domestic coal, 2) manufacture, from these raw materials, an artificial analogue to the industrial standard of a coking coal at the time, and 3) oven-test various blends and determine which of them resulted in the best coke and, ultimately, get to the blast-furnace grade coke. This three-step testing protocol was key to developing a serviceable recipe for manufacturing coal that would serve as an adequate substitute for the kind of coal normally used to produce metallurgical grade coke. The attempts to hunt down a steady supply source for that kind of coal began with a vast array of domestic coals from all over Japan, from the islands of Hokkaido in the north to Kyûshû in the south. The approach of wide-net testing was as impressive as the logistics required. For several months in

1898–1899, new coal samples came to Osaka (1–2 tons at a time) and were methodically tested. The Shimomura and his team dug deeper than usual in industrial coal assaying, investigating the chemical makeup of their samples, looking beyond caloric value and overall percentage of volatile matter (the usual testing parameters). The early trials led them to identify eight specific subsets of impurities constituting the overall volatile matter mix in most Japanese coal. Then, they proceeded to examine the impact of these small chemical variations on the ultimate quality of the coke obtained. These experiments showed that, for Japanese coal to be turned into blast furnace coke successfully, what mattered was not simply the overall volume of volatile matter but the exact nature of the mix of impurities within the coals. In other words, they realized that what mattered was not simply the overall volume of aromatic carbohydrates, but the ratio of key specific elements within the mix. It turned out that if a given coal had less than 20 percent ash content and under 2 percent sulphur while maintaining less than 40 percent volatile matter overall, it could be prodded into working. This assaying process allowed the technicians to shortlist eighteen mines in Japan that contained coals with the potential to be doctored into viable coking coal.

The next step in this procedure involved an innovative method of processing coal prior to loading it into ovens. Usually, the coal was first washed and then ground before being loaded into the coke ovens, but Shimomura came up with a plan to reverse the process. Not only did the Osaka Chemical Works' engineers install the Hardy Patent Pick Company washing machinery in reverse order (the proposal that the technicians in Sheffield had called 'suicidal'), but they also upgraded the process by adding a pulsometer (a vacuum pump for pressure washing) obtained from the Jeffrey Manufacturing Company in Columbus, Ohio. The Japanese thus pre-processed

the coal by grinding it first and then washing it under pressure. Although this procedure had seemed nonsensical to sales technicians in Sheffield, it made sense when considering the Japanese coal, which could benefit from any and all methods of impurity elimination. Grinding the pieces of coal first and washing them later meant using more water and slowing down the process relative to what it would have been, had the washing process involved lump coal. Reversing the standard order also meant physically disrupting the coal's structure through grinding, thus making it possible to partially mechanically dislodge or free the impurities, for further elimination through washing. Pressure washing added power to the elimination process, and thus led to better results while also modestly speeding up this stage of the process. Experiments with this process allowed Shimomura and his colleagues to identify coals from four home island sites that could be developed into viable coking coal.²²

The coke produced from these coals beat the odds and met the expectations of Osaka Chemical Work's technicians. They had not only discovered that viable coke could be produced from domestic coals, but had also successfully identified and quantified the amounts of specific volatile elements in their coal, thereby contributing to a greater understanding of the chemistry of the coking process itself. Seeking to confirm his findings, Shimomura sent samples to Solvay's facilities in Belgium, asking them for independent confirmation of the results. In order to keep secret the source of the potentially highly-valuable coal supply, he gave no indication of any specific sites of origin, opting instead to label the samples numerically. The results from Belgium were reassuring, as they corroborated the findings made in Japan.

In the final analysis, Shimomura did not tinker with existing coking technology represented by the Solvay coke ovens as much as he designed a novel technique for manufacturing coking coals,

while leaving the coking technology largely intact. Careful mapping of the trial and error period of the Osaka Chemical Company's efforts to produce metallurgical-grade coke in the 1890s and 1900s raises questions about the accepted understanding of what constitutes raw materials in industrial processes. The technicians at Osaka Chemical Works left no evidence that they considered themselves producers of raw materials. Yet, even though they did not label it as such, a careful look at the meticulously documented research and production process preserved in Shimomura's papers indicates a de facto manufacturing of coals and the development of a coal product fitted to a particular specification that was required by the technology available. Raw materials for industry were considered something you either had or did not have. Unlike agriculture, which yields new crops, typical heavy industry raw materials cannot be grown or cultivated. What is remarkable about the efforts of Shimomura and his team at Osaka Chemical Works then, was their success in sufficiently modifying their natural resources to the degree that they created a product in its own right.

Hard woods

The hope

As with the Osaka Chemical Works' coals, this story begins with archives that did not fit the historical narrative. When I – Sarah – was searching for material regarding the design and manufacture of Western-style furniture in early twentieth century Japan, library and archival classification systems repeatedly directed me to the forestry section. What the classification system and the archival documents themselves made clear was that before asking questions about designs for wood products, I had to ask questions about materials, or more specifically,

about the properties of local wood materials and the behaviours these afforded, within the socio-technical systems created for their use.

In 1906, researchers at Japan's national Forestry Agency began a ten-year initiative to capitalize on local hardwoods as an untapped industrial resource through the use of European processing technologies. Similar to the case of coal experiments at the Osaka Chemical Works, this section of the article argues that the Forestry Agency's adoption of European wood processing technologies ultimately required modifying the input materials themselves, to suit the system's affordances.

Research into hardwoods formed part of a longer-standing interest in Japan from the 1870s onwards. Leaders in the Forestry Agency, supported by politicians in the Ministry of Commerce and Agriculture and the Ministry of the Interior, sought to employ European technology and methods to transform forests, primarily stands of evergreen trees but also 'low-value' largely deciduous scrubland, into high-value products.²³ In Tokugawa and Meiji period Japan, many hardwood species had not been used for capital-intensive industrial purposes. Forestry Agency researchers noted that European manufacturers such as Thonet had exploited European hardwood stands and Europe's increasing industrial infrastructure to create mass-manufactured, standardized, value-added products such as furniture and architectural components for growing urban populations.²⁴ Mechanized mass-manufacturing systems could also transform trees into military, industrial and logistics hardware such as gunstocks, spindles and shipping crates, thus supporting European imperial expansion and global market profits. Forestry Agency officials and their political backers thought that applying European technology for the industrial use of local

hardwoods would advance Meiji policy around income generation and infrastructural creation, too, through the exploitation of readily-available local materials and labour.

The challenge

Thus, in around 1910, the Forestry Agency established an experimental sawmill near Kajiyasawa, a hamlet near Sendai in north-eastern Japan.²⁵ The Agency charged researchers assigned to the sawmill to prototype ‘the production (*seisaku* 制作) of timber (*seizai* 製材) and raw materials (*genryô* 原料)’ for wood products using European industrial technology.²⁶ The sawmill was steam-powered, configured to German standard designs and furnished with machinery imported from Kirchner and Co., a manufacturer of sawmill and woodworking machinery in Leipzig and London.²⁷ By 1911, a workshop had been added for prototyping interior furnishings and architectural components from boards milled at the sawmill. Murata Shigeharu 村田重治 (1861–1942), a career forestry bureaucrat, led a team including Satô Shingorô 佐藤銀五郎 (1883–1945), a Forestry Agency researcher and specialist in wood utilization, in other words, the transformation of forests into commodities.²⁸ Satô brought observational as well as theoretical knowledge to the project: following the decision to invest in hardwood processing, the Forestry Agency had posted him to Europe in 1906 to study factory production techniques at government and university wood utilisation research institutes in Germany and Austria for three years. He arrived in Kajiyasawa directly following completion of this trip.²⁹ Sato, along with fellow Forestry Agency researchers Matsuo Ryôsuke 松尾良助 and Kawamura Makishi 河村牧司, conducted experiments onsite, then published 139 pages of data and analysis in the Ministry of Agriculture and Commerce Forestry Agency’s *Forestry Experimental Reports* in 1915.

Their experiments focused on hardwoods felled in the adjacent national forest, paying particular attention to buna (ぶな, 山毛櫨), a categorical term then encompassing *Fagus Sieboldi* Enal (buna) and *Fagus Japonica* Maxim (*inubuna* イヌブナ or *kurobuna* クロブナ, 犬山毛櫨), now known as *Fagus crenata* Blume.³⁰ Forestry Agency staff considered buna as a potential substitute for European common beech (*Fagus sylvatica* L. subsp. *Sylvatica*), for two reasons. First, buna was arguably the most common deciduous tree in early twentieth-century Japan, found in cool to temperate deciduous forests around the archipelago.³¹ One estimate suggested that buna trees accounted for 30 percent of all hardwood forests globally in the early twentieth century, and 65 percent of hardwood forests in northern Japan, the location of the Kajiyasawa station.³² Buna grew in large quantities but had not been considered a suitable material for mass harvest, production and sale.³³ For the most part, villagers gathered it for firewood, charcoal and to make farm implements for their own use. In the Tokugawa period, a few locally-specific industrial areas began employing buna for small items like the wooden bases of lacquerware. But production remained highly localized, and the material was not integrated into regional or national supply chains and markets. But by 1911 the researchers thought that buna's plenitude, along with its physical similarity to European beech, rendered it potentially useful for making all manner of mass-produced products, along the lines of those mass-produced in Europe from European beech.

A second reason for their interest was buna's physical properties. Some of these were considered desirable for woods used in manufacturing.³⁴ Buna is denser than softwoods and therefore less likely to split, more resistant to pressure and less flammable when properly cured. It is relatively heavy, shines when polished and absorbs surface colour treatments, all characteristics

appropriate for imitating expensive, increasingly-scarce hardwoods such as sakura さくら、桜 (cherry, *Prunus serrulata*) and kurumi くるみ、胡桃 (Japanese walnut, *Juglans ailantifolia*). Based on these properties, and on the popularity of its beech analogue in Europe, Forestry Agency researchers saw value in developing processes for manufacturing goods from buna. But some of buna's properties were undesirable. Buna's physiological characteristics rendered it harder to control than other local hardwoods. As an organic material containing water, wood is ordinarily dried, or cured, before use, to create material stability. Products made from uncured wood can warp, rot or split as the water content evaporates over time and in response to changes in atmospheric humidity. Buna has a relatively high water content – on average 85 percent of a tree is water, and 60 percent of its wood before any treatment – making drying particularly important for any industrial use.³⁵ The higher water content also makes buna more permeable and susceptible to microbial and fungal growth, which leads to rotting when undried or poorly dried. It also means that undried buna flexes, cracks and warps more easily, and to a greater extent, than woods with a lower water content.

Buna's physiology further compounds the difficulties in drying it consistently and making good-quality boards. All trees comprise an outer layer of sapwood, with a higher water content, and an inner core of denser, drier heartwood. Both buna and European beech are characterized by an additional layer of false heartwood, which has different drying characteristics to both sapwood and heartwood.³⁶ If dried too quickly, this wood can crack and its strength decrease, rendering it unsuitable for load-bearing uses. Buna's variegated physiology means that appropriate drying parameters for one part of the board can induce flaws in another part, and that unless boards dried together have approximate comparable composition, drying protocols calibrated for some

boards can be unsuitable for others in the same batch. Thus, buna requires additional attention to create boards with a similar physiological makeup, and to store them between sawing and use.

In sum, without close calibration of input and process, buna boards and products made from them were more likely to contain flaws, and would generate them more quickly than products from other available species. All of this made buna, already a lower market-value wood, more resource-intensive to process and maintain at standard specifications and minimum quality standards. Spoiled wood led to inferior products, resulting in diminished profits for an already low-value material. And differences between environmental and climatic conditions in Japanese forestry zones and in those in Germany and Austria, where the drying techniques for mass-production using European beech had been developed, meant that European systems calibrated to German and Austrian trees and conditions would not simply work for drying buna.

Until the early 1900s, the challenges presented by buna's properties and the availability of more predictable, controllable woods had kept manufacturers and researchers alike from exploiting buna, despite its proliferation. Indeed, given these challenges, investing resources into working with a 'bad' wood seemed counterintuitive. But by the early twentieth century, commonly-used hardwoods were becoming scarcer and more expensive – especially after the Russo-Japanese War's (1904–05) large-scale mobilization of these woods for military hardware, and after post-war manufacturing of industrial components for mills. Buna's plenitude in Japan and beech's profitable exploitation in Europe thus nudged Forestry Agency staff to invest upfront in trying to understand how to make it behave. Some manufacturers adopted buna, despite its shortcomings, as a material for cotton mill spindles, military rifle butts and other small items. Such small items reduced the risk of loss-making when one piece was bad, but mass-production from bad boards

put spoilage outside manufacturers' control. One estimate from 1912, for example, noted that 20 to 30 percent of buna rifle butts supplied to the Japanese military were unusable, due to wood rot.³⁷ In response, Forestry Agency researchers developed and adopted techniques for rendering buna more stable, though each brought its own problems. For example, large outdoor-use items like telegraph poles and railway sleepers could be injected with preservatives such as chalcantite or coated with creosote or naphthalene (all chemicals potentially obtained from the Osaka Chemical Works). Forestry Agency researchers concluded, however, that treatments with such toxic substances were inappropriate for products frequently touched and used by humans.³⁸ They therefore developed a technique for storing the logs in water, then smoking half-split logs over a fire to drive out the moisture, but these processes did not reliably prevent warping or rotting over time.

The solution

Producing reliably stable, standard boards that would meet minimum performance specifications was thus the experimental sawmill's remit. The researchers applied German observational and experimental wood science understandings of woods' material properties and behaviour to local timber, designing experiments that focused on woods' behaviour during transformation into two types of products: boards, and furniture and interior architectural components made from them. Their interest lay in identifying the impact of different parameters at each stage of production processes on the behaviour of different wood species, to understand the impact of those specific material interactions. By experimenting with changing parameters – dimension, time, material, heat, process and so on – the researchers were able to compile a description of possible resultant behaviours. The hope was that, once generated, this knowledge would allow sawmills and

manufacturers alike to select the most optimal materials and processes for their desired outcomes and, by demystifying and codifying these behaviours, enable the materials to be put to use in new enterprises and industries.

To these ends, the sawmill experiments focused on producing boards with the Kircher & Co. equipment. The results published in 1915 foregrounded ‘economical’ outcomes, that is, efficiency, the number of trees that could be processed or boards made per day, in comparison to technical set-ups in non-steam-powered sawmills, and on the standard dimensions achieved for boards from each tree species, based on average log size.³⁹ However, the data provided for individual species makes it clear that the researchers also determined optimal belt speeds, for example, for each species tested. In other words, in that instance, researchers calibrated the technology that needed to be applied to the materials, to process a tree into a satisfactory board.⁴⁰

Work to calibrate the material to fit the technology occurred in the next stage: the readying and storage of boards – which the researchers called ‘raw material (*genryô*)’ in their reports. By testing boards of different species and cuts in set dimensions and conditions and observing the boards’ responses, they sought to gain knowledge that would allow manufacturers to increase material stability, both while in storage and once made into consumer products. Interactions between different woods and their environment – particularly heat and moisture – at each stage of material preparation were key. Some of the experiments replicated and modified local processes for air-drying and storing boards, while others compared their results to those of processes facilitated by the sawmill’s imported European technology and knowledge, for example comparing the moisture content of air-dried boards to those dried in the sawmill’s steam-powered kilns. Other experiments focused on identifying the ‘least worst’ option for all

necessary stages in the process of transforming boards into consumer durables, such as variations in moisture content according to whether boards were stored in air or water, pre-use.

Observing such interactions between materials, environment and technology at each stage of the process proved key to the researchers' findings. Drying experiments, for example, divided the process into air and kiln-drying, using three types of wood including buna. They varied the cut and the length, width and depth of boards as afforded by the standard form and physiology of each species, then measured the percentage of water lost from each type of board over a ten-month period. While most experiments compared the results of varying parameters across logs and boards from several species, researchers also experimented with controlling rotting in the sawing and processing of buna boards alone, again varying dimensions and cut and observing the results. The charts and accompanying descriptions in the 1915 reports make it clear that the experiments enabled the team to identify which specific board cuts and dimensions would produce optimal and stable moisture levels for each species, increasing the likelihood that the boards would become usable materials in fabrication.⁴¹ The researchers could then instruct the sawmill technicians to cut boards to specific dimensions and orientation within a log, creating optimally usable materials for manufacturing.

The relationship of board to tree was crucial. For buna, the researchers recognized that orienting sawing to maximize the heartwood – rather than the sapwood or false heartwood – content in each board, then modifying the curing and storage processes to work with the specific likely moisture content of that cut, would produce the greatest stability. Thus, the log and sawmill apparatus needed to be orientated to each other to create boards that would behave within the subsequent system. The team also recognized that some interventions needed to occur prior to

milling. They found that boards from timber felled at different times of year dried at different speeds, and to different degrees. With climatic variations at the time of felling affecting the long-term stability of boards (and thus of secondary products), it became clear that logs as ‘raw materials’ were themselves already processed variably, and that timing felling appropriately could improve product quality as well. To further underline this point, research results from the fabrication workshop experiments, too, emphasized that stable boards were key to creating viable consumer products, and that the products themselves needed to be scaled to fit the types of boards that could be reliably supplied.⁴² Thus the crucial result of the fabrication experiments was not convincingly attractive products or protocols for their manufacture, but insight into the necessary makeup of buna boards to construct viable products, based on the affordances of the imported technology and local climate.

In sum, the Kajiyasawa researchers learned that modifying the ‘input’ – bending local woods to the behaviours afforded by the imported technology – allowed them to use European technology to produce both viable manufacturing materials and prototypes for mass-manufactured products made out of them. Carpenters in Japan did not need the Kajiyasawa researchers’ experiments with European wood science or technology to learn this. The point, then, is not that the Kajiyasawa researchers identified different species’ behaviour and volatility for the first time during this research – they did not – but that they recognized it was necessary to change the local materials to use imported machinery and processes. Furthermore, they reconfigured the imported system – in this instance, the order and parameters of interactions between machinery, knowledge and raw materials – to create a product that approximated German production. Like coal, buna and other hardwoods would only become usable raw material for imported processes

and machinery if they could be processed into materials that predictably functioned like those in Germany. Again, solving the problems presented by local materials' properties was the central challenge in using imported technology .

Conclusion

In closely examining how two different groups of actors in late nineteenth and early twentieth-century Japan pondered the physical and chemical characteristics and behaviours of organic matter available to them, and carved out their margin of manoeuvre, this article contributes to a subtle but fundamental reconceptualization of raw materials as products. The two stories of coals and wood recounted in this article may differ, but both concern successful efforts at making local materials comply with the limitations of imported industrial processing systems and knowledge. Both teams were commissioned to use an imported technology, for coke or board and wood furnishing manufacturing. In both cases, imported technologies needed to work with local inputs. To do this, the raw materials themselves needed to be produced: in other words, the processing of natural resources was in effect the functional equivalent of manufacturing of raw materials defined as an essential prerequisite for the effective working of the whole system. A difference in degree became a difference in kind. In the final analysis, both teams used experimental methods and manufacturing protocols alike to transform the input – coals or wood – into industrial raw materials or, in other words, materials that were 'readable' by the imported technical assemblage. This has implications for standard narratives of how technology moves. Industrial technology rarely travelled light or worked its 'magic' upon landing. In Meiji Japan, because the political and economic stakes of making things work were so high, much time and effort was invested in working quietly around and against imported technologies. No amount of capital layout on

imported technology could have in itself turned Japanese coal into metallurgical coke or buna trees into railway sleepers, wainscoting and hatstands. It is not possible to simply cut, paste and fine tune in order to use techniques and machinery outside the ecosystem of their original design. The degree of redesigning coking and sawing protocols, and working around the limitations of the technology available to the people involved cannot be fully described with the language of appropriation or adaptation promoted by much current literature on technology transfer. While beyond the strict scope of this article, the evidence marshalled and the story told also reveal ways in which the focus on adaptation and circulation in discussions of technology transfer, as well-meaning and theoretically informed as they are, can fail to bring forth the lived experiences of technical actors in landing sites. The stories of manufacturing coking coals and hardwood boards explored in this article would be effectively invisible through the lens of technology transfer and adaptation.

Instead, we contend that Meiji industrial success was also and often about engineering indigenous materials to work in industrial systems not designed for them: not only adapting imported techniques and training people to work with them but creatively manufacturing the inputs as well. When told from the perspective of the history of technology and materiality of coal and wood, it becomes clear that the stories of the Osaka Chemical Works and the Kajiyasawa experimental sawmill are less about transfer and more about the understated but crucial creativity of technical actors who humbly bore the brunt of Japan's industrial rise. These two stories suggest that what has been often billed as transferred and mastered imported technology was, in practice, often a product of a painstaking process of reinvention and

innovation. By recounting these stories, this article restores and pays tribute to the understated creative energy that went into industrial projects outside of the limelight and headlines.

Endnotes

¹ A powerful exception and counterbalance to this narrative is Tanimoto, *Japan's Industrialization*. Also see Choi, "Another Spinning Innovation."

² Low, *New Japan*; Wittner, *Progress in Meiji Japan*; Raina and Günergun, *Science*.

³ See Lean, *Vernacular Industrialism*; Guth, *Craft Culture*; Kobiljski, "Energy Workarounds"; Teasley, *Designing Modern Japan*; and Choi, "Before Localization," in this special issue.

⁴ Examples of exceptions include Hunter's careful analysis of the distribution of innovative technical know-how in "Reviving the Kansai cotton industry"; and Clancey's analysis of know-how amongst carpenters in Meiji Japan. Clancey, "Modernity and Carpenters."

⁵ An influential example of diffusionist assumptions in the understanding of technology in industrialization is Mokyr, *Gifts of Athena*. For a poignant critique of diffusionist logic within the European context, see Hilaire-Perez and Verna, "Dissemination of Technical Knowledge." For recent efforts to deprovincialize the Industrial Revolution see Riello, *The Spinning World*; Berg et al., *Goods from the East*.

⁶ While outside the parameters of this article, this point is crucial to understanding the persistence of diffusionist logic. See, for example, Chakrabarty, *Provincializing Europe*, and Walter D. Mignolo and Walsh, *On Decoloniality*.

⁷ See Francks, "Industrial Revolution"; Guth, *Craft Culture*. Dong, "Red Brick Imperialism," and Lean, *Vernacular Industrialism*, explore how local know-how and the materiality of local materials shaped uses of imported technologies in modern East Asia. Notably, Dong, Francks, and Guth use recent European historiography in STS, industrialisation and material histories of making, respectively, to argue for new approaches to histories of industrialisation and making in East Asian contexts. More widely, see Medina et al., *Beyond Imported Magic*; Law and Lin, "Provincializing STS"; Souza Dias, "International Design Organizations."

⁸ Hunter and Stoltz, *Institutional and Technological Change*; Hunter, "People and Post Offices"; Ericson. "Taming the Iron Horse"; McDonald, "Asymmetrical Integration."

⁹ Edgerton, *Shock of the Old*.

¹⁰ Low, *New Japan*, 3.

¹¹ Similar arguments exist outside the history of technology in East Asia. See, for example, Sougy, *Les Charbons*; and Rezende, "Manufacturing the Raw."

¹² On the history of the trope, see Hunter, "Deficient in Commercial Morality?" and Francks, "Industrial Revolution."

¹³ On the intersections of steel and nation building, see Misa, *Nation of Steel*. For an English-language survey of the Japanese steel industry, see Yonekura, *Japanese Iron*.

¹⁴ For biographical information on Shimomura, see Kobiljski, "Shimomura Kôtarô"; Kobiljski, "On Science and Faith."

¹⁵ On contemporary coking technology in Europe and North America, see Fulton, *Coke*; Parker, *Manufacture of Coke*.

¹⁶ Sawai, “Meiji chûkôki Osaka no kikai kôgyô”; Suzuki, *Meiji no kikai kogyô*.

¹⁷ Four à Coke Semet-Solvay, 63.

¹⁸ Chōsajo, *Imperial Geological Survey*.

¹⁹ Letters from Hardy Patent Pick Co. Ltd., Sheffield, to Shimomura Kōtarō, September 1, 1898, and September 6, 1898.

²⁰ For an English-language account of the work of Oshima Takato at Kamaishi, see Wittner, *Progress in Meiji Japan*, 77–98.

²¹ Letter from Shimomura Kōtaro to Messers Solvay & co, January 15, 1904.

²² Three of these sites remain unknown since they were kept confidential in correspondence. The one known site is the mine of Yubari in Hokkaido in which Osaka Chemical Works subsequently purchased shares to secure supply. Further research is needed to piece together the location of other three sources.

²³ On ‘low-value’ trees, see Totman, *Japan’s Imperial Forest*, 11–13.

²⁴ For further elaboration of this logic see the introduction to the Forestry Agency’s 1430-page report on wood utilization, Sanrinkyoku, “Mokuzai no kōgei-teki riyō.”

²⁵ Sanrinkyoku, “Ringyō shikenjo yōran,” a summary of Forestry Agency experimental stations’ activities, gives the sawmill’s first year as 1911. The comprehensive general history of forestry and forest products manufacturing in Japan edited by the Nihon Ringyō Gijutsu Kyōkai gives the date as 1909. Nihon Ringyō Gijutsu Kyōkai-hen, *Ringyō gijutsu-shi*, 5: 30.

²⁶ Sanrinkyoku, “Ringyō shikenjo yōran,” 21.

²⁷ Configurations including drawings are included in Kawamura, “Kajitanisawa Mokkōjo.” Kirchner and Co. were prominent in their field, with a notable presence at international exhibitions and an office in London; significantly, they advertised some of their machinery as being appropriate for colonial sawmills, i.e., for woods other than European species.

²⁸ On Murata, see Dai Nihon Sanrinkai, *Murata Shigeharu okina*. On Satō see Ōta Yujirō, “Satō Shingorō.”

²⁹ Nihon Ringyō Gijutsu Kyōkai-hen, 30. Satō’s report is Sanrinkyoku 1909.

³⁰ Period Japanese-language sources provide differing information about the naming, classification, social reception and use of these species in the early modern and modern periods alike. The inter-war Buna Association's explanation, for example, lists the Japanese buna species as buna: *Fagus Sieboldi* Enal and inubuna: *Kagus Japonica* Maxim. As Mechtild Mertz explains, 'It is quite common for more than one species to be included under a single timber name, either because the wood species are functionally equivalent and can be used interchangeably, or because once they are cut, they are very difficult or impossible to distinguish.' Mertz, *Wood*, 28. In contrast, the contemporary wood science literature offers detailed studies of both genera, including their genetic profiles and distribution around Japan. See Okaura and Harada, "Phylogeographical Structure." On *Fagus crenata* and the *Fagus sylvatica* L. subspecies *sylvatica* (European common beech), see "Fagus L.," in Wiersema and León, *World Economic Plants*, 223. Researchers have shown that the two species sometimes interbreed; see Okaura and Harada, "Phylogeographical Structure."

³¹ On the distribution and prevalence of buna in Japanese deciduous forests, see Okitsu, "Forest Vegetation," 231–61.

³² Taniguchi, *Bunazai ni kansuru chōsa*, 4–5. See also Mertz, *Wood*, 13.

³³ A summary of the history of buna use in early modern and modern Japan is given in Nihon Ringyō Gijutsu Kyōkai-hen, *Ringyō gijutsu-shi*, 5: 29–33. See also Sanrinkyoku, "Mokuzai no kōgei-teki riyō," 1243–44 and Mertz, *Wood*, 13.

³⁴ Buna's physical characteristics are described in Sanrinkyoku, "Mokuzai no kōgei-teki riyō," 1243–44. We offer this source rather than other sources, including current ones, as it describes the characteristics recognized by period researchers.

³⁵ Taniguchi, *Bunazai ni kansuru chōsa*, 4–5. See also Okaura and Harada, "Phylogeographical Structure."

³⁶ A useful description of the physiological and behavioural characteristics of European beech is given in Barański et al., "High Temperature Drying Process."

³⁷ Sanrinkyoku, "Mokuzai no kōgei-teki riyō," 1246.

³⁸ Ibid.

³⁹ Sawmill and board curing and storage results are reported in Kawamura, "Kajitanisawa Mokkōjo."

⁴⁰ Kawamura, "Kajitanisawa Mokkōjo." 194.

⁴¹ Buna rift-sawn steamed veneers were highly stable between 15 and 144 days after sawing and steaming with a much smaller variance in further moisture loss than any other woods tested. This pointed to the effectiveness of steaming buna before drying it, to reduce the fibre/material movement that came from moisture loss, and thus reduced cracking and warping as the wood dried out, for both sapwood-only and mixed (sapwood, false heartwood and heartwood) boards. See Kawamura, "Kajitanisawa Mokkōjo," 155, table 4.

⁴² The fabrication results are presented in tabular form and discussed in Sato and Matsuo, “Kagu.”

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