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"Mountains of the State:
Precious Metal Production in Tokugawa Japan"

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Mountains of the State:

Precious Metal Production in Tokugawa Japan

Geert Schreurs[1]

Abstract:

This study ties together a number of aspects influencing the production of precious metals in Tokugawa Japan (1600-1867), including international trade, technology and institutional arrangements. The main goal is to provide comprehensive estimates of the production silver, copper, and gold, as well as the economic relevance of this production. These estimates are arrived at by combining existing data and interpolating missing data under specific assumptions. Supply side and use side data are confronted to check consistency. The results show pronounced peaks in the production of silver circa 1630, and copper around 1700. Silver output comprised around 3% of GDP at its peak, which was unsurpassed by other mining sectors during the Tokugawa or even the Meiji period.

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During the writing of this paper I have benefited greatly from discussion with and tips from Fukao Kyoji, Moriguchi Chiaki, Saito Osamu and Takashima Masanori.

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Note: In this document numbers are represented using spaces as thousand separator and comma as decimal mark.

1. Introduction

Precious metals by their nature have historically played an important part in facilitating trade. Silver in particular has been described as the commodity to first connect trade from all continents. After the Spanish gained access to the mineral wealth of the Americas, a world wide system of trade emerged, with silver flowing across both the Atlantic and the Pacific to Europe and Asia. (Flynn & Giráldez, 1995) Japan played an important part in this system as the largest silver producer outside the Spanish Empire around the year 1600, and a leading copper producer after that. This position attracted significant attention from European trade powers as well as Chinese merchants. The domestic production of precious metals and the management of these outside contacts became crucial elements of Tokugawa (1603-1867) government policy.

A famous policy decision taken by the in the 1630s is the so-called 'closed country' policy, or *sakoku*. In truth the country was not completely closed, with foreign trade still playing an important part in the Japanese economy. Through a variety of intermediaries Japanese international trade continued throughout the Tokugawa period and maintained a large impact on both the world and the domestic economy.

Through the sale of silver, copper and gold on the world market, the Japanese mining industry had a profound impact on matters as diverse as the Chinese money supply and the profits of the Dutch East India Company (Vereenigde Oost-Indische Compagnie, VOC). It also put its mark on the home market, where precious metal exports facilitated imports of raw silk for the silk industry and mining revenues boosted government income.

The significance of Japanese precious metal production and export during the Edo era has not escaped scholarly attention. The mining sector has been studied mostly by Japanese researchers. Kobata Atsushi (1956, 1968, 1986) has dedicated decades of research to the production of the mining industry and the effects on foreign trade and Japan's currency. Iwao Seiichi (1966) has described the international trade in Japanese precious metals. Yamamura Kozo and Kamiki Tetsuo (Yamamura & Kamiki, 1983) have also written about the effects of mining and trade on the monetary situation in Japan. Sasaki Jun'nosuke (1983a, 1983b) meanwhile has focussed more on the technical aspects that made it possible to extract these amounts of metal.

The international trade of Japanese metals has gotten the most broad attention. Ralph Innes (1980) has written a very extensive account of Japan's international trade during the 17th century, while also

dedicating a large part of his 600 page dissertation to the mining sector. As the final destination of most exported Japanese precious metals at that time, the connection with China has been described, among others, by Richard Von Glahn (1996), George Bryan Souza (2004) and Yamamura & Kamiki (1983). Tashiro Kazui (1981, 1989, 2004) has focussed on the trade flows through Tsushima, via Korea, to China. Another intermediary was the Dutch VOC, whose trade flows are the best documented, thanks to detailed contemporaneous bookkeeping and current archive work. The trade in Japanese metals by the VOC has been described by Kristof Glamann (1953, 1981) and more recently by Shimada Ryuto (2006).

The different viewpoints from which this subject has been approached, has led to wide-ranging estimates of the Tokugawa period production and trade of precious metals, particularly for silver. Based on export figures, Iwao and Yamamura & Kamiki come to relatively high estimates of traded silver quantities. Meanwhile, according to Innes, Von Glahn and Souza, amounts were much smaller. Estimates based on silver production figures are much rarer. However, Kobata has made a rough estimate that is consistent with the higher export estimates.

The main objective of this paper is to improve estimates of the production and trade volumes of precious metals[2] in Tokugawa period Japan. The approach will be to confront the supply and demand sides for each respective commodity. Where possible data for production, imports, exports and domestic use have been compared to arrive at consistent estimates. A comprehensive evaluation of this type of data is currently lacking, both regarding the entire length of the Tokugawa period, as well as regarding the inclusion of all three metals. Special attention has been paid to the silver volumes, given the importance in trade history and the disagreement between existing estimates. A new approach has been used to interpolate production data for the largest silver mines to check against the demand side data. The improved estimates of all three metals are subsequently set off against international production estimates as well as against the latest estimates of Tokugawa period GDP. The latter is partly intended to assist efforts to improve GDP statistics for this period.

The institutional and technological setting will be the subject of chapter 2, while chapter 3 will cover the development of foreign trade. Chapters 4, 5 and 6 form the central part of this paper, describing respectively the silver, copper and gold estimates by the combination of supply and demand data. Chapter 7 looks at the significance of the precious metals production, both as a share of the domestic economy and in international comparison. Chapter 8 concludes.

2 In this context 'precious metals' includes copper as well as silver and gold. In current parlance the term usually does not include copper, however given the contemporaneous value of copper in the export trade – not to mention its use as coinage metal – it can justifiably be included when used regarding Tokugawa period Japan.

2. Institutions and technologies

The Japanese precious metals mining sector operated under specific institutional and technological circumstances that partly explain the growth pattern that will be shown in later chapters. More than that, the information given here can be used to inform certain assumptions necessary for some of the estimates, as will be explained later.

2.1. The beginnings of Japanese mining

Mining has been practised in Japan from at least the 7th century. A silver mine was in operation from 675 C.E. on the island of Tsushima, halfway between Korea and Kyushu, the southernmost of the main islands of Japan. In 701 the government sent an official to the province of Mutsu in in the north-eastern part of Japan's main island of Honshū with the objective of opening a gold mine. (Yamamura & Kamiki, 1983, pp. 331–332) This same mine is credited to be the source of the original gilding of the Tōdaiji Daibutsu in Nara, which was finished in 749 C.E. (Bender, 1979, p. 134) Copper has been mined from about the same period. The mine at Akenobe, in Tajima province on the Sea of Japan, was established before the 8th century. (Sasaki, 1983b, p. 181) Little is known about the volumes of production of these metals during this early period. However, the production of gold was sufficient to establish exports to China. In return Chinese minted copper coins were imported, starting from the Sung (960-1126) dynasty. This trade seems to have stemmed from a Japanese demand for means of exchange. The increasing export of copper coins in the 12th and 13th centuries prompted a ban on this trade by the Chinese government. (Yamamura & Kamiki, 1983, pp. 336–339)

There is not much evidence of big changes to the volume or technology of the production of precious metals in Japan in the following few hundred years. However, two mines were opened that would later become major centres of metal production. The gold mine on the island of Sado, off the west coast of northern Honshu, was opened during the Bun'ei era (1264-1274). Another was the silver mine at Ōmori, in the Iwami province of western Honshu, which was opened during the Enkyō era (1308-1310). (Sasaki, 1983b, pp. 179–181)

2.2. The Institutional setting of the early modern mining industry

Through a process of technological development that started during the second half of the *sengoku* or Warring States period (1467-1568) production of especially silver mines increased strongly. This meant that they were becoming increasingly important strategical assets for the competing warlords. They strived to open up new mines in their own territories or tried to gain control over existing ones in order to pay for their armies. A trend of centralisation is visible in the governance of the mines. During the sengoku period most mines were claimed by *daimyō*, local warlords. The three unifiers Oda Nobunaga, Toyotomi Hideyoshi and Tokugawa Ieyasu all sought possession of the important mining regions (Naohiro, 1991, pp. 61–64) Hideyoshi took a large step to gain control over the important mines, declaring them “mountains of the state” in 1589-90. (Sasaki, 1980, p. 7) This policy was continued when Tokugawa Ieyasu established his dynasty. Although of strategic importance, to what extent the increasing output of precious metals has contributed to the unification of Japan is uncertain. While Nobunaga's initial base of power in Owari and surrounding lands did not contain any of the major mines, he did succeed in gaining control over the important silver mine at Ikuno in Tajima, which would have increased his power. Once the Tokugawa shogunate was established, the centralisation of profitable mines into its hands increased its fiscal potential which might have increased the shogunate's grasp on power.

There was no unified strategy on the side of the *bakufu* (shogunate) to organise the ownership and administration of the mines. The ownership of a mine could be in the hands of either the central government or the *han* government i.e. the local daimyō. (Sasaki, 1980, p. 8) Daimyō were expected to pay royalties to the bakufu based on their mines' output. After the death of Ieyasu in 1616 the offered mining royalties were always returned by the bakufu. This suggests the later *shogun* might have put more importance on non-financial concerns compared with Ieyasu. The fact that the offering of the royalties nonetheless continued could be interpreted as an affirmation of the principle that the bakufu had a right to claim part of the revenue of all mines.

The bakufu at different times exercised its right to take control of a mine. A number of mines were confiscated from the losing side's daimyō after Ieyasu's victory at Sekigahara. Loyal daimyō could also have their mine taken over by the bakufu, like the Nobezawa silver mine in Dewa province in 1634. In that case the confiscation was motivation by a rapid increase in output from the mine. Another example is the dispossession in 1704 of the Iyo Tachikawa copper mine from the daimyō of Saijō to add it to the adjacent bakufu-held Besshi copper mine. (Innes, 1980, pp. 545–6)

The mines owned by either level of government were either managed by officials, titled *bugyō*, or the management was outsourced under contract to a mining operator. The last situation was more

common for smaller mines. This was not exclusively restricted to small mines though, as in the case of a dominant copper mine of the period, at Besshi. This mine was located in bakufu territory, but was operated by the Sumitomo family and a big source of their wealth. The bugyō in charge of government mines, would subcontract the work to miners who would either pay the government official a fixed fee for a concession, or make an output sharing agreement. For big, profitable mines these concessions could be very limited in time and scope. In the case of the rich Innai silver mine, shortly after its opening in 1603 there were 36 different contractors operating simultaneously, some under concessions as short as 10 days. (Innes, 1980, pp. 546–547)

It can not be a surprise that this would lead to rather suboptimal situations. Contractors will not plan ahead or invest in the mine under such short concessions, instead opting for quick wins and haphazard excavation. This opportunistic behaviour resulted in very sharp boom and bust cycles.

There seems to have been a move away from these types of concessions to more long-term contracts, with more production sharing agreements instead of fixed fees. Perhaps as a sign of a more short-term view, the shortest concessions were given out by daimyō. Long term planning and investment by the owner became more important as mines got older and less rich in ore, necessitating deeper mines. This situation also put pressure on the mining profits, leading to falling government shares of the output. In bakufu controlled gold and silver mines the government share of gross output was in the range of 25% to 50%. The higher government shares would most likely only apply during the earliest, most profitable years of operation of a mine. When the mine output levels declined the operation would no longer be able to afford such high royalty payments. (Innes, 1980, pp. 546–558)

The circumstances for copper mining operators were different from those in the gold and silver sectors. Instead of relying on royalty payments the government mandated that all the copper was to be delivered to the central authorities. It set production targets for each mine and determined a price. The copper was smelted on site and delivered to refineries in Ōsaka, where it was cast in one of several predetermined shapes. As a way to control the export, only copper in the shape of a bar was allowed to be exported.[3]

While the government had price control over copper at every stage from production to sale, the pricing strategy was somewhat curious. The offered price to the mines was below domestic market rates, as would be expected. The difference between the offered rate for producers and the domestic market rate can be regarded as a government tax. Part of this must have been used to cover the transport and refining costs. However, the rates at which copper was sold to Chinese exporters were lower than the rates offered to the mines, and the rates for Dutch exporters were lower still. This

3 The Japanese term is *saodō*, while in the documents of the Dutch VOC it is referred to as *staafkoper*.

would make export a losing proposition for the government, an unlikely situation to persist. Part of the explanation is that the government not only set copper prices for export, but also negotiated what it got in return as imports as part of a zero-sum game. In essence it was therefore a virtual price, as in the end the copper was traded for other goods which were valued at the same total price as the copper. The reason for the low prices was that the export of copper was restricted to a certain maximum value in silver. At a lower price the export (and import) volumes were larger, benefiting both officials and traders at Nagasaki. (Shimada, 2006, pp. 51–59)

Besides royalties, han could profit in other ways from the mines on their land. They could tax the businesses that provided services in the mining towns, levy import duties on goods transported into the mining areas and reserve the right to sell rice and other goods to the mining operators. Akita han sold rice and lead to the Innai silver mine under monopoly conditions. The rice was often excess tax rice that would otherwise have had to be traded elsewhere. The lead was purchased at local lead mines and resold to the silver mine with a mark-up from 25% to as much as 200%, depending on economic situations at Innai. Of all non-royalty revenue from the mine during 9 months of 1620, rice sales represented 45% and lead sales 41%. Total payments from Innai mine to the han, including royalties and other taxes, has been estimated at 2/3 of the value of total mine production (Innes, 1980, pp. 549, 550)

The enforcement of royalty payments and monopolies on intermediate goods obviously relied on control of flows of goods into and out of the mining area. Another reason to guard the roads to these areas was to keep the local labour market under control and prevent disruption of the local agriculture economy. Newly opened and fast-growing mines attracted specialised mining labourers from wide areas. Much of the unskilled labour was provided by the local population, however. There are numerous examples of daimyō issuing bans on farmers moving to mining towns. Farmers abandoning their field would be detrimental to the main source of government revenue, the tax on agricultural production. Therefore, there was a strong motivation to keep the farmers on their fields. (Innes, 1980, pp. 563–566)

During the late Tokugawa years the output of metal mines had decreased, and after the Meiji Restoration in 1868 the government had to decide what to do with existing as well as potential new mines. Given a situation of little private capital, the government at first tried to operate a number of mines itself, bringing in foreign experts to help modernise the sector. Silver and gold were of particular interest to the government for their use as coin material. A majority of foreign engineers, however, was employed for coal mining, a relatively unknown activity in Tokugawa Japan. The government gradually sold its mines to private companies as capital became more readily available. The last government mines were sold to the Mitsubishi company in 1896. (Yoshiki, 1980)

2.3. Technological development of the mining industry

2.3.1. Smelting and refining

From the middle of the sengoku period new technology was introduced to Japan that transformed the mining industry. In 1533 a merchant from Hakata (present day Fukuoka), who had recently reopened the Ōmori mine in Iwami, brought in two Korean mining experts. They introduced the *haifuki* or cupellation method by which silver (as well as gold) can be separated from other metals with which it is often mixed, such as lead. (Innes, 1980, pp. 23–25) This step is performed after the smelting stage, in which the metal alloy (silver-bearing lead) is separated from the ore. In the cupellation method the lead is melted in a bone ash 'cupel' and then air is blown across it, causing the lead to react with the ash, leaving the silver. Because of this, the method is sometimes referred to as 'ash-blowing'.

The cupellation method has been known in the Mediterranean and the Middle East regions since the bronze age, but finally reached Japan probably through China and Korea. Its first use in China is unknown. The process was described in a 15th century Chinese work by Lu Yung called "Shu-yuan Tsa-chi". (Innes, 1980, pp. 23–25)With the long history of the cupellation method further west, it is not unlikely that the Chinese knew it well before that. The following translated quotation, through a tenuous string of references, is accredited to an alchemical text called Jinbi Jing, 金碧經 (Scripture of Gold and Jasper) from around the year 200 CE (Sivin, 1976, pp. 513–514):

> *Refine silver within lead*
> *And the spiritual being is born of itself.*
> *In the ash reservoir, melting in the flame,*
> *Lead sinks down, silver floats up.*
> *Pristine white the Treasure appears*
> *With which to make the Golden Sprout.*

While the significance is hard to judge given its origin, the quote fits the cupellation technique remarkably well. It is unknown when the cupellation method transferred to Korea, although silver was reportedly extracted from lead there since at least 1528. (Innes, 1980, pp. 23–25) Around the same time that cupellation found its way to Japan domestic development led to the discovery of the *mabuki* method. The method is applied during the smelting stage, before cupellation would be applied. It is meant to rid the copper ore of excess sulphur by oxidising it with blasts of air in a furnace. The old process achieved the same result by roasting the ore for a number of weeks. The new technique represented large savings in the time, manpower and fuel needed for this step. The mabuki method was developed in the village of Yamashita, in Settsu province near Ōsaka. Because of this it is sometimes referred to as the Yamashita method. (Innes, 1980, pp. 537–

538) Another refining improvement was the *nanban-fuki*[4] technique taught to Soga Riemon by the Spanish or Portuguese during the Keichō era (1596-1615). Soga was the owner of a Kyoto copper smelting company and brother-in-law to Sumitomo Masamoto, founder of the Sumitomo company.[5] The nanban-fuki technique for refining copper that Soga learned, consists of adding lead to impure, silver-bearing copper. This alloy is then heated and mixed until the lead and silver melt, leaving pure copper. The cupellation method can then be used to separate the lead from the silver. Soga used this new process to establish a copper refining business. (Innes, 1980, p. 84)

During the 16th century the Spanish were operating the largest silver production system in the world in their possessions in the Americas. There they discovered the amalgamation process for isolating silver from lead in 1557. Although the amalgamation method is considered to be an advancement over the cupellation method, it was not used extensively in pre-modern Japan because of a shortage of mercury. Domestic production of mercury was small and although it could be imported, this made it expensive. The only place where it seems to have been used extensively is the island of Sado, where the amalgamation process was applied for a time since 1610. By which way knowledge of the method spread to Sado is unclear. (Innes, 1980, pp. 540–541)

A final refining method worth mentioning is the chlorination process, also called the salt roasting process. In this method gold was isolated from gold-bearing silver in a process similar to the cupellation method, but using ordinary salt instead of ash. When and how the chlorination process appeared in Japan is not completely certain. Innes (1980, p. 539) supposes it was introduced from China some time before being used on Sado in 1643. Sasaki (1980, p. 10) adds that the method was devised around 1608 by gold- and silversmiths in the employ of the government. With this last piece of knowledge Japanese smelters could separate lead, copper, silver and gold from any mix they might encounter in ores.

2.3.2. Mining techniques

Because of improvements in refining, ore with increasingly small amounts of metal could be profitably mined. This prolonged the economic lifespan of mines where the metal-rich ore was depleted. This also meant mines were going deeper and deeper to get out all the ore that they could.

Around the same time that refining technology was advancing, surveying and excavating techniques saw big improvements. Through the improvement of metalworking, bigger hammers and harder chisels became available, improving the efficiency of miners.(Nagahara & Yamamura, 1988, p. 80)

4 *Nanban* means 'southern barbarian', a contemporary term for the Portuguese and Spanish. The stem of *fuki* (吹) means 'to blow'.

5 Soga's son Tomomochi married into the Sumitomo family, uniting the business ventures of the two families.

However, there seems to have been a strong preference for manual labour. As late as 1907 mechanical mining (use of rock drills and similar) was virtually non-existent in Japan. In that year at 35 major mines 98% of mining output was achieved with hammer and chisel. (Sasaki, 1980, p. 14)

Surveying was a skill developed by Japanese miners starting toward the end of the 15th century. The term used for this method was *sunpō-kiri. Sunpō* refers to taking measurements and *kiri* means to cut. It involved not only establishing the run of the ore vein, but also planning the required tunnel so it would optimise the removal of water and circulation of air. If necessary, supporting tunnels called adits were constructed for drainage and ventilation. Previously miners would only dig surface trenches, or simply follow the vein into the mountain without regard for flows of water and air or overall efficiency. (Nagahara & Yamamura, 1988, pp. 79–80) Innes credits the Spanish or Portuguese for the innovation of horizontal adits to assist with drainage.(1980, p. 534)

The importance of optimal drainage and ventilation must not be underestimated. Miners typically succumbed to respiratory illnesses after 4 or 5 years underground due to the use oil fired lamps and charcoal fires to fracture rocks. As F.G. Notehelfer put it: “The life of the Tokugawa miner was harsh and brief” (1984, p. 14) Techniques for drainage and ventilation were relatively primitive. The latter was attempted by fans and partitions to direct airflows. Water was removed from the lower levels of the mine by manpower. Various tools were used including buckets and manual piston pumps. Archimedes' screws were first used on Sado in 1637. The spread of this technique seems to have been hampered by the amount of maintenance required and by the fact that the scholar who introduced it demanded royalty payments. If necessary, a number of pumps or screws would be set up in a relay. The Sado gold mine used efficient double-action Dutch pumps for a short while from 1782, but reverted back to older methods because of the maintenance requirements. (Nagase-Reimer, 2013, pp. 32–36) The Dutch again attempted to import a pump in 1825. However, the Japanese concluded that such a machine was not as effective as intensive use of human labour. (Shimada, 2006, p. 52)

With few straight vertical or horizontal tunnels there was little opportunity to use transport equipment to move ore to the entrance of the mine. Ore had to be removed manually, on the miners' backs. Add to that to the labour-intensive methods for drainage, and a mine will need increasingly more people to operate as the tunnels go deeper. Employment statistics on the Besshi copper mine, opened by the Sumitomo family in 1691, show this problem quite clearly. In 1713 there were 750 labourers working underground, consisting of miner/carriers, drainage workers and tunnel constructors. In 1769 the total number had risen to 1075. Most of this growth was caused by extra drainage workers, which increased from 250 to 455. Because of a simultaneous decrease of total

copper output of the mine, production per worker decreased during these years, from 107,1 tonnes of ore to 50,4. During the peak of the mine's output, which took place before 1713, productivity might have been even higher. (Shimada, 2006, p. 56)

2.3.3. Productivity and mechanisation

Japanese efforts to increase labour productivity typically involved more effective use of manpower instead of mechanisation. Particularly in the mines only manual power was used. In contrast, European and American mining used animal, water and later steam power to do the heavy lifting. The Spanish mine at Potosí in South America used tens of thousands of mules and llamas for their labour. (Moore, 2010) In the 18th century, English mines pioneered the use of steam power for drainage. The great Swedish copper mine at Falun in the 17th century used both animal and hydro power. Ulf Sundberg (1991) has analysed the energy flows of this last mine, which can be used to get a sense of the potential for the use of non-human power sources in a pre-industrial mining environment.

At the Falun mine manual and horse-powered winches were used to drain water from the shafts, until floodings occurred in the 1550's and hydro power was added. Once the hydro power system was in place, the hydro power was used for lifting out water and ore from the mine as well as powering the bellows of nearby foundries. According to Sundberg (1991, pp. 11–12) of the energy required to excavate and haul up the ore and pump up water, about 180 MWh per year was provided by men and 200 MWh per year was provided by horses. In addition, the watermills could provide a maximum of 460 MWh per year, from which an unknown part was used at the foundries. Supposing that half of this hydro power was used at the mine, this would mean that only around 30% of the power used at the mine was provided by men. Even centuries later, most Japanese mines by contrast were still run on 100% manual power. The Aikawa mine on Sado island seems to have been an exception. A water wheel was intermittently used there to crush ore starting in 1626, being reintroduced in 1794 and used more intensively from the 1820s. (Sasaki, 1980, p. 17)

Given the different energy applications you would expect the Swedish miner to outperform the Japanese miner in terms of productivity. At Falun in the mid-17th century it took about 1050 men and 200 horses to produce around 1900 tonnes of copper per year (excluding transportation and refining of ore outside of the mine). (Sundberg, 1991, pp. 5, 11, 12) The productivity was therefore about 1,81 tonnes of copper per miner per year. In the large Besshi copper mine output per worker

was 1,10 tonnes in 1713 and 0,43 tonnes in 1769.[6] Clearly the Falun miners were able to extract more copper. However, direct comparisons are not very revealing, since geology and other circumstances vary greatly from mine to mine. Although this might not say all that much about the relative effectiveness of the miners, it *does* show how the productivity at Besshi would change if for example drainage was done by some other, non-manual source of power. When drainage workers are excluded, productivity at Besshi increases to 1,64 tonnes per worker in 1713 and 0,74 tonnes in 1769. Additional gains could have been made by substituting part of the human labour used for hauling up the ore and other tasks. Clearly Japanese mines could have benefited from alternative power sources. So why were they not used?

The techniques used in the West were not unknown in Japan. As mentioned, at Sado a water wheel was used to crush ore and efficient Dutch pumps were known and even recommended by the bakufu. Neither of these tools were widely used by the mining sector, reportedly because of maintenance requirements. (Nagase-Reimer, 2013, pp. 37–38)

Other clues can be taken from the people that first tried to implement Western mining techniques in Japan. Contemporary Dutch observer and scientist H. Burger paints a picture of a mining sector relying not so much on science as on experience. In his opinion the methods used were relatively effective where it came to prospecting, smelting, refining and metalworking, but the geological knowledge and the mechanical process used in the mining itself he regarded as very primitive. (Burger, 1836)

When foreign engineers were hired to modernize the industry after the opening up of the country they analysed the shortcomings of the existing system. The single biggest obstacle they identified was the subcontracting system inherited from the Tokugawa period. The government and later the mining companies purchased the ore from subcontractors. The subcontractors could make their own decisions about where and how to excavate. This led to the situation of large numbers of haphazard tunnels, abandoned because of hard rock layers or flooding. In addition, the subcontractors discarded large quantities of low-grade ore, which was refinable with the proper techniques. To successfully modernise the industry the mining operation had to be centralised, with the mining company directing the labour and installing the machinery. (Yoshiki, 1980, pp. 18–22)

Moreover, the circumstances at the mining sites determines the successful use of machines. Hydro power has obvious situational requirements, but the narrow and irregular shape of the tunnels meant

6 Number of workers from (Shimada, 2006, p. 56), copper output from (Sumitomo Metal Mining Co., 1991, pp. 225–229)

that any type of non-manual power was very costly to implement as it would have required a completely different layout of the underground portion of the mine.

Another circumstance undermining the mechanisation of the mining sector was the low cost of labour. An interesting anecdote is provided by J.H. Gubbins, who in the early 1870s visited the Aikawa mining town on Sado island. He describes it as a poor town where labour is "absurdly cheap". Three years before his visit, a tramway was built to transport ore from the mine to the town but the service had discontinued. As he put it:

> *"Owing to the carelessness and ignorance of those in charge of the tramways, accidents were of constant occurrence, and moreover, labour being so cheap, it was found to be just as economical to employ manual labour".* (1884, p. 87)

In addition, the transport of ore was an important occupation for the local women, making the tramway unpopular.[7]

In the 1870's the Japanese government employed the American geologist Benjamin Smith Lyman to perform a geological survey of Japan, focussing on oil and mineral deposits. Lyman noted the opportunities and difficulties of introducing labour-saving technologies:

> *"It seems pretty certain that, in many cases at least, there would be decided economy in making use of horse power (with a gin) or water power in digging the oil wells; since so large a portion of the power required is applied in so purely mechanical a way. Nevertheless the cost of the capital needed and the expense of repairs to machinery make it advisable to begin experiments in that direction rather cautiously. I am more than ever of the opinion that the setting up of steam engines and boring machines would be unprofitable; for the experiment has had now for a year or more a long trial in Kubikigōri in Echigo… Although the well proved to be in an exceptionally favorable place, the progress of the work was slow and expensive on the whole, and pieces of the apparatus had to be sent for repairs to this city, some two hundred miles."* (Lyman, 1879, p. 13)

The limited availability and know-how of the more advanced machinery – even in the years after the opening of the country – illustrate the technological disadvantage suffered from the isolation policy. It is interesting, however, that the report also mentions the underutilisation of more traditional labour-saving techniques that should have been well inside the technical capabilities of the contemporary Japanese craftsmen. Lyman noted that the cost of a horse and driver were only about double that of one worker, and still costs remained prohibitive in many situation. In addition,

7 The mine was operating at a loss. This was partly due to the increasing problem of drainage, which had caused the miners to abandon parts of the mine and made the remaining tunnels more and more difficult to work in without modern equipment. Moreover the organisational overhead seems to have been very large due to nepotism.

power from small water mills was used in villages to pound and clean rice, but larger applications were uncommon. Lyman supposed this was because of unfamiliarity with the building of large dams and gathering larger sums of capital.(Lyman, 1879, pp. 9–16) These observations suggest that the large scale of mining operations might have been an obstacle for mechanisation.

Besides the low wages there were other factors working to keep the number of employed miners high. According to Nagase-Reimer Keiko, labour intensive mining was lucrative for mining operators because they could make profits on the sale of rice to their employees, in effect lowering the real wage even more. The mining operators bought rice from government tax rice surpluses at a preferential rate. They sold this rice on to their miners at a higher price. The miners were trapped in this system, because they were not allowed to freely move out of the mining district. (Nagase-Reimer, 2013, pp. 37–38)

The above descriptions show that the precious metal mining sector, and in a certain sense the Tokugawa economy as a whole, was faced with challenging institutional and technological circumstances. Management of the mines was at times inconsistent and fragmented, and many technologies were not used to their full potential. It is perhaps too easy, though, to evaluate this situation merely through the lens of efficiency or profit maximisation. In Burger's opinion (1836, p. 5) the most important role of late Tokugawa Japanese copper mining was in providing employment, both directly and indirectly. Besides that he mentions as an important factor the role copper played as an international trade good. This dimension will be explored next.

3. International trade in metals

During the Tokugawa period international trade and the mining sector were deeply intertwined. Not only did several technological advancements result from international contact, the availability of silver and copper were a clear incentive for European, Chinese and other trading partners to seek contact with Japan. Additionally, international trade kept large production volumes from overwhelming the local market and lowering the price dramatically. For the Tokugawa regime the interaction between trade and the mining sector was an active area of regulation, motivated by politics, the money supply and financial gain.

3.1. Pre-Tokugawa foreign trade

Although the regulations limiting seafaring during the Tokugawa period are better known, they were not the first instance of such rules. When Hideyoshi forbade farmers from owning swords in his 'sword hunt' edict of 1588, he also issued an edict prohibiting fishermen from taking part in piracy. The year before he had pacified Kyūshū, the home base for many *wakō* pirates that harassed particularly the Chinese coast and disrupted trade relations between Japan and China. With Kyūshū under his control, Hideyoshi had a chance to improve this situation. Hideyoshi took further control of international trade relations in 1592 by establishing a system wherein Japanese traders were permitted to perform international trading missions under licenses called *shuinjō* or 'red seals'. He seems to have been motivated by the desire for war material, as vital materials such as gunpowder had to be brought from abroad. For Japanese traders the trading permissions were a chance to exchange some of the abundant silver for Chinese manufactures, particularly silk. (Von Glahn, 1996, pp. 119–120) Hideyoshi bought up both the military products and the consumer goods from overseas, to his strategic and commercial advantage. (Naohiro, 1991, p. 63)

3.2. Trading partners during the Tokugawa period

When Tokugawa Ieyasu took to power he consolidated Hideyoshi's system, issuing shuinjō, trading on his private account and controlling the parties Japan did business with. The trading partners that called at Japan's ports during Ieyasu's time consisted of the Chinese, Dutch, Portuguese, Spanish and English. In addition to the shuinjō trade, Japanese trading missions were conducted by the Sō

clan of Tsushima who acted as an intermediary to Korea and the Shimazu clan of Satsuma who filled a similar role regarding Ryūkyū. Lastly there were small-scale trading contacts with the Ainu of Hokkaido (then known as Ezo). (Tashiro, 2004, p. 105)

Despite the many different trade partners, the ultimate source and destination for the large majority of trade was China. For long stretches of time direct trade between Japan and China was not permitted by either one or both countries' government. Because of this circumstance, several actors functioned as intermediaries between the two countries. It had been the main reason for the profitable trade of the Portuguese between Macao and Nagasaki. The shuinjō traders travelled mostly to South-East Asia, but there often met with Chinese traders. The same is true for the Dutch, after they lost their trading post on the island of Formosa (Taiwan). The Chinese that were allowed entry to Japanese harbours did so without the permission of their own government. Korea and Ryūkyū also acted as intermediaries, being traditional tributary states to China. (Innes, 1980, pp. 54, 65)

The shuinjō system was abolished in 1635, when the owning of ocean-going vessels and foreign travel were banned for Japanese nationals by the third shogun Tokugawa Iemitsu. The trade with Korea and Satsuma continued however. In 1639 all foreigners were expelled from the country except the Chinese and Dutch. The apparent motivation for the 'closed country' policy or sakoku was to counter the influence of Christianity in Japan, which had the potential of undermining the shogun's power. The edicts severely restricted the number contacts with the world outside Japan. It also had the result of centralising control over foreign trade even more into the hands of the bakufu, at the expense of daimyō and merchants. The effects on the overall size of foreign trade might not necessarily have been very large however. According to Innes (1980, p. 149) the gaps left by the expelled trading groups were filled by the Chinese and Dutch traders.

Table 1 shows the Japanese foreign trade values by the various carriers. In the early Tokugawa period the Portuguese and shuinjō ships handled most of the trade, although the value of Chinese trade was likely significantly higher than indicated here (see also Table 2 in paragraph 4.2.1 for the volume of traded silver). After 1635 the amount of trade handled by the Chinese and Dutch increased significantly, first taking advantage of the end of the shuinjō system, and after 1639 enjoying exclusive trading rights. During the 17th century a number of additional trade restrictions were put in place specifically targeting the trade in metals. Between 1637 and 1646 restrictions were put on the export of copper, as the bakufu needed the copper for reminting copper coins. (Shimada, 2006, p. 12)

The dwindling silver deposits caused increasingly tight regulation of the trade of silver. In an attempt to lure the Dutch and Chinese away from silver they were authorised to export gold coins in

1664. Because of a high mark-up however, the exchange rates were very unfavourable. This mark-up – *aigin* – went to the people of Nagasaki. From 1668 the export of monetary silver was abolished, although trade in silver utensils was still allowed. At the same time the aigin was abolished as well, causing the export of gold to soar. Meanwhile the bakufu tried to depress demand for imported items – which were usually luxury goods – through sumptuary laws. The sumptuary law of 1668 stands out for the targeting of imported goods. From 1672 the Chinese were again permitted to export silver, but the Dutch were still restricted to gold, with a reinstated aigin going to the bakufu. Around the same time Nagasaki merchants organised themselves to create a monopsony on imports, lowering the offered rates and decreasing profitability for the foreign traders.(Innes, 1980, pp. 302–307)

Table 1: Yearly average value of Japanese foreign trade by carrier, in tonnes of coin silver equivalent

Carrier	1604-1638	1639-1684	1685-1715
Chinese	1,4+	47,4	27,7
Dutch	7,9+	28,5	13,9
Tsushima	?	0,2+	9,4
Ryūkyū	0,7+	0,4+	5,0
Smugglers	?	?	14,0+
Portuguese	22,7	0	0
Shuinjō	28,5	0	0
English/Spanish	0,3+	0	0
Total yearly trade value	61,5+	76,5+	70,0+

Source: (Innes, 1980, pp. 379, 380, 408, 410, 416, 417)

Note: The source material is not complete for all carriers and periods. The actual amounts would likely be higher. Figures for which a significant number of years is missing are indicated by (+)

In 1685 limits were set on the value of imports. The Chinese were restricted to a value equal to 6000 kanme (22.500 kilograms) of silver. The Dutch could import goods worth 3400 kanme (12.750 kilograms) of silver, of which 400 kanme was reserved for private trade. According to Innes (1980, pp. 418–422) enforcement of the trade restrictions was relatively lax. Year after year Chinese ships would enter the harbour of Nagasaki with total merchandise exceeding 6000 kanme. Moreover, a substantial number of ships were turned away from Nagasaki, because of additional limits on the number of Chinese ships allowed in the harbour every year. These ships would have had to find another place on the coast of Japan to sell their cargo clandestinely. Innes reasons that unless the merchandise could be traded profitably, the Chinese captains would not return every year.

Therefore, the trade amount listed for smugglers during 1685-1715 in Table 1 consists of the goods on board Chinese ships that were turned away and goods that were officially unsold at Chinese ships in Nagasaki harbour. During the years up to 1700, the last year for which this kind of information is available, clandestine trade was regularly the largest single trade category. From 1695 on, barter trading of copper was allowed on top of the official quota. This possibly decreased the amount of smuggling, although the limit on the number of ships remained in place. However, in earlier years the ships being turned away had been the smaller part of the irregular activities. Within two decades however, the additional barter trade amount diminished from over 3000 tonnes of copper to under 100 tonnes. (Gramlich-Oka, 2008, pp. 78–80)

In 1715 new, lower quotas were set on the number of Chinese and Dutch ships permitted into Nagasaki, as well as the volume of metal to be exported. In the following years these quotas were at times amended, but the supply of copper was such that in many years these quotas were not met. (Gramlich-Oka, 2008, pp. 93–97)

3.3. Japan's import and export goods

Although detailed accounts of the goods carried to Japan are very fragmented, by all available accounts silk made up the bulk of the trade from before the start of the Tokugawa period, and it mostly originated in China. Initially the Portuguese were ideally situated to supply silk from Macao to Nagasaki. A Dutch observer in Macao wrote “the commodity taken from Macao to Japan is silk, while only silver is brought from Japan”. (Von Glahn, 1996, p. 126) In the early 17th century the Portuguese routinely carried over 1000 piculs – 60 000 kilograms – of raw silk per ship, representing about 75% of the value of the cargo. As part of the trade regulations, imports through Nagasaki were prescribed to be 1/3 silk yarn, 1/3 silk cloth and the rest medicine and miscellaneous items. Although it is uncertain precisely when this rule was first applied, for the Dutch it was in effect by 1689. As for the trade through Tsushima, in 1694 nearly 60% of the imports from Korea was silk. (Innes, 1980, pp. 197, 198, 322, 323, 382)

The main export goods were the metals discussed so far: silver, gold and copper. Since the Kamakura period (1185-1333) Japan had been importing Chinese copper coins for the domestic money supply in return for Japanese gold. By the second half of the 16th century the trade of Japanese silver for Chinese silk seems to have been established. Around this time silver began transforming and integrating trade on a global scale. The Spanish mines in the Americas were

producing unprecedented amounts of silver, an estimated 368 tonnes per year in the first half of the 17th century. Much of this silver flowed naturally to Spain. However, considerable amounts were re-exported to South and East Asia, or shipped there from the Americas across the Pacific Ocean. China in particular imported an estimated 7.300 tonnes of silver between 1550 and 1645, about half of which came from Japan. (Findlay & O'Rourke, 2007, pp. 214–218) The immediate cause of this flow was the higher price of silver in China compared to other locations. In terms of the number of units of silver that could be traded for a unit of gold, during the second half of the 16th century the exchange rate was between 6 and 7 in China, in Japan the ratio rose from 7 to 10 in the same period, and in Europe the ratio was around 12. (Von Glahn, 1996, pp. 127, 128)

The Chinese preference for silver stemmed from several factors. Firstly, since the 11th century the Chinese economy had relied in part on paper money for its money supply. When this system gradually came undone during the 14th and 15th centuries there was a chronic shortage in the supply of money. This shortage was exacerbated by a large and fast-growing economy. The low amount of domestic production of monetary metal was not enough to cope with these trends. Moreover, the Chinese government began to demand tax payments in silver, with a big push towards this goal in the middle of the 16th century. (Flynn & Giraldez, 1994, pp. 71–72)

On the supply side of the silver trade the Japanese mines' production was in decline in the second half of the 17th century. Silver began began to be substituted as the principal export from the 1660s, initially by gold but eventually by copper. Although there was some demand from Europe, most Japanese export copper headed to destinations in Asia. In various countries, including China, small denomination coins were made of copper. Besides the use as currency, copper was manufactured into items as various as Buddha statues, household objects and ship-plating.(Glamann, 1953, p. 104) In the case of copper as well as silver, at certain times the export competed with internal use, especially for the currency supply. A copper shortage in 1700 meant silver needed to be exported. (Innes, 1980, p. 344) By the second half of the 18th century however, tables had turned completely, with copper being used to import silver and gold for the money supply. Between 1766 and 1842 about one quarter of the value of copper exports were used to import these precious metals. (Shimada, 2006, p. 64)

During the waning years of Japanese silver production efforts increased to divert the flow of silver from export to internal use. The high level of silver exports, at a time of decreasing production, was threatening the internal money supply. Besides practical reasons, there were also ideological motivations similar to the bullionism that gained some standing in Europe at the time. In order to prevent the outflow of precious metals, shogunal adviser Arai Hakuseki stressed self-sufficiency in

the production of silk, cotton and other goods. This way the export of metals could be decreased while maintaining employment in the garment sector. (Tatsuya & Bolitho, 1991) In the longer term self-sufficiency efforts did pay off, as Japan was able to supply itself with sufficient amounts of silk by the second half of the 18th century.(Shimada, 2006, p. 60) While silk imports decreased, sugar imports grew to take up its place as the most important import item. Here too though, import substitution took place and by the early 19th century cheap domestic sugar production drove imports from the market. (Shimbo & Hasegawa, 2004, p. 168)

3.4. Late Tokugawa trade

During the 19th century Western powers increased their reach over many parts of the world. The English and French defeated China in the Opium Wars, Russia consolidated its hold over eastern Siberia, and the United States gained access to the Pacific coast. From all these sides there were attempts, to establish trade relations and gain access to the Japanese market. The arrival of Commodore Perry in Edo Bay in 1853 and the concessions he was able to obtain in the following year have been exhaustively written about. On the particular subject of the mining industry there are, however, a few salient points to repeat here.

The US was primarily seeking openings for trade, assistance to shipwrecked sailors and access to coal and other shipping supplies. The availability of coal in Japan was of particular relevance for the establishment of a steamer route between America's West Coast and China.(Beasley, 1989) By the 1850's coal mining had already developed from a sporadic activity performed in primitive pits close to the surface, to a more organised and commercialised pursuit. The progression of the method of extraction was similar to that of metal ores. In some cases miners from the metal sector advised on improvements to the techniques. At the same time the application of coal developed from a household fuel to an input for salt production. Through these changes the national output of coal increased from between 40 000 and 50 000 tonnes at the end of the 18th century, to between 120 000 and 150 000 tonnes by the 1820's. This was further boosted by the arrival of steam technology to Japan. As desired by the US, Japanese coal came to supply steamships who called at her ports. With these ships also came the technological advancement that allowed the Japanese coal mines to industrialise. Output increased to between 300 000 and 400 000 tonnes in the 1860's. During the Meiji period this multiplied by a factor of 10 and more.(Murakushi, 1980, pp. 6–7)

The international treaties also had a very specific effect on the exchange of gold and silver coins. A follow-up treaty, concluded in 1859, arranged the terms under which Western powers could trade on

Japanese soil. As part of these terms an exchange rate by weight was set between the Mexican silver dollar and the Japanese Tenpō Ichibuban silver coin, issued from 1837. The Ichibuban was made of nearly pure silver and was denominated in units of gold currency, which made it a kind of fiat currency. Four of these silver coins were on a fixed exchange rate to one Koban gold coin. At that time however, the silver-to-gold ratio on the Japanese market was about 5 to 1, while on the international market the prevailing rate was closer to 15 to 1. This situation enabled enormous profits through arbitrage, as traders could exchange Mexican dollars for Koban and exchange those outside Japan for three times the amount of dollars they started with. The Japanese government could not directly intervene in the resulting outflow of gold under the statutes of the trade treaty. The shogunate remedied the imbalance the next year by minting new coins which traded at a lower amount of gold per unit of silver. This enabled the shogunate to simultaneously make a recoinage profit to pay for defensive upgrades, be it at the cost of high inflation.(Saito, 2011)

The later Tokugawa years before the encounter with Perry are perhaps the period to which the term 'sakoku' can be most fittingly applied. It is only by 1801 that this word is used for the first time. (Tashiro & Videen, 1982, p. 283) As mentioned earlier, the edicts of the first half of the 17th century, while restricting foreign travel, contact and trade partners, did not directly restrict trade volume. Over time the production of precious metals shrank and the self-sufficiency of the Japanese economy increased. This did have a big impact on trade volumes.

Precious metal production fluctuations have been mentioned several times so far. Let us now have a detailed look into the available data on the output and use of precious metals, starting with silver.

4. Silver

Part of the intended major contribution of this work is to present a complete picture of the size of precious metal mining in the Tokugawa period. This adds to previous works because of the focus in many of those works on either one metal, a shorter period, or both. Notable exceptions include Kobata's (1956, 1968, 1986) descriptions of the development of Japan's metal mining sector and Innes' (1980) account of Tokugawa period trade in precious metals. However, even those works stop short of providing a full quantitative report on the output of the mining sector. Kobata describes the mining production in qualitative terms and gives production data on certain individual mines. Innes provides many data points, but is primarily focussed on the export side. For silver in particular, the coverage of production data is far from complete. In this section a new approach will be tried to interpolate the production data for the four biggest silver mines, in order to obtain a complete production estimate, which can be compared to the available demand side data.

4.1. Silver supply

As explained in Chapter 2, Japanese silver production techniques improved during the so-called "Christian century". Estimates of national silver output during the Tokugawa period are generally based on export data. Nevertheless, one of the most cited numbers regarding the size of the Japanese silver output is based on production data and comes from Kobata Atsushi. He used a figure of 30 tonnes in annual fees paid to the local governor of Sado island around 1620 to arrive at a production estimate for the island of 60 to 90 tonnes – reflecting royalty rates of 33,3%-50%. He also notes royalty payments by mines at Ikuno and Iwami of 10 and 12 tonnes. Based on this material he makes, in his own words, "a bold conjecture" of annual exports of 200 tonnes in the early 1600s, which he supposed lasted for roughly a century. (1965, p. 248) While this number of 200 tonnes is often quoted, there are some problems with the estimate. For one the estimated peak production at Sado is higher than reported by some other sources as quoted below. A much bigger problem with these numbers is the assumption that this level of production was sustained for an entire century. All indications based on mine production and royalty payment information point to a pattern of very pronounced peaks followed by longer periods of much lower production. The three mines mentioned by Kobata did not even experience those peak levels at the same point in time. Therefore it is highly doubtful that a production level of 200 tonnes was reached, much less maintained.

However, Kobata's is the only national silver production estimate for the period, as other estimates are based on demand side data. For this reason, a new interpolation approach will be tried, based on the available data from the four biggest producers. That data will be discussed first.

4.1.1. Existing data on individual mines

In this section the focus will be on the production at the four biggest sliver mines of the Tokugawa period, as these are responsible for a major part of production and are the best documented. The main mines are a) the mines on Sado island; b) the Ōmori mine in Iwami province; c) the Ikuno mine in Tajima province, and d) the Innai mine in Dewa province. The first three of these mines were under Tokugawa control after it came to power. (Innes, 1980, p. 545)

4.1.1.a. Sado

There is no data about the early years of the silver production on Sado. This changes with the opening of silver production at the Aikawa mine on Sado in 1601.[8] Sasaki (1983b, p. 182) notes a peak of around 25 tonnes in royalties from the Aikawa mine in 1620. According to Kobata (1965, p. 248) from 1618 to 1627 royalties from the whole island of Sado reached an average of 30 tonnes per year. He supposes this level of production could have lasted for an entire century. Sasaki's series, however, show that Kobata's figure coincides with the absolute peak of production of the mine and that production shrinks rapidly afterwards. Innes' (1980, p. 557) estimates also come in lower than Kobata's, at roughly half the size around the same time, with yearly royalty payments of 14 tonnes during 1615-1623 and dropping slightly for the next 20 years. His figures correspond well to the longer term estimates of Yamamura & Kamiki. (1983, p. 345)

In paragraph 2.2 it was mentioned that government royalties typically made up 25% to 50% of output. Under the assumption that the government take was highest during the most productive years, peak royalty payments of 25 to 30 tonnes result in a production estimate of 50 to 60 tonnes. For the 30 most productive years, average production was at least 25 tonnes, based on Innes's figures. From the 1640s a steady decline set in until royalties reached roughly 1 tonne around the 1730s and levelled out. At a royalty rate of 25% this would represent 4 tonnes of production per year. See Figure 1 for a graphical representation of the various royalty data series.

8 It should be noted that of the sources listed for Sado silver mining, only Sasaki expressly states that the figures refer to the Aikawa mine. For the others it is not certain if the figures represent only this mine, or additionally the mines at Tsurushi and Niibo, also situated on Sado island.

4.1.1.b. Ōmori

The Ōmori silver mine in Iwami was originally opened in the early 14th century, but reopened shortly before the introduction of the haifuki process. The earliest available data indicate that production was not yet at a high level just after this introduction, with tax payments averaging just 80 kilograms per year from 1532 to 1554. (Sasaki, 1980, p. 183) During the second half of the 16th century production approached 400 kilograms. A breakthrough came with the discovery of new silver deposits and the opening of the Kamayabu tunnel in 1601. This pushed tax payments up to 13,5 tonnes. With an assumed tax rate of 50% this means a production of over 25 tonnes. This high yield was short lived, as payments fell below 5 tonnes per year in the 1620s. In the 1670s total production per year fell to 1-1,5 tonnes. From the 1730s on production was down to around 400 kilograms.(Kobata, 1956, pp. 64–65) See Figure 2 for the full series.

4.1.1.c. Ikuno

The Ikuno mine opened in 1542 in Tajima province. It was not until 1598 that the mine reached a peak of 10 tonnes of silver in royalty payments. (Sasaki, 1983b, p. 184) Between then and the 1680s there is no data about the mine output. In terms of circumstantial evidence, the mining town population was largest between 1600 and 1650, at 15 to 20 thousand people, based on the volume of rice shipments. Although there is no information about output per person, total production must have been substantial to support this kind of population. Reportedly there was a large fire at the mine in 1660, dispersing a large part of the workers to other mines. (Innes, 1980, p. 561) In the 1680s royalty payments were around 2 tonnes, climbing to 4 tonnes around 1710. After that payments to the government settled just below 2 tonnes, dropping off a bit more during the 19th century. This indicates a peak production of about 20 tonnes around the year 1600, with production levels around 8 tonnes in the longer term.(Kobata, 1954, pp. 20,40–41) See also Figure 3.

4.1.1.d. Innai

The Innai mine was opened in 1606 and was owned by the Akita clan of northern Honshū. Innes (1980, pp. 562–563) describes that the mine had a high peak production just after opening, but by 1612 production began to decline. There are however no figures available for the size of production until the 19th century.

In the absence of production data the number of people living and working in the mining town provides circumstantial evidence for the size of the mining operation. At Innai the number of workers associated with the mine was estimated at 7000 at its peak. In comparison with the number

of inhabitants at Ikuno's mining town – 15 000 to 20 000 including dependants and supporting tradespeople – the Innai mining town would have been at least as big as the one at Ikuno. (Innes, 1980, pp. 561–2) Without data on the relative labour productivity for these locations, the number of workers does not give us definitive information on the level of production. However circumstantial, these data points do suggest that Innai's peak production was plausibly of a similar scale as Ikuno.

There is more information about the production during the 19th century, when yearly production climbed from several hundred kilograms in the early years of that century to a peak of around 5000 kilograms in the 1830s, after which it dropped off again. According to the Furukawa Mining Company who purchased the mine in 1884, previous peak production was just below 5000 kilograms, possibly referring to the level observed in the 1830s. After transfer tot he Furukawa company production quickly increased to around 9 tonnes per year. By the early 20th century production had dropped back to 5 tonnes. (Furukawa Mining Company, 1910, p. 51) See Figure 4 for the graphical representation.

4.1.2. A new approach to estimating national silver production

The four big mines described in the previous section all reached peak output in a relatively short time from around the turn of the 17th century to 1630. Given the volatility of output in this period, it is very difficult to estimate yearly production levels for this period. Although peak royalty levels and some indications for other periods are available, the data for the period as a whole are far from complete.

In an effort to overcome this problem, this section will present a model for the estimation of output for each of the four big mines. This model is based on the level of peak royalty output and a plausible development path based on the remaining available data. I will use the almost complete set of data on the Sado mine to infer a pattern of development that can be applied to the other mines as well. The data on the Sado mine is complete enough to form a generalised picture of the successive stages the mine went through in terms of the size of its royalty payments. The assumption is that the other mines had a similar trajectory of development, given that they were operating in similar institutional and technological circumstances that influenced their development. The size of each mine's output is scaled to the height of peak royalty payments. Where data shows a different pattern, the pattern of development is adjusted to take this into account.

It should be stressed that this method will not give an exact answer on the development of production. It is merely meant as a conjecture of the development that is consistent with the available pieces of evidence. It should be seen as an indication of the order of magnitude of the actual production. It is, however, a useful sketch of the development of the production of silver that can be confronted with demand side data to see if the assumptions were realistic.

4.1.2.a. Sado

Looking at the development of the Sado mine it is possible to discern three different stages: a boom, a decline and a tail. The period of highest output consists of the initial boom, the peak and the decline of output. In the case of Sado the boom lasted for 8 years and the decline took 26 years. The 'tail' is a period of low output and only a very gradual decline that was sustained for over two centuries. See Figure 1 for how the model compares with the historical data. The model itself consists of 3 equations expressed in relation to the peak royalty payments and visually fitted to the available data points.

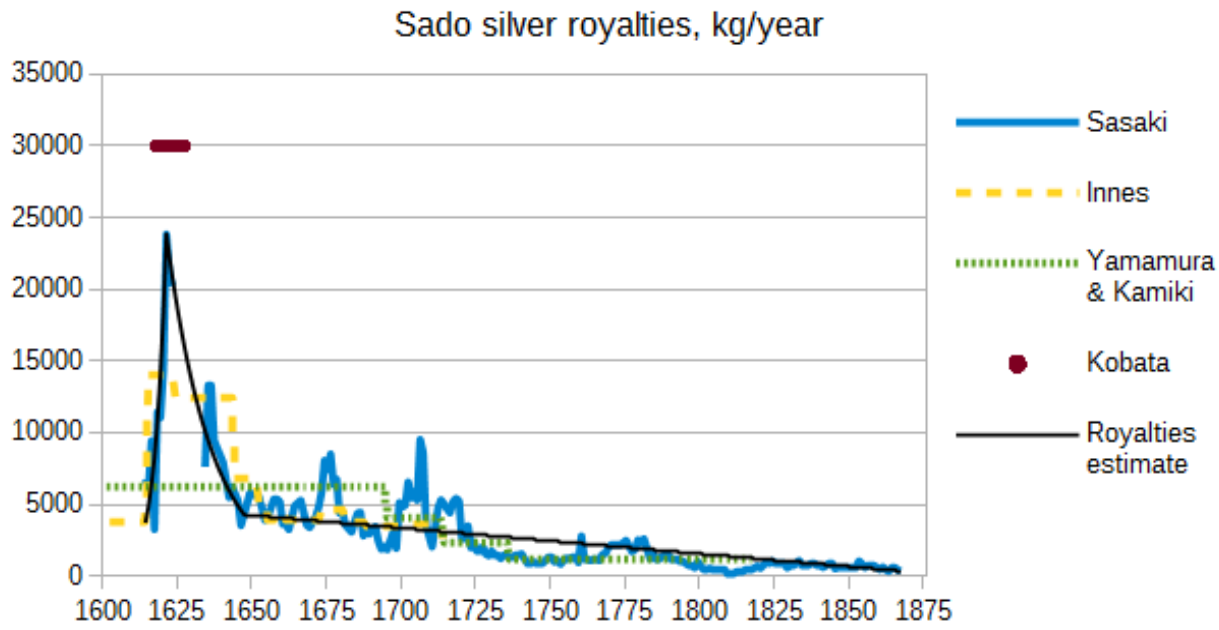

Figure 1: Sado silver royalties

Sources: (Sasaki, 1983b, p. 183); (Kobata, 1965, p. 248); (Innes, 1980, p. 557); (Yamamura & Kamiki, 1983, p. 345)

For the peak measurement the value by Sasaki (1983b, p. 182) of 23 865 kg is used, as one of the more conservative estimate. Moreover, the series is much more complete than any other available series. For the boom period an exponential equation is used with a growth factor of 1,304 per year and a starting point of 3742 kg (the average yearly royalty payments in the period leading up to the boom; Innes, 1980, p. 557). The decline stage is also described by an exponential function, starting from the peak in the 8th year and decaying with a factor of 0,936 per year. An exponential equation was chosen for the first two stages, based on the fact that typically mines in Tokugawa Japan saw a very volatile growth and decay pattern in the early years after opening a mine, as explained in the section on the institutional setting. In contrast, the tail stage is linear, starting at 4292 kg in the 34th year and decaying by 18 kg per year. The level and timing of this transition point is based on Sasaki's series. The linear decay reflects the more carefully managed exploitation pattern of mature mines. The total amount of royalties of the resulting series differs 1,6% from the level of the Sasaki series for the available years. A summary of data and equations used in this model and the models for the other mines are provided in the appendix.

With a series of royalty estimates in hand, the next step is to use these to estimate production levels. According to accounts from bakufu controlled mines the share of royalties in the total output varied from 50% in the higher output years, down to 25% in the lower output years.(Innes, 1980, p. 555) This relationship between the royalty share R in period t and total output Y_t in the same period is expressed as follows:

$$R_t = 0{,}25 + 0{,}25 * Y_t / Y_{peak} \quad (1)$$

For the Sado mine this results in a royalty share of roughly 30%-50% in the boom and decline years and a share of 25%-30% in the tail stage.

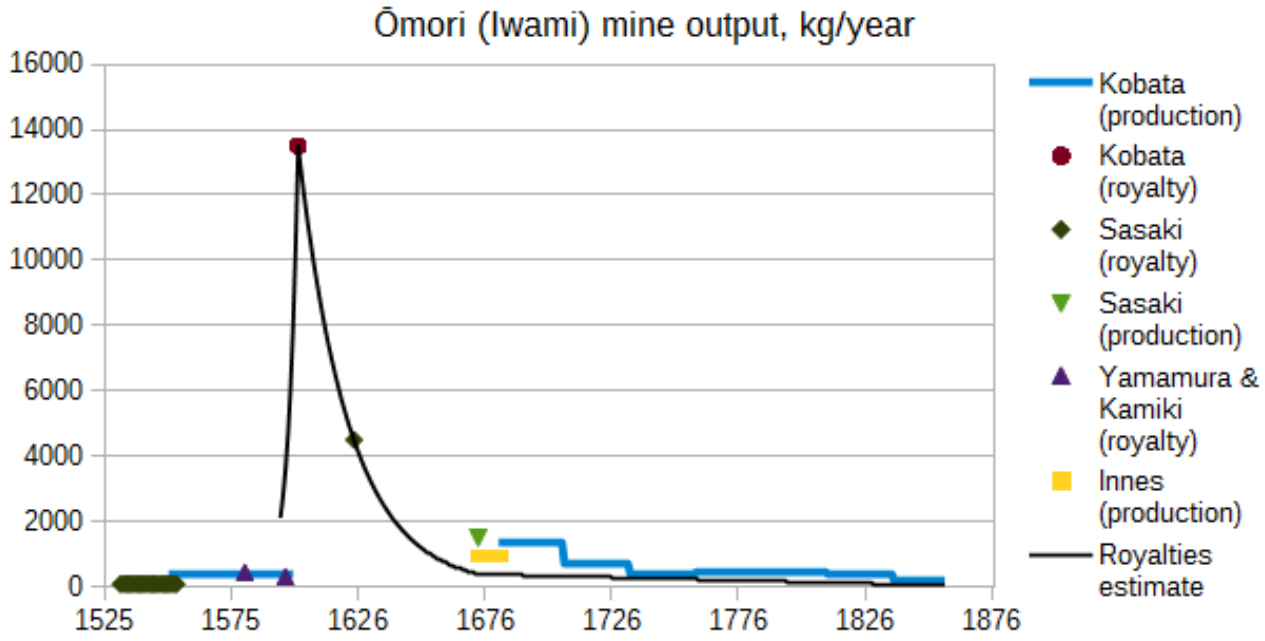

Figure 2: Ōmori silver output

Sources:(Sasaki, 1983b, p. 183) (Yamamura & Kamiki, 1983, p. 343); (Kobata, 1956, pp. 64–65)*; (Innes, 1980, p. 555)*

4.1.2.b. Ōmori

Based on the known level of the peak output, the same growth pattern can be applied to other mines. After Sado the mine with the most complete output data is Ōmori. Although not all sources agree on the exact year (Innes, 1980 in 1615; Kobata, 1956 in 1602; Sasaki, 1983b in 1596), peak royalty payments for the mine amounted to 13,5 tonnes per year. This mine also shows a very rapid growth and decline, although the data suggests a slightly different pattern to Sado, see Figure 2. By 22 years after the peak the royalty payments are still about a third of the peak level, higher than in the case of Sado, but 49 years after that royalties had dropped to a very low level of less than 3%. (Sasaki, 1983b, p. 183) In the case of Ōmori the later observations are production levels, which were converted back to royalties by the equation above in order to use them in the model.

In fitting an equation to the Ōmori output data, the boom period is taken from Sado at a lower level based on the peak output. The exponential decay of the decline stage lasts almost 3 times as long at 71 years, though with a slower decay with a factor of 0,955. The tail stage starts at a low royalty level of 387 kg and decays by only about 2 kg per year. See the appendix for the data and equations

used. The method of calculation of production based on the royalty amounts is the same as described above.

4.1.2.c. Ikuno

Data for the Ikuno mine is restricted to one observation for the peak of royalty payments and a relatively long series describing the payments during the middle and later Tokugawa period, see Figure 3. Given the absence of information about the periods before and immediately after the peak, the pattern of Sado's development will be applied to the boom and decline periods, scaled to Ikuno's peak output of around 10 tonnes. The turning point from exponential to linear decay is not recorded, but the assumption here is that the heyday of production at Ikuno lasted a similar time as at Sado, and that royalty payments equally fell to around 18% of peak output at the end of the decline stage. From there royalties declined, but data from the 18th and 19th centuries shows that Ikuno was able to sustain a relatively high output of around 600 kg by the 1860s.[9]

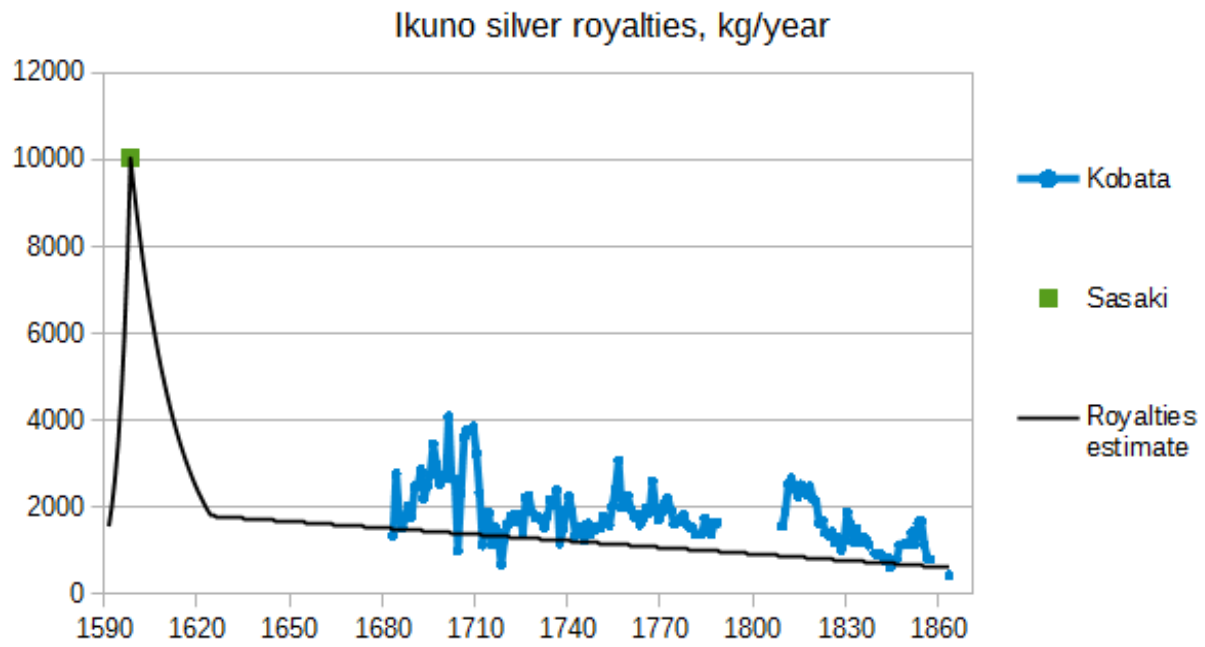

Figure 3: Ikuno silver royalties

Sources: (Kobata, 1954, pp. 20, 40, 41); (Sasaki, 1983b, p. 184)

9 In this case an average of the final two observations is used, since the final observation of 429 kg in 1863 was clearly below the trend. (Kobata, 1954, pp. 20,40–41)

4.1.2.d. Innai

Unfortunately there is no data about Innai's initial boom period and corresponding peak output, making an estimation of production levels even more speculative. From the information quoted in paragraph 4.1.1 about the size of the mining workforce at Innai, it seems the mine was of a comparable scale to Ikuno. In order to account for Innai's production an option is then to use the Ikuno mine as a template and use its peak production data to estimate Innai's boom and decline stages – be it offset to let the peak coincide with the reported timing of peak of production at Innai around 1612.(Innes, 1980, pp. 562–63) This is even more speculative than the estimates of the other three mines, but without it there would be an unacceptable gap in the data. There is production data available spanning the middle of the 19th century, which provides a data point for the end of the tail stage. The end point of 296 kg of royalties in 1875 implies that the decay during the tail stage was slightly more rapid than for the Ikuno mine. See the appendix for the model specifications.

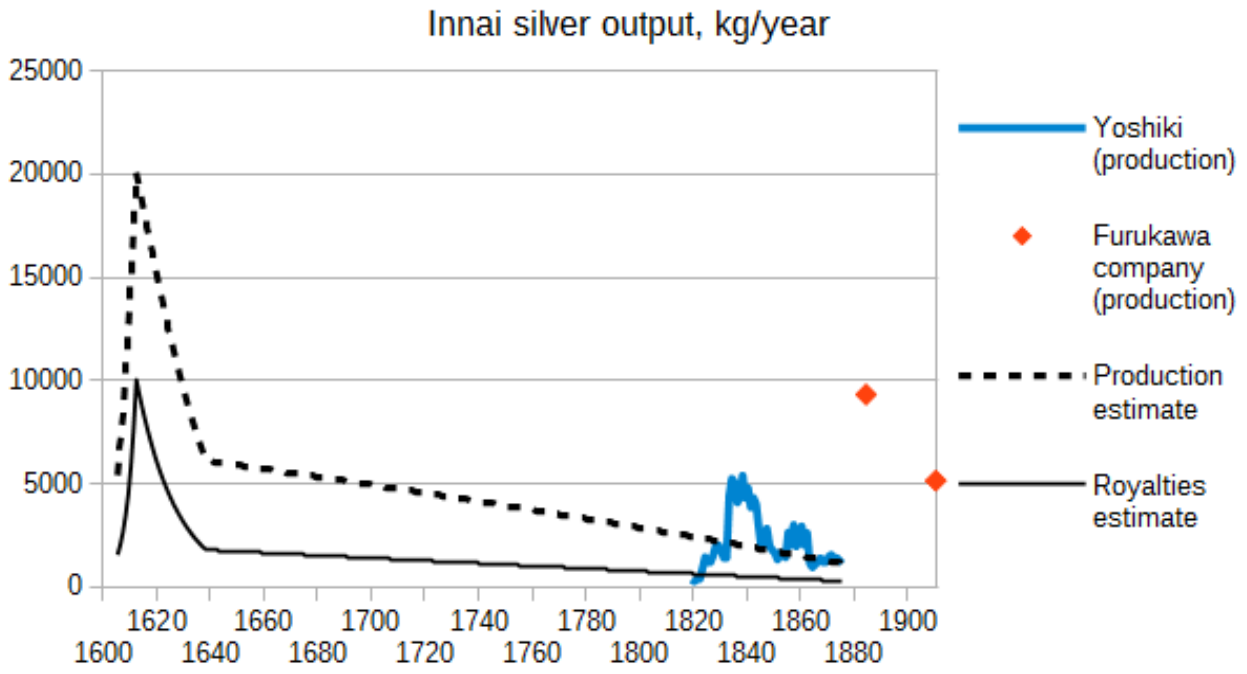

Figure 4: Innai silver output

Sources: (Yoshiki, 1980, p. 1); (Furukawa Mining Company, 1910, p. 51)

4.1.2.e. Other mines

A remaining unknown quantity is the production of the smaller mines. The exact number of these mines is unclear, but could have numbered into the hundreds. There were a number of medium sized mines, like the Tada mine in Settsu which had its peak production of almost 6 tonnes of silver per year in the second half of the 17th century. (Innes, 1980, pp. 566–568) Smaller operations, such as at the towns of Yoshino and Kameya had an average production of several dozen kilograms per year. (Kobata, 1956, pp. 440–441) With a handful of medium-sized and up to hundreds of small mines, yearly production at these sites could have been 10 tonnes or more. In addition, silver was sometimes a minor side-product of copper mines, depending on the ore type. Therefore the previous estimates should be seen as minimum figures. A conservative estimate of the output of smaller mines is that they made up 10% of total production, compared to 90% for the big 4. This results in a peak of 9,4 tonnes in 1621.

4.1.2.f. National production

Adding the estimated production of the smaller mines to the production estimates of the large mines, arrived at by the method described above, results in the total silver production curve in Figure 5.[10] The aggregate curve presents a fast, almost uninterrupted rise to a peak of over 90 tonnes and a smooth decline which decelerates significantly after the 1630s. Initially Sado and Ōmori dominate, but by the end of the period Ōmori barely had any production while the other three mines combined for about 5 tonnes of production.

10 The equations from Appendix 1: Silver Mine Production Model are extended to project the production estimate beyond the final observations of the individual mines, except for Innai where this was not necessary.

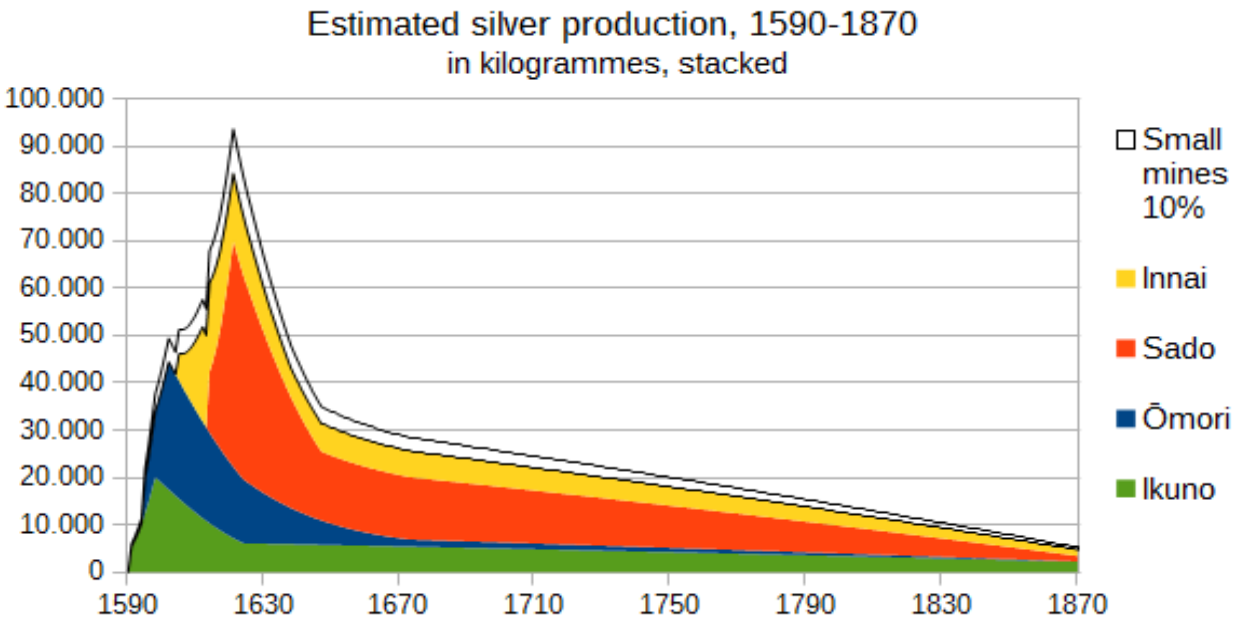

Figure 5: Model estimates of silver production

This rather stylised result can be combined with the available observations for each mine to make optimal use of all existing information. In addition, information about national silver production from the Long-Term Economic Statistics (LTES, No. 10: Shinohara, 1972) is used to extend the production data from 1874 to 1909. This is presented in Figure 6. The Y-axis is cut off to improve comparison with the curve of the previous graph, however national production grew to 128 tonnes in 1909. There are a few periods where the additional data changes the model graph to a greater extent. Data on early 17th century Sado royalties, converted to production, adds almost 13 tonnes on a yearly basis. Then there are a few periods in the tail stage where production temporarily flared up, the most striking one taking place around 1700-1710 when both Sado and Ikuno had a spike in production.

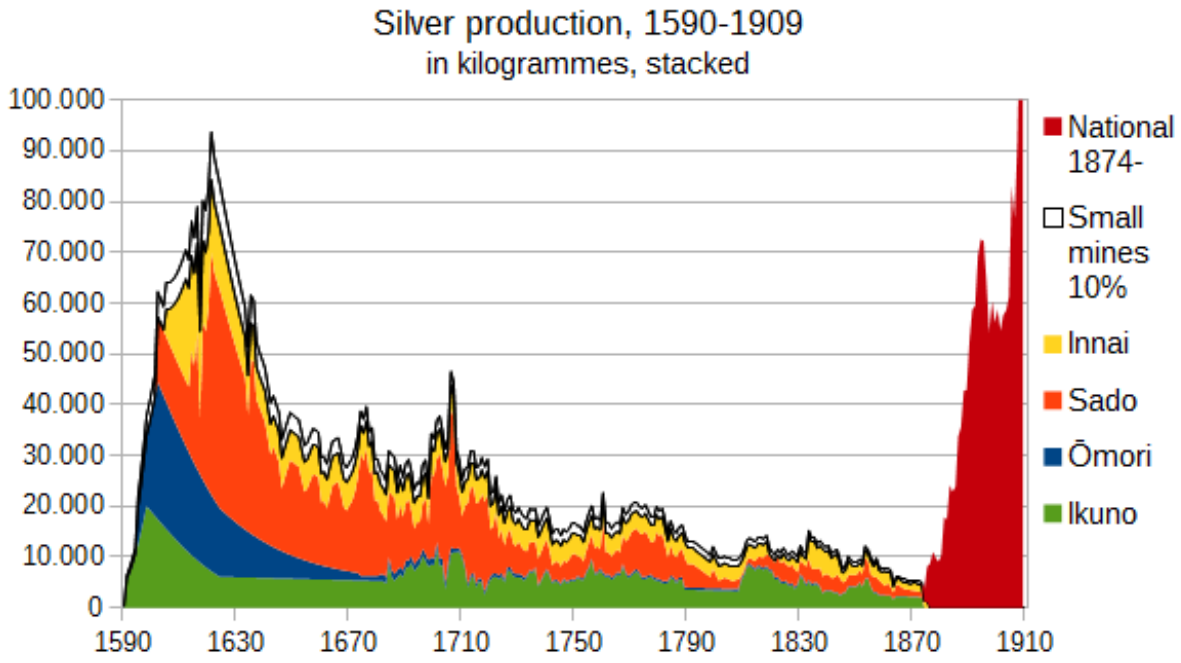

Figure 6: Silver production data combined with model estimates

Sources: Ikuno: 1598: (Sasaki, 1983b, p. 184) 1683-1788, 1809-1837, 1839-1857, 1863: (Kobata, 1954, pp. 20, 40–41) *Innai: 1819-1875: (Yoshiki, 1980, p. 1); Ōmori: 1590-1594, 1602, 1681-1857:* (Kobata, 1956, pp. 64–65)*, 1673: (Sasaki, 1983b, p. 183) 1674-1680: (Innes, 1980, p. 555); Sado: 1602-1613: (Innes, 1980, p. 557); 1614-1623, 1634-1867: (Sasaki, 1983b, p. 182); National 1874-: (Shinohara, 1972 Table 51); Small mines output: 10% of total including production data.*

The years around the end of the Tokugawa period were a time of great turmoil, possibly explaining the drop production in those years. Soon thereafter production grew quickly, surpassing 70 tonnes in the 1894 and 100 tonnes tonnes in 1908. (Shinohara, 1972, Table 51) Mining was one of the industries where foreign experts were brought in to modernise production. For the silver mines the Meiji period brought a boom in production on a similar scale to the one around the beginning of the Tokugawa period.

4.1.3. Silver imports

Besides production, the other component on the supply side are imports. During the later Tokugawa period silver came to be imported into Japan by Chinese and Dutch traders. According to Shimada (2006, p. 61) this was motivated by bullionism, of which he identifies Arai Hakuseki as the first Japanese proponent. However, an account by G.F. Meylan (1833, pp. 198–200), a chief of the

VOC's mission in Nagasaki, suggests there were also other considerations in play. In 1768 a Dutch ships was lost at sea on the way from Batavia (current Jakarta) to Nagasaki, leaving the single remaining ship unable to carry the full export quota of copper for that year. The next year the two ships allowed entry into Nagasaki exported both that year's and the previous year's remaining copper, but were not able to carry enough imports to balance the trade. The difference was compensated in silver paid to the Nagasaki traders. Since during the earlier Tokugawa period trade was generally balanced, this was a change in policy.

The Chinese traders started the import of silver a few years earlier around 1762. Between 1763 and 1782 the Chinese and Dutch combined imported 2,9 tonnes of silver coins per year, or 2,7 tonnes of silver at a purity of 93%.(Uchida, 1921, pp. 456–57) These silver imports continued at a rate of about one quarter ad valorem of copper exports between 1766 and 1842.(Shimada, 2006, p. 64) Silver imports are depicted in Figure 7 at 2,7 tonnes from 1763 to 1782, and after that at a fixed rate of 0,18% to the copper export volume, equal to the rate during 1763-1782. After 1782 imports are estimated to be less than 2 tonnes per year. Given the increasing import substitution taking place during the Tokugawa period (See Chapter 3) the import of silver could be seen as a consequence of the fact that Japanese traders were lessening their trade of goods such as silk or sugar.

4.2. Silver demand

4.2.1. Silver exports

As described in the section on foreign trade, silver was the main export product of Japan during the late 16th and early 17th centuries. The exact size of this trade is the subject of some debate. One group of researchers suggests relatively high silver exports. The estimate of 200 tonnes per year for the 17th century by Kobata has already been mentioned. Another often quoted source is Iwao Seiichi, who combined estimates of the quantities exported to by the separate carriers during the early 17th century.[11] Converted to 93% purity, his total comes to 140 to nearly 180 tonnes per year. (Iwao, 1966, pp. 222–23) Based on this data, Shimbo Hiroshi and Hasegawa Akira (2004, p. 167) estimate that in the early 17th century silver exports represented a value equal to around 10% of *agricultural* output. Yamamura & Kamiki have used Iwao's and other, supplemental information to come to their own estimates for the late 16th and early 17th centuries. For the former period they

11 Iwao himself is somewhat vague about the period his estimates refer to. Others have interpreted his figures to apply to the years 1596-1623 (Shimbo & Hasegawa, 2004, pp. 166–67) or 1615-25 (Souza, 2004, p. 58). The widest plausible limits of the applicable period are the start of the shuinjō system in the 1590s and the start of seclusion in 1639.

come to exports of around 40 tonnes per year, while for the latter they suppose exports of 150 to almost 190 tonnes per year.(Yamamura & Kamiki, 1983, pp. 351–352) The various estimates are summarised in Table 2.

Several other researchers come to quite different, lower estimates. George Bryan Souza used numbers and types of ships making the voyages between Macao and Japan to estimate Portuguese silver exports from Japan to China. He arrived at 14,9 to 18,3 tonnes per year during the period 1546-1597.(Souza, 2004, p. 56) For the first half of the 17th century Richard Von Glahn has estimated silver exports by using the data for the value of total external trade from Innes quoted in Table 1. Based on VOC accounts for certain years, Von Glahn estimated that at least 80% of the value of the imports was traded for silver. By this method he arrived at yearly exports of silver during 1601-1645 of 54 tonnes, about a third of the figures proposed by Iwao and Yamamura & Kamiki.(Von Glahn, 1996, p. 136)

Table 2: Estimates of silver export from Japan to China by carrier, in tonnes per year

	Iwao[12] early 17th C.	Y&K 1560-1599	Y&K 1600-1639	Von Glahn 1550-1600	Von Glahn 1601-1645
Portuguese	48 – 57	22,5 – 37,5	45,0 – 56,25	14,5 – 18,0	14,4
Chinese	38 – 49			8,8	13,3
Shuinjō	43 – 53	11,25*		?	18,7
Dutch	13 – 19	-		-	7,6
Total	141 – 177	33,75 – 48,75	150,0 – 187,5	23,3 – 26,8+	54,0+

Sources: (Iwao, 1966, pp. 222–23; Von Glahn, 1996, p. 140; Yamamura & Kamiki, 1983, pp. 351–52). All figures 93% pure. Totals may differ from individual values due to rounding. *Together with Chinese traders.

According to Von Glahn and Innes, the figures by Iwao, Kobata and Yamamura & Kamiki are overestimations of the actual silver exports, because those researchers used each carrier's top years for their estimates of the period. This can lead to very different outcomes, as the export amounts of the traders were very changeable. The Portuguese, Chinese, Dutch and Japanese traders were all competing with each other for trade. The availability of ships, capital and merchandise, the incidence of shipwrecks and temporary bans of trade for certain carriers all influenced the trade volume of the individual carriers and their relative dominance during the years.

12 Iwao gives estimate of total export in pure silver and figures per carrier in coin quality silver, apparently using a range of possible purities to arrive at a wider estimate range for the level of the total in pure silver. The carrier figures have been back-calculated to be consistent with the total, both at 93% purity.

As an example, let us take a look at the value of Portuguese silver exports during different periods and see how Iwao's estimates compare to known data points. Iwao estimates that during the early 17th century the Portuguese exported 15 000 kanme, or 56¼ tonnes of silver per year. In the 18 years between 1600 and 1617 a total of only 10 Portuguese *carracks* (large cargo ships used by the Portuguese) made the journey to Japan.(Souza, 2004, p. 55) From the surviving records of the cargo carried by the Portuguese on the Nagasaki-Macao route, 3000 to 4000 kanme (11¼ to 15 tonnes) of silver seems to have been a typical value of the total cargo of each carrack.(Innes, 1980, p. 382) With less than one ship arriving per year, the average yearly export value would have been only 7,7 to 10,2 tonnes of silver. Taking a longer view, 1598 sticks out as an unusually good year in which 3 ships arrived. Yet even that high mark is only good for an estimated trade value of 33,75 to 45 tonnes of silver.

From 1618 the Portuguese traders started using the smaller *galliots*, in reaction to their carracks being captured by the Dutch. During the 16 years between 1618 and 1633 a total of 69 galliots made the journey. The best year was 1619 with 8 ships. Trade was halted for a few years in the late 1620s by a Japanese trade embargo on the Portuguese, in reaction to a shuinjō ship under Japanese protection being attacked by a Spanish fleet stationed in Manilla. (Souza, 2004, pp. 56–60) In 1618, 6 galliots made a total trade of 7000 kanme (26 25 tonnes of silver).(Innes, 1980, p. 383) Going by the average cargo value per ship in that year (4 375 tonnes of silver) the average yearly export value during 1618-1633 would have been an estimated 18,9 tonnes of silver, with a high of 35 tonnes in 1619.

During 1634-1638 the Portuguese trade did reach a size similar to the figure used by Iwao. During those five years trade value averaged 58 tonnes of silver.(Innes, 1980, p. 17) This high trade level was due to the specific circumstances of the time. From 1635 overseas voyages by Japanese traders were forbidden and the shuinjō system was ended, leaving the Portuguese, Dutch and Chinese to pick up the slack and increase their trade.(Souza, 2004, p. 58) In addition, the prohibition on Japanese international trading missions restricted the number of trading partners and possibly caused prices on imports to rise, as the number of suppliers of foreign goods was restricted and the supply of Japanese silver was unchanged. The result would have been a worsening of the terms of trade for Japanese exports. A few years later when the Portuguese were also barred from trade and only the Dutch and Chinese were allowed to trade, the price of foreign goods doubled according to Arai Hakuseki. This worsening of the terms of trade has been connected to the increased outflow of Japanese specie in those years. (Takekoshi, 1930a, p. 130)

As the Portuguese case shows, the figures of Iwao and Yamamura & Kamiki are consistent with only the best export years for the Portuguese and are overestimations for the rest of the period. By contrast, Von Glahn uses data spanning a much wider period. Using mostly data gathered by Innes, he has constructed a 5-yearly time series of silver exports starting in 1606. Until 1647 the estimates are based on the assumption that 80% of the value of imports was paid in silver. From 1648 to 1672 actual silver exports through Nagasaki are available. The Dutch were not allowed to export silver from 1668, therefore exports of silver through Nagasaki for 1673-1684 are based on Chinese export figures. The Chinese exported mostly silver until the mid-1680s when the shogunate applied restrictions on silver exports through Nagasaki, and the profitability of copper exports motivated a switch to that metal. (Von Glahn, 1996, p. 232) From 1686 the silver export data represents the trade through the island of Tsushima to Korea, as that became the main route for silver to flow out of the country. Two successive series by Tashiro Kazui are used for the export through Tsushima until 1752. (Tashiro, 1981, p. 325, 1989, Table 1) The combined series converted to pure silver is shown in Figure 7 below, together with the production estimate explained above and the use of silver in the money supply which will be discussed below.

4.2.2. Silver in the money supply

Export was not the only destination for the silver produced in the Tokugawa period, as large amounts ended up in the money supply. The gradual commercialisation and monetisation of the economy during this period has been extensively documented. See for instance Hayami et al. (2004) During the Tokugawa era both the volume and purity of silver coins varied greatly from period to period. There was a general tendency for coins to become less pure, as the shogunate was tempted to augment their income by currency devaluation. In addition, from 1765 the shogunate began issuing silver coins with a nominal value expressed in *ryō*, a gold coin of the time. This was in effect a type of fiat money, although it still required substantial amounts of precious metal, be it silver instead of gold.

Table 3 Shows the average yearly addition of silver to the money supply from to beginning of the Tokugawa period to 1854. It is based on an estimate of the currency in circulation at different times, combined with information on the purity of issued coins. It should be noted that the amount in circulation at times differed greatly from the coins issued. During 1600-1695 a very large amount of coins was stamped, using 3600 tonnes of pure silver in total.(Nishikawa, 2000, p. 8) This is close to the total production of silver during those years as estimated above at 3700 tonnes. Most of the

silver coins issued in those years were exported, however. Total exports from 1606 to 1695 were almost 3400 tonnes. Conversely, the currency in circulation in 1695 only contained about 470 tonnes of pure silver.(Yamaguchi, 1963) Comparing the silver in circulation and exported a possibly conclusion is that the production is underestimated. However, the shogunate could also have used existing stocks of silver and gold. After the siege of Osaka castle in 1615 the shogunate claimed the substantial Toyotomi treasure for the issue of new coin.(Miyamoto, 2004b, p. 84) Another aspect to take into account is the fact that existing coins could be melted down to use the specie for the issue of new coins.

Besides the coins valued as their weight in silver, Table 3 also includes silver coins which were denominated in units of gold coin. The former category is converted from *kanme* (3,75 kg) of coins to tonnes of pure silver, using purity figures for the coins issued in the preceding period. (Nishikawa, 2000, p. 8) For 1710 and 1714 it was necessary to use average purity figures as there were many successive coin issues in those years. Therefore the 1710 purity is an average of the purity of the 1695 and 1706 issues, while 1714 uses the purity of the 1710 and 1711 issues.
Gold denominated silver coins entered the money supply in 1765 and are counted in the table starting in 1818 in millions of ryō. The majority of gold denominated silver coins at that time were the *Meiwa nanryō nishugin* issued from 1772. These weighed 2,7 *monme* (1 monme = 3,75 grammes), consisting for 97,8% of silver with a face value of 1/8 of a ryō gold coin. Using these ratios it is possible to calculate the exchange rate of monme pure silver per ryō of gold and through it the amount of silver used in the issue of these coins.[13] (Taya, 1963) Adding up the silver content of the silver coins by weight and the gold denominated silver coins in circulation yields the total amount of silver contained in the money supply in the estimated years. Subtracting the silver amount in the money supply in the previous known year and dividing by the number of intervening years yields the yearly change of silver in the money supply.

For most of the Tokugawa period the money supply absorbed more and more silver. However, according to these calculations, during 1710-1714 and 1818-1854 there was a net extraction of silver from the money supply. These years line up with known periods during which the shogunate used its minting monopoly to support the budget. (Miyamoto, 2004a, 2004b)

13 For the 1818 stock the exchange rate was 21,1 monme silver per ryō. The 1832 stock consisted in roughly equal parts of a 2 monme coin with a 1/8 ryō face value, and a 0,7 monme coin with a nominal value of 1/16 ryō, resulting in a weighted exchange rate of 13,2 monme per ryō. From 1837 a 2,3 monme, 1/4 ryō coin was issued in large amounts, resulting in an even lower rate of 9,1 monme per ryō.

Table 3: Silver used in money supply

Year	Silver by weight (1000 kanme)	Silver purity (%)	Silver by weight (tonne pure)	Gold denom. silver (M. ryō)	Monme pure silver/ ryō	Gold denom. silver (tonne pure)	Total silver money (tonne pure)	Yearly growth of silver supply (tonne pure)
1695	157,1	80	471,2	-	-	-	471,2	5,0
1710	394,2	57	842,6	-	-	-	842,6	24,8
1714	774,5	26	755,1	-	-	-	755,1	-21,9
1736	331,0	80	993,1	-	-	-	993,1	10,8
1818	527,8	46	908,7	5,9	21,1	469,3	1378,0	4,7
1832	381,4	36	515,0	16,3*	13,2	809,4	1324,3	-3,8
1854	234,1	26	228,2	20,5	9,1	700,3	928,6	-18,0

Sources: Columns 2 and 5: (Yamaguchi, 1963); column 3: (Nishikawa, 2000, p. 8); *, column 6: (Taya, 1963, p. 388)

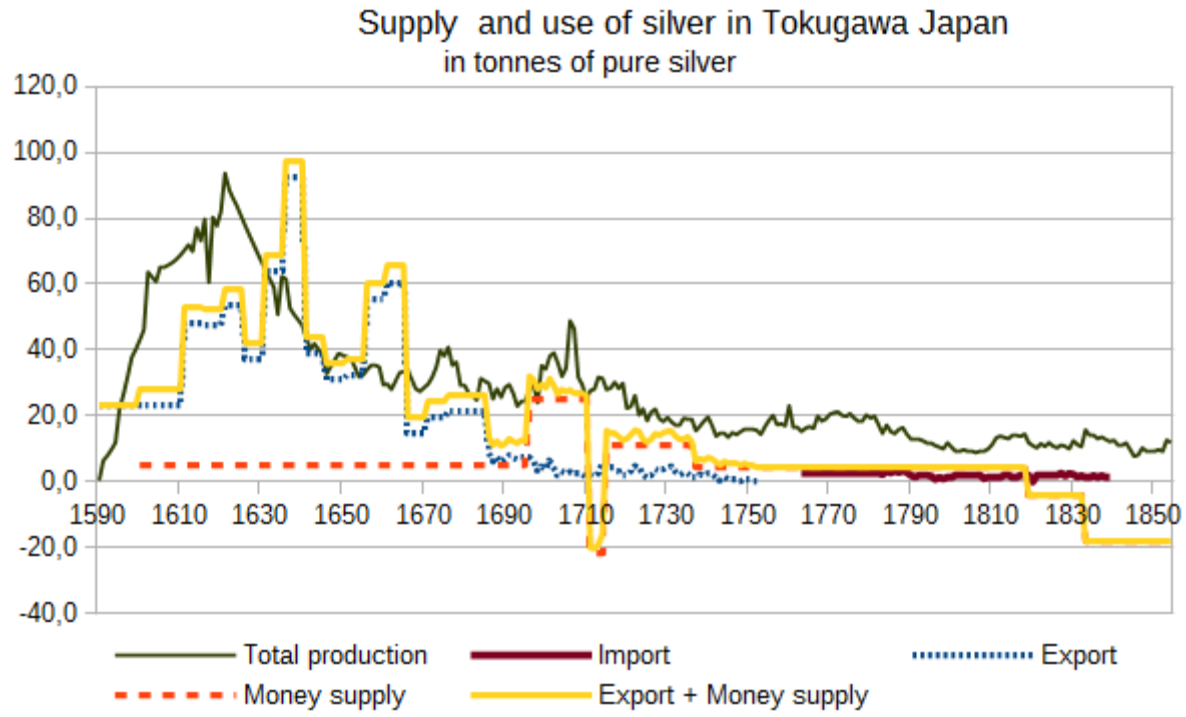

Figure 7: Supply and use of silver in Tokugawa Japan

Sources: Production: see Figure 6; Import: 1763-1782: (Uchida, 1921, pp. 456–57)*, after 1782: fixed rate to copper exports; Export: 1590-1685: (Von Glahn, 1996, pp. 140, 232), 1686-1752: (Tashiro, 1981, p. 325, 1989 Table 1); Money supply: Table 3*

4.3. Confronting supply and demand

Figure 7 shows the estimates of production and imports together with those of exports and use in the silver supply. These make up the known sources of supply and demand of silver in Tokugawa Japan. A few things are obvious from the graph. Firstly, the peak in silver exports occurs after the peak in production. This is to be expected, as a large part of the silver was first made into coin, possibly spent some time in circulation, and was only then exported. In addition, the production of coins would be likely be focussed mostly in the early years of the period of issue, for instance in the early 1600s, while in the calculations the use of silver is assumed to be spread equally. A second period of high production relative to observed consumption is when exports of silver were at a low level in the 18th and 19th centuries. Given the impact of the casting of coin on silver consumption in certain periods, and the uncertain spread of currency issue over the time span of currency regimes, it is best to compare the supply and use of silver based on the currency regime periods. In Table 4 this is done for four periods.

Estimated supply includes the production of the big 4 mines and 10% of production for smaller mines, plus silver imports. Imports of silver start from 1763 but remain at a comparatively low level. On the use side silver exports are added to the silver absorbed in coinage. The 1600 to 1695 time span includes the period of highest production and export, resulting in excess supply of 568 tonnes, or 5,9 tonnes per year. In the following two periods the yearly excess is about twice as high, and in the final period it doubles again.

Table 4: Silver supply and use compared, in tonnes pure silver

	Supply	Use	Excess supply	Yearly excess
1600-1695	4557	3989	568	5,9
1696-1736	1120	660	460	11,2
1737-1818	1374	403	971	11,8
1819-1854	443	-449	892	24,8

Sources: see Figure 7

For the interpretation of these results there are a few possibilities to keep in mind. Firstly, the production estimates may be too high. The production estimates are speculative, although data availability differs per period. This puts a lower bound on the production estimates for the more complete years. For the 1737-1818 years for instance information is relatively good, with data from three mines being mostly complete. During those years, Sado paid an average of 1,2 tonnes in

royalties. For Ikuno data is missing for 1789-1808, but during the remaining years royalties averaged 1,8 tonnes. Therefore royalties for this period from just these two mines amounted to about 3 tonnes per year on average. Even at a relatively high royalty share of 50% this would represent a production of 6 tonnes, but as these periods were far from the peak years royalties were likely closer to 25%, putting production at 12 tonnes. In addition there was the production from Ōmori, known to have been 0,4 tonnes per year on average, as well as Innai, smaller production centres, and silver imports during the later years. Conversely, the average use of silver during the same period is estimated at to less than 5 tonnes per year. Although overestimation of production is a possibility, it is at most only a partial explanation of the difference between supply and use.

A second explanation is that there is more use of silver than shown here. There was likely illicit trade taking place between Japan and China during certain periods of the Tokugawa period, as Chapter 3 describes. Smuggling could have taken place during the time when silver was allowed to be exported but limited by amount or value, but also during the later Tokugawa period, when trade in silver was banned from Nagasaki. According to Robert Sakai (1964) smuggling was relatively widespread in Satsuma, a domain which was distant and relatively independent from the Edo government, and had a semi-independent outpost in the Ryūkyū islands. Especially during the earlier period of high silver production, silver would have been an attractive export commodity for smuggling, being both in demand and having a high value-to-weight ratio.

Besides unaccounted international trade, the domestic market would have absorbed a certain amount of silver in decorative and household objects. Unfortunately, estimates of domestic consumption are not available. From qualitative accounts it appears there was a growing market for luxury decorations and objects, to the degree that successive shogun found it necessary to increasingly restrict the type of materials people of different social classes could use. There were restriction on the use of silver and gold in objects like building ornaments, altars, clothing and equipment worn during festivals, the clothing of prostitutes, women's combs and bodkins, tray-stands, bowls and cups used when entertaining, and even the costumes of puppets in the theatre.[14] The fact that these sumptuary laws had to be issues again and again, and that many of the restricted uses were hard to police, suggests that these restrictions were not very effective.(Shively, 1964) It is a distinct possibility that the domestic use of silver increased during the Tokugawa period.

Table 4 suggests that after the moratorium on silver exports in the late 17th century the excess, unaccounted, supply of silver increased. This makes sense, for if the demand for silver through (official) export was cut off, this would have induced illicit trade and/or the domestic consumer

14 Amusingly, there was an exception for puppet generals.

market to capture a larger amount of silver. A separate growth of the domestic luxury goods market as a whole could have contributed to this development.

Comparing the supply and use of silver in Tokugawa Japan the estimates used here are broadly consistent with each other. Given the speculative nature of the production estimates, the level of total production carries an amount of uncertainty. Since the timing and height of the peak output and the late Tokugawa output are mostly based on observations, these are the more reliable aspects of the production side estimates. The amount of silver used in export and currency is supported by more extensive data than the production side. There are, however, gaps in the use side data as well, such as the unknown amounts of silver used in the domestic market and illicit trade, which could plausibly account for the excess production. Therefore the difference between the supply and use estimates cannot simply be assumed to be an overestimation of the production side. Especially for the most important period of silver production, the 17th century, the supply and use totals seem very plausible.

5. Copper

Copper was also a major export commodity in the Tokugawa period. The level of output of copper is much less disputed than the output of silver, however. The much higher availability of data undoubtedly contributes to this fact. Export through Nagasaki, starting in honest in the 1640's was much better recorded than the earlier silver trade. When export data starts to show gaps in the 18th century, production data is much more complete than in the case of the silver mines. This is due in part to the fact that the copper mines were administrated in a far more centralised style. The fact that the data was recorded does not necessarily mean that it is all gathered in one place. There are a number of valuable sources that present data on the production or export of copper during the Tokugawa period, including works by Shimada (2006), Glamann (1953), Izawa (2013), Innes (1980), Sasaki (1983a, 1983b) and Kobata (1968, 1986). However, most of these works focus only on part of the Tokugawa period, typically the late 17th and 18th centuries, or on only one aspect of the copper market. In this section the goal is to gather and present data from both the copper supply and use sides for the entire Tokugawa period.

5.1. Copper supply

Copper was in many ways a successor to silver after deposits of that metal became more scarce. Copper mine openings were concentrated most heavily in the second half of the 17th century. (Sasaki, 1983b, pp. 179–181) Several silver mines, including the previously discussed Ikuno mine, expanded their production to include copper in order to stay operational. As mentioned earlier, by 1703 copper was mined at an impressive 243 locations around the country. (Innes, 1980, p. 568) Among these were the largest copper mines at Besshi, Ashio and Ani, in addition to the province of Mutsu which featured a large number of smaller mines. (Murakami, 2006, p. 628) The most important mining locations will be described briefly below. Their production is summarised in Figure 8.

5.1.1. Copper production

5.1.1.a. Besshi

The Besshi copper mine on the island of Shikoku was situated on bakufu land, but was managed by the Sumitomo family since its opening in 1691. In 1749 the Tatsukawa mine was removed from the control of the daimyō of Saijō and added to the Sumitomo mining operations. The reason for the

transfer was that the Tatsukawa mine was located on the same mountain as the Besshi mine and targeted the same copper vein. Production statistics on the Besshi mine are available for the whole period, owing to the fact that it was continuously operated by the Sumitomo company until the 1970s. (Shimada, 2006, p. 49)

Due to its association with the Sumitomo company and continued sizeable production the Besshi mine is perhaps the most famous copper mine of the period. Peak capacity reached over 1500 tonnes in 1698. Two decades later the mine stabilised at an output of 400 to 500 tonnes annually, which lasted until the 1870s, when it started growing quickly. Total production between 1691 and 1867 was around 100 000 tonnes. (Sumitomo Metal Mining Co., 1991, pp. 225–229)

5.1.1.b. Ani

The Ani mine was situated in the Akita domain in Dewa province in northern Honshū. The whole region was rich in copper deposits with numerous mines in operation. Ani was the biggest of these. While initially a silver and gold mine, its main production was switched to copper when supply of those ores dried up. Ani produced 130 000 tonnes of copper between 1670 and 1867. Its rate of production was roughly 400 tonnes per year before the end of the 17th century, and by the early 18th century it reached a peak of around 1800 tonnes. After that followed alternating periods of decay and growth, trending down to an output of about 400 tonnes around the end of the Tokugawa period. (Izawa, 2013, p. 18; Sasaki, 1983b, p. 184) In 1885 the Ani mine was sold to the Furukawa mining company and in the early 20th century it produced around 1400 tonnes per years. (Furukawa Mining Company, 1910, p. 21)

5.1.1.c. Ashio

Ashio is not mentioned in all overviews of major Japanese early modern copper mines. For instance, Innes (1980, p. 568) and Shimada (2006, p. 48) do not include it in their tables counting up the national production. Yet according to Izawa Eiji (2013, p. 18) it is the mine with the largest known total production during the Tokugawa period at close to 150 000 tonnes from 1610 to 1867. Production topped 1000 tonnes from the 1660s to the 1720s, peaking in the early 18th century. At the end of the Tokugawa period production had decreased to a few dozen tonnes. Ashio was privatised in 1871 and sold to the Furukawa company in 1877. Under Furukawa management production increased to 7600 tonnes in 1891, becoming the largest producer in Japan with around 40% of national production. (Murakami, 2006, p. 628; Shinohara, 1972, pp. 266–267)

5.1.1.d. Mutsu

Mutsu was the largest province of Tokugawa Japan, spanning most of northern Honshū. As in neighbouring Dewa province there were many small and medium-sized mines. Largest of these was the Osarizawa mine, a former gold mine. During most years between the late 17th and early 19th centuries it produced 200-400 tonnes of copper. (Izawa, 2013, p. 18) Another mine at Shirane produced 120-360 tonnes during the 1660s to 1680s. (Shimada, 2006, p. 49) Additionally, in the early 18th century there were several other mines that produced around 100 tonnes per year. (Kobata, 1956, pp. 179–180) Although the data is fragmented, during the 18th century the yearly output for the whole province seems to have ranged from 300 to 800 tonnes. By the 1840s however, production had decreased to around 100 tonnes. (Shimada, 2006, p. 48)

5.1.1.e. Ikuno

The Ikuno mine – also covered in the chapter on silver – had diversified into copper by 1708. Production rose from over 200 tonnes per year around 1710 to over 300 a few years later. Production mostly seems to have fluctuated around those levels until the 1780s when a downward trend started that brought levels down to 50 tonnes in the 1810s. (Kobata, 1956, p. 69, 1968, pp. 236–238; Shimada, 2006, p. 48)

5.1.1.f. National production

The production developments of copper mines for the Tokugawa period is shown in Figure 8, including 6 mines already mentioned and the Tada mine near Osaka. For the early 17th century only production data on the Ashio mine is available. There are a few mines that are known to have opened around the same time as the Ashio mine, but production amounts for them are not known. (Sasaki, 1983b, pp. 179–181) The second half of the 17th century saw more mines opening up and total production peaked in the early 18th century.

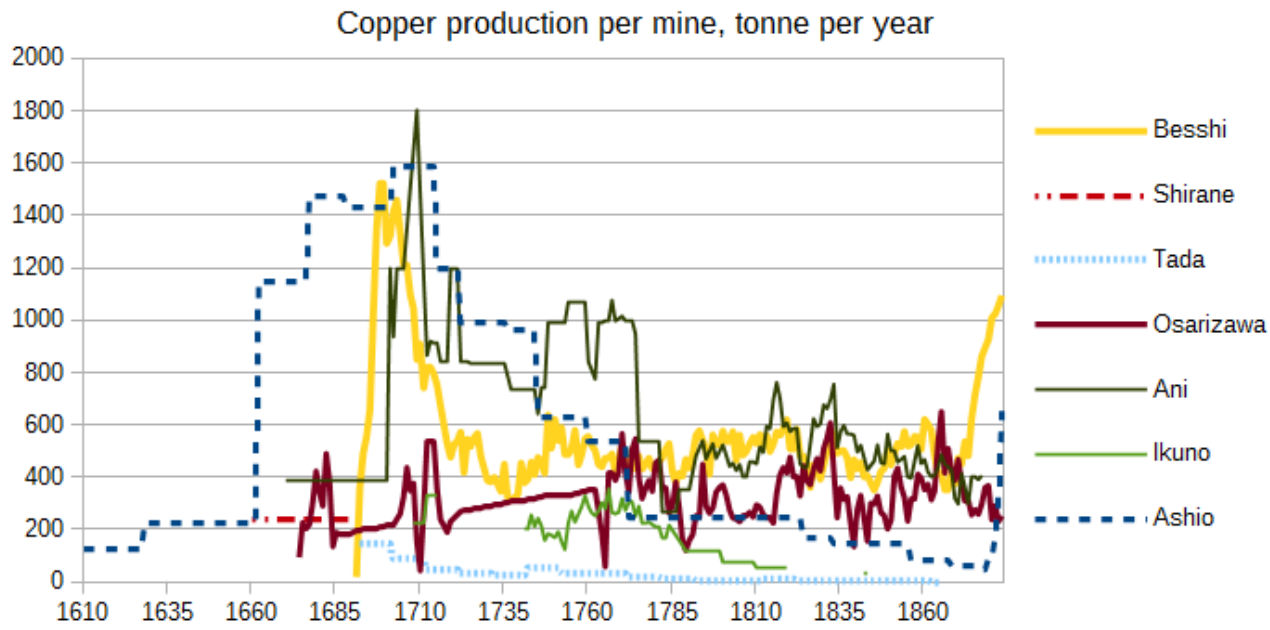

Figure 8: Copper production major mines

Sources: Ashio: (Murakami, 2006, p. 628); Tada: (Kobata, 1986, p. 242); Osarizawa: 1674-1685, 1765-1883: (Fumoto, 1964, pp. 56–57, 436–39)*, 1686-1764: (Izawa, 2013, p. 18); Ani: 1670-1700, 1811-1877: (Sasaki, 1983b, p. 184), 1701-1810: (Izawa, 2013, p. 18); Besshi:* (Sumitomo Metal Mining Co., 1991, pp. 225–29)*; Ikuno: 1741-1784, 1789-1819:*(Kobata, 1956, p. 69, 1986, pp. 236–38)*, 1785-1788: interpolated, 1842-1843: (Shimada, 2006, p. 48)*

5.1.2. Copper import

From the Heian (974-1185) through the sengoku (1476-1573) periods large amounts of Chinese copper coins flowed into Japan to serve as the country's money supply. Gradually Japanese imitations of these coins, called *bitasen*, came to replace the Chinese-made coins. By the late 16th century only “samples” were imported, to be used as a template for domestic mass production.(Von Glahn, 1996, pp. 89–95) Assuming copper imports had stopped by the beginning of the Tokugawa period, that leaves domestic production as the only supply for the period in review here.

5.2. Copper use

Data on the use of copper concerns mostly export. By far most of these exports were carried by the Dutch and Chinese traders at Nagasaki. During the early 17th century copper exports were sporadic and small in scale. From 1637 to 1646 exports stopped completely as copper output was reserved for the issue of new copper coins. As silver became increasingly scarce its export was restricted,

most notably by a ban on the export of silver coins in 1668. Copper took over silver's position as export commodity and exports increased. In 1685 the value of total imports at Nagasaki were limited, with a ratio of roughly 2:1 to the Chinese and Dutch respectively. In practice his new policy held copper exports at a level of around 3000 – 3500 tonnes per year. From 1695 a barter trade was allowed on top of the official quota, in response to a petition from a Japanese trading house that evidently had an abundant supply of copper to sell. Copper exports quickly reached 6000 tonnes, but this level could not be sustained and two decades after its start the barter system became obsolete. The quotas were lowered to 2700 tonnes in 1715, and further reduced to under 1900 tonnes in 1746. However, in most years the shogunate could not provide enough supply to the Nagasaki traders to reach these limits. (Gramlich-Oka, 2008)

The export through the Tsushima domain to Korea also shows a peak at the end of the 17th century. The shogunal restrictions mentioned above did not apply to this part of Japan's foreign trade. However, a 1695 recoinage, resulting in a silver coin of lower purity, hurt the desirability of Japanese silver coins for the Korean market. Immediately after the currency change Korean traders increased their copper imports, but they soon lost interest in the commodity. (Innes, 1980, pp. 599–601)

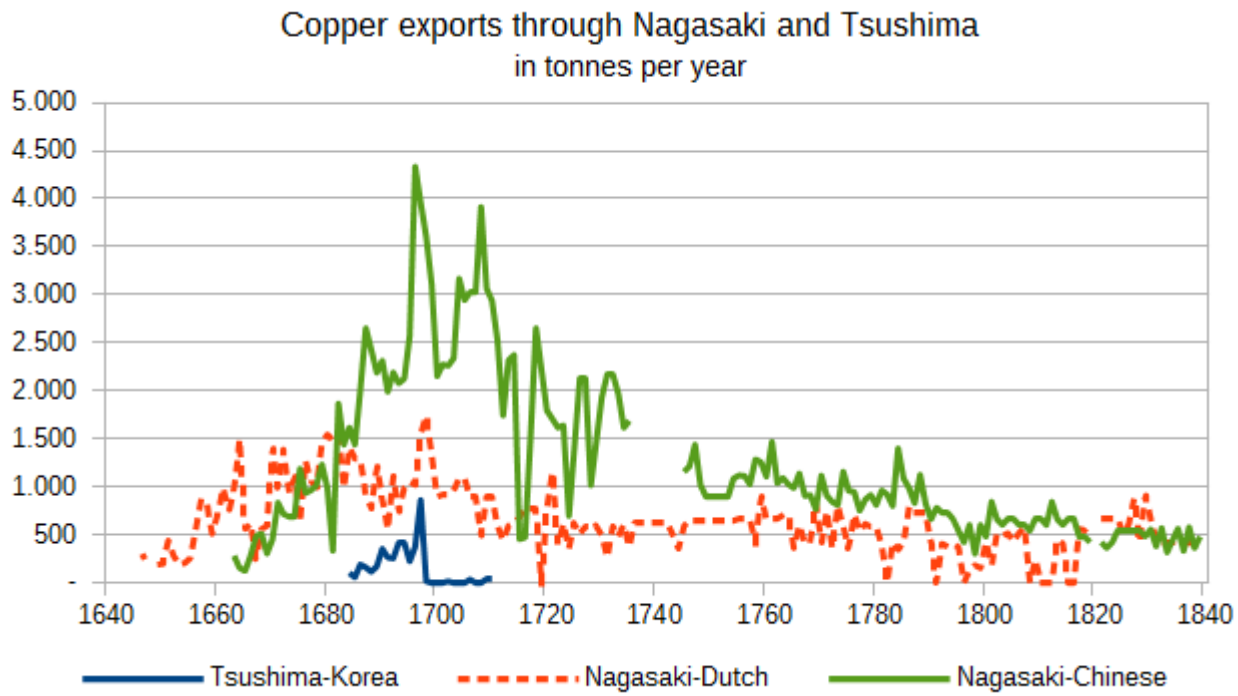

Figure 9: Export of copper from Nagasaki and through Tsushima

Sources: Tsushima: (Tashiro, 1981, p. 274); Dutch: 1646-1649: (Glamann, 1953, Table 1), 1650-1754, 1775-1777: (Shimada, 2006, p. 198); 1755-1774, 1778-1839: (Katsu, 1929, pp. 2–10)*; Chinese: 1650-1715:(Shimada, 2006, p. 199); 1716-1754: (Gramlich-Oka, 2008, p. 76); 1755-1839:* (Katsu, 1929, pp. 11–29)

5.3. Confronting copper supply and use

As in the case of silver, the supply and use sides of copper are confronted to determine the consistency of the data. Unlike for silver, there is no detailed information about the amount of copper used in coins. Fortunately there is a lengthy period for which relatively reliable data is available for both the production and export of copper to be confronted with each other.

As mentioned before, the only production information for the early Tokugawa period is on the Ashio mine. Production was almost certainly taking place at other locations as well, given the already-established copper coin manufacture and the opening of other mines around the same time as the Ashio mine. The fact that during the casting of the *Kanei tsūhō* coins from 1636 the export of copper was prohibited, suggests that domestic production at the time was large enough to allow for the making of the new coins, but not enough to permit exports at the same time. Unfortunately the

size of the coin issue is unknown. A late Tokugawa period issue of copper coins (*Bunkyū Eihō*, 1863-1869) took roughly 10 000 tonnes of copper.(Izawa, 2013, p. 15) Given that in the early Tokugawa period the population was smaller and the economy less monetised, the size of the Kanei coin emission was likely smaller, but perhaps still requiring some thousands of tonnes of copper.

In addition to the casting of coins, copper would have been used on the domestic market for utensils, religious statues, roof construction, etc. In the case of copper the allocation decision towards export or domestic was made by the bakufu. The copper for the two destinations was subsequently refined and cast to the appropriate specifications at the Osaka refineries. For 1708-1712 an average of 763 tonnes of copper per year was destined for the domestic market in this way. (Gramlich-Oka, 2008, p. 87) Since imports are assumed to be zero in the Tokugawa period, the domestic consumption plus export should in principle be equal to production. In Figure 10 the production and export series from the previous graphs are respectively added up and can be compared.

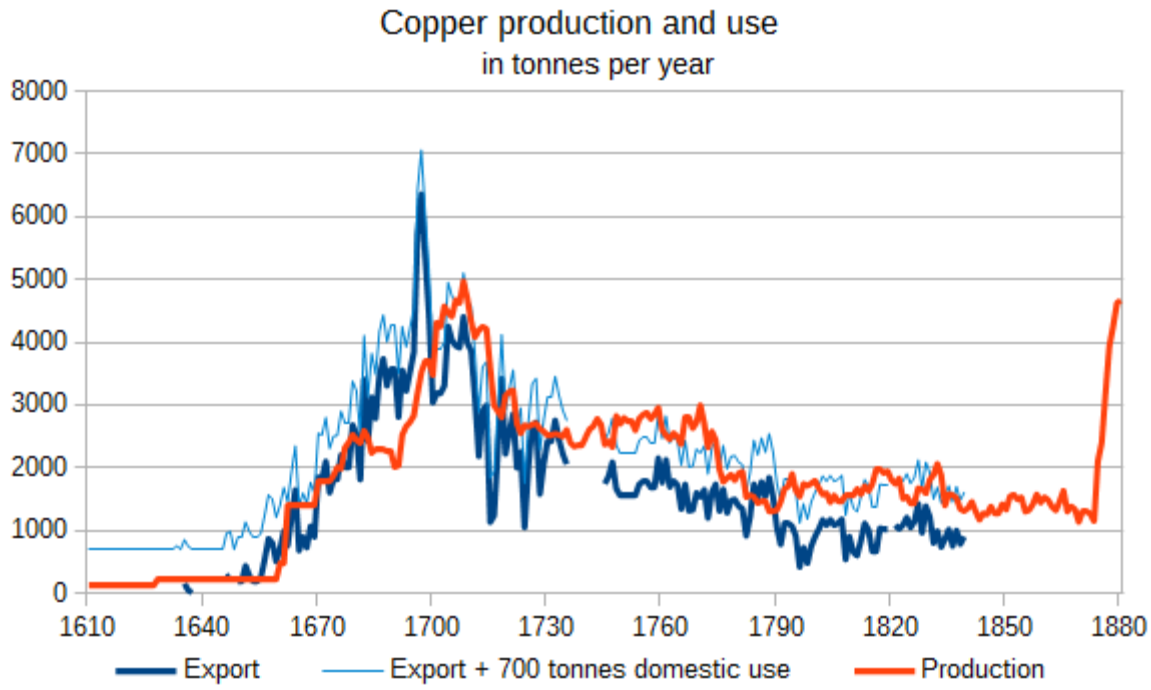

Figure 10: Production and use of copper

Sources: see Figure 8 and Figure 9, Production 1875-1880: (Shinohara, 1972, Table 51).

From around 1650 export and production roughly keep pace with each other until the mid-1680's, when output at Osarizawa and Ashio stagnated and the Ani and Besshi mines had not yet reached a high level of output. Meanwhile, copper exports plateaued at a level higher than recorded production, bound by a value limit for total exports starting in 1685. After 1695, when barter trade for copper was allowed, the difference between export and production grew even larger until exports dropped to a level below production from 1700. After that, production generally exceeded exports. Since in the long term production is expected to be higher than export, the reverse relationship between 1685 and 1700 is puzzling. Adding to this is the fact that in 1695 at least some trading houses had a surplus of copper, as evidenced by their petition to start the barter trade for copper. Assuming the export figures are correct, it is possible the production series is an underestimation. Not all mines are covered, possibly the biggest omission being the Tatsukawa mine, adjacent to Besshi. It opened in 1636 and in 1715, before being added to the Besshi mine, it had a production of over 400 tonnes. (Innes, 1980, p. 568; Sumitomo Metal Mining Co., 1991, p. 271)

The possible underestimation of production before 1700 does not even take account of domestic consumption. From 1700 to 1839, the final year of the exports series, the average surplus of production over exports amounted to 703 tonnes per year. Assuming domestic consumption was 700 tonnes per year, we can add that to the export figures to arrive at total use amounts. Looking at the total use series, the gap with production from 1685 to 1699 grows to nearly 2000 tonnes per year. Although not included in the review of production data of individual mines, two sources report national output in excess of the export figures in these years. In 1668 there was reportedly a peak output of 5400 tonnes (Sasaki, 1983a, p. 181), and in 1685 total production was reportedly 5200 tonnes (Yoshiki, 1980, p. 2). These estimates do not come with a breakdown of individual contributing mines, so it is not possible to say where the difference with the individual series total comes from. It is possible Tatsukawa had its peak output in these years and accounted for a substantial part of the missing output, but this is as yet unverified.

Given the possibility of underestimating the production before 1700, and the indication that there was excess supply, for these years the data on copper use seems more reliable than the data on copper production. After 1700 the production data seems more complete and forms a plausible total for export plus domestic use. Because of this, and the gaps in the export data in some of the later years, the production side data appears the best of the two after 1700.

6. Gold

The data available for the production of gold is much less broad than for silver copper. Not only is the number of mines with production data much smaller, it also spans a shorter time period, and sources on the other elements of gold use and supply are much less developed. First the known gold production will be presented, and subsequently the import and the use of gold will be discussed.

6.1. Gold supply

Gold mines had their period of high output around the same time as silver mines. In fact, some mines simultaneously produced both gold and silver in significant amounts. Sado island, already discussed in the silver chapter, was similarly prominent in Japanese gold production. The Sado mines were overseen by a governor on behalf of the bakufu. For most years Sado's actual production levels are unknown, but data on government royalties is known for many years. As discussed above, the government typically took between 25% - 50% of production. The revenues from the Sado mines for the 17th and early 18th century show an average of over 200 kilogrammes per year for the period 1615-1643, decreasing to an average of 90 kilogrammes per year until 1715. (Innes, 1980, p. 557) Conservative production estimates – using 50% royalties – imply production of less than 200 kilogrammes in the low-output years and around 400 kilogrammes per year during the peak.

Besides the island of Sado the other important location of gold mining was in the southern part of Kyushu in the territory of Satsuma han (Kagoshima), including mines at Yamagano and Serikano. Yamagano was operated by Satsuma han and had a much more pronounced output fluctuation. For 10 years around 1660 the average production was almost 1000 kilogrammes of gold, after which an exponential decay set in, ending in a yearly production of a few dozen kilogrammes. (Innes, 1980, p. 566)

For a few years gold production figures are available for the whole country and a number of important mines. This data puts national output at just under 600 kilogrammes in 1597, and around 800 kilogrammes per year around 1630. (Takekoshi, 1930b, pp. 416–17, 551–52) In these tallies the output from mines other than Sado was almost 450 kilogrammes in the former figure and just over 400 kilogrammes in the latter. In Figure 11 the national production estimate is presented, based on Sado royalty data,[15] Satsuma production data,[16] and total production data.[17] A second series is also

15 Up to 1715

16 From 1656 to 1727

17 For 1624-1635, 1699-1715

presented, which includes an estimate of the non-Sado production for those years where there is only data for the Sado output. This non-Sado production is set at 400 kilogrammes, at the lower amount indicated by the national total of 1630. According to these estimates, aggregate output was at a high point in the early 17th century, before being surpassed in the late 1650's when output at Yamagano peaked. After that output gradually decreased.

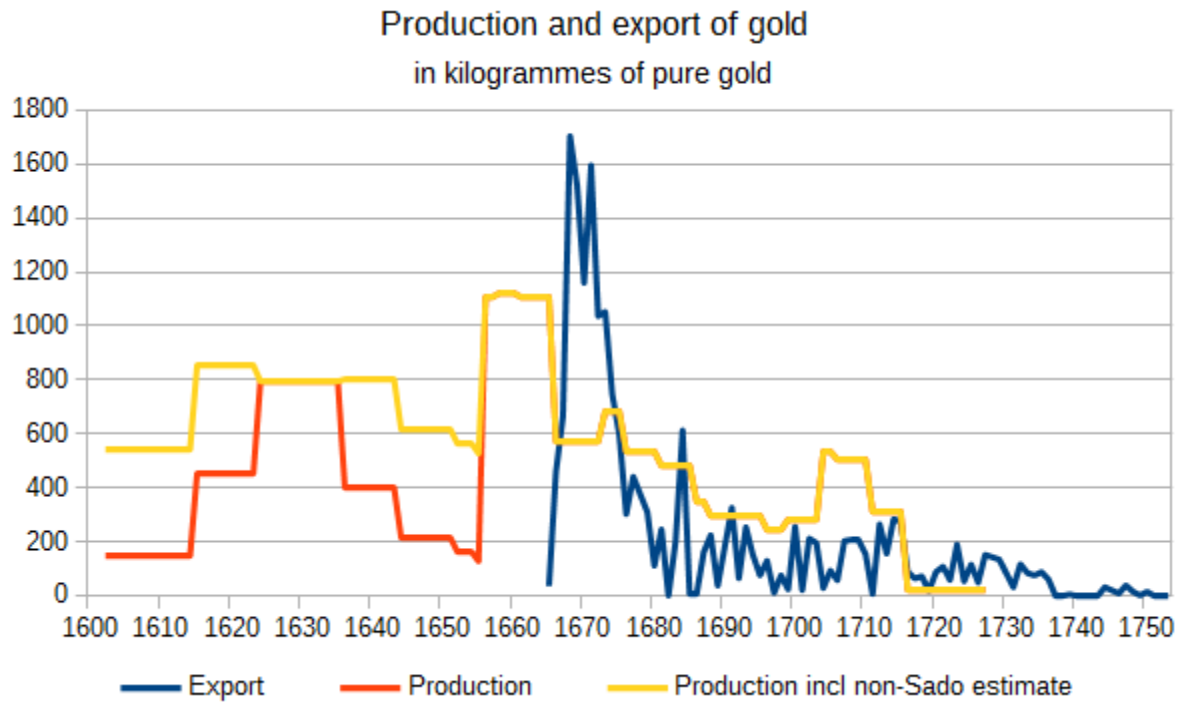

Figure 11: Production and export of gold

Sources: Export: (Gramlich-Oka, 2008, p. 69); Production: Total 1624-1635: (Takekoshi, 1930b, pp. 551–52)*, Sado: (Innes, 1980, p. 557; Takekoshi, 1930a, p. 371), Satsuma:* (Innes, 1980, p. 566; Takekoshi, 1930a, pp. 230–31)*, Other mines:* (Takekoshi, 1930a, pp. 230–31, 371)*; 1602-1623, 1636-1655: Non-Sado production estimated at 400 tonnes.*

As was the case for the silver trade, in the second half of the Tokugawa period Japan changed from a net exporter to a net importer. Not many statistics are available on this point, but Japan reportedly imported nearly 750 kilogrammes of gold per year from 1763 to 1815. (Takekoshi, 1930a, p. 406) In contrast to silver, this amount is relatively large compared to the historical gold production.

6.2. Gold use

Figure 11 also presents the amounts of gold exported during the middle of the Tokugawa period. These exports suddenly spiked after the ban on silver exports in 1668. As described in Chapter 3 the shogunate tried to shift the export focus to gold coins for a short time. However, according to, this shift to gold exports took place just as gold production fell. The fact that the exported gold was in coin form tells us that the exports were likely not from concurrent production, but rather from an existing stock of gold. In the long term the gold output was not enough to pay for Japan's imports. Eventually copper emerged as the main export commodity.

In the case of gold, the amount contained in the currency supply was very large relative to yearly production. In 1695 gold coins in circulation amounted to 10,6 million ryō.(Yamaguchi, 1963) At a purity of 84,5% and a weight of slightly less than 18 grammes, these coins in total contained about 160 tonnes of pure gold. Given the highest known yearly production during the Tokugawa period of 1125 kilogrammes, this represents 142 years of peak level output. Comparing this to the silver in circulation, at 471 tonnes (see Table 3) this represents 5 years of peak output (as estimated in Figure 6). The relatively large amount of gold in the currency supply means that it is crucial to estimate the yearly change of gold in circulation in order to compare the supply and use of gold in the economy. However, similarly as for silver, information on the gold in circulation is only available for a few specific years, making it impossible to estimate yearly changes. Moreover, the money supply at the start of the Tokugawa period is unknown.

Lastly, the domestic use of gold for decoration was responsible for an unknown part of the total use of gold. Similar to silver, this application of gold possibly increased as the Tokugawa period wore on, however data on this use is not available.

When it comes to estimating the production of the gold mining sector, the confrontation of supply and use data does not give any opportunity to test the data accuracy. The peak in gold exports was likely from existing stock of gold coins instead of from contemporary production. Gold coins in general formed a relatively large stock of gold. Without estimates of the stock at the beginning of the period, nor of the yearly change in the stock, this creates uncertainty for the total amount of gold used. Other domestic use of gold is even more uncertain. As the total use of gold is unknown, it can not possibly be compared to production or supply. Therefore, the production data will be used without the benefit of a consistency check.

7. Significance of the precious metals sector

In this section the significance of the precious metals mining sector will be shown by comparing the value of these activities with total GDP. Secondly, the importance of the sector will be discussed in terms of providing employment. And lastly the production volumes will be compared with the major international producers.

7.1. Value added

When studying modern economies one of the common ways to look at the importance of a certain sector is to look at its share in total Gross Domestic Product (GDP). It has not always been possible to do this for historical periods, but thanks to improvements in Japanese historical national accounts it can now be attempted. GDP estimates of the pre-modern Japanese economy have enjoyed growing interest from researchers, resulting in expansive time series stretching back to the 8th century. (Bassino, Broadberry, Fukao, Gupta, & Takashima, 2015) For the Tokugawa period these estimates use data on output from farming, forestry and fishing, which formed the main part of GDP. Production in the other sectors of the economy is estimated indirectly by looking at the relationship with urbanisation and population density in the Meiji period. Regression analysis is used separately for the secondary and tertiary sectors to determine how output in these sectors changes with changes in population density and urbanisation. The resulting coefficients were applied the to Tokugawa period using contemporary measures of urbanisation and population density. The idea behind this approach is that industry and services take place either in cities or in densely populated rural areas. The mining sector is not separately included in these estimates. However, it is included in the secondary sector estimates, which is correct in the sense that large mining operations tended to create substantial mining towns, which should be accounted for in the urbanisation rate. The same work includes estimates of Meiji period GDP, based on extensive source material such as the Long-Term Economic Statistics (LTES). The GDP estimates, provided at intervals of 10 to 50 years, have been linearly interpolated for this research to facilitate comparison with the mining output on a yearly basis.

With a GDP estimate in hand the remaining challenge lies in making the output of the precious metals mining sector comparable to these GDP series. By definition GDP measures the value added of industries. The value of intermediate goods and services should therefore be subtracted from the value of produced goods should. Mining is by its nature an activity that stands at the beginning of many production columns, which means the share of intermediate goods in the final production can

be expected to be relatively small. However, there were some intermediate inputs used in the mining and refining of precious metals, such as wood – both as fuel and for construction – and other metals, such as lead. The scarcity of data makes it problematic to construct detailed data on the value added share of production. The GDP shares calculated below therefore include supporting activities such as procuring wood and other metals.

The Japanese historical GDP series are expressed in terms of rice, since it was a major output of the Tokugawa economy, and it was used as a quasi money. In addition, because rice was such an important commodity, there are good historical price series for rice in terms of for instance silver or gold. Therefore, the best way to compare the precious metals mining output to total GDP is to first convert it to units of rice. It can then be easily expressed as a percentage of GDP. In the next sections the output of silver, copper and gold will be converted to rice values and compared to total GDP.

7.1.1. Silver

The silver production estimate was presented in Chapter 4. As noted there, the estimated total is higher for the silver supply than for the silver use, especially for the later Tokugawa period. However, the use estimate does not include illicit trade and domestic use outside the money supply. For the important period of high production before 1695, supply was only 14% higher than use. In addition the production series better reflect the timing of economic activity in the silver mining sector. There was a possibly substantial delay between production and export, which fact is supported by the export peak taking place in a later period. Therefore, despite the better coverage of export data, the production series will be used for the GDP comparison. The series is extended to 1909 by using the LTES series, which provides silver production in weight as well as in yen. See Figure 6 for the sources.

The output is converted from kilogrammes of pure silver to *koku*[18] of rice by using yearly rice prices in silver monme. The monme was a unit of account representing 3,75 grammes of silver. The price series used are mainly from the Hiroshima rice market (Iwahashi, 1981, p. 460; supplemented by Kin'yūkenkyūkai [Financial research group], 1937, pp. 1–18). However, during the Tokugawa period the purity of this silver differed according to the currency in circulation, which the silver price has to be adjusted for. This is done by using information on issue and validity dates of silver

18 A koku is about 150 kilogrammes, considered at the time the amount of rice necessary to feed a person for one year.

currency. (Nishikawa, 2000, p. 8)[19] The resulting price of pure silver expressed in koku of rice is presented in Figure 12. The value of a kilogramme of silver was over 30 koku around 1600, but it dropped to 16 koku by 1606. The silver value plateaued around that level until it fell to less than 10 koku per kilogramme in the 1630s. After a short rebound the value dropped to around 6 koku per kilogramme. In the long term, however, there was a rising trend starting in the early 18th century.

The falling value of silver is possibly a sign that the Japanese market became saturated with silver in the early Tokugawa period. The price fluctuations are of course equally a reflection of the value of rice as they are of silver. It should be noted that the turning point in the early 18th century takes place around a fundamental change in Japanese demography, when the country switched from a high population growth during the early Tokugawa period to virtual demographic stagnation. This could be an underlying process that explains part of the change in rice value. During the 17th century arable land and production per capita were falling, but from around 1720 arable land, land productivity and labour productivity started to increase.(Fukao et al., 2015, p. 239; Miyamoto, 2004b, p. 38) This fits the pattern of rice becoming gradually cheaper from that point on.

19 The purity of silver currency is in principle adjusted starting from the year after a major issue of silver at a different purity level. Generally a change of purity meant a lower purity. Under Gresham's Law – bad money drives out good – the adjustment of prices should have been relatively quick. During the Tokugawa period the purity of silver was increased only once, in the 1714 currency re-issue that raised it from 20% to 80%. The 20% silver was legal tender until 1719. For this case Gresham's law implies that people will hoard the good money and only spend the bad, and market prices would reflect that. In the case of rice prices they declined by 20% in the year following the issue of the new silver, but by 65% in the year the old silver left the market. Therefore the silver purity rate used in combination with the rice price is 20%, until 1719 when it is changed to 80%.

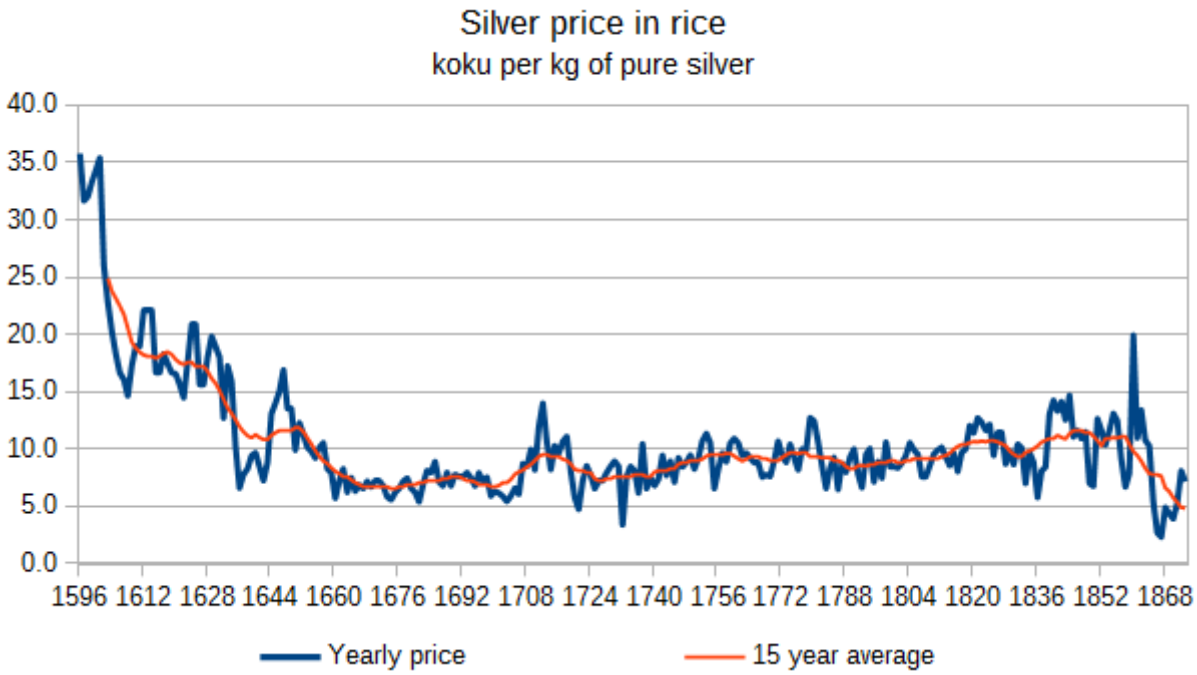

Figure 12: Silver value expressed in rice

Sources: 1620-1858: Hiroshima rice prices (Iwahashi, 1981, p. 460), 1596-1619, 1859-1873: (Kin'yūkenkyūkai [Financial research group], 1937, pp. 1–18, 9 years linearly interpolated), silver coin purity: (Nishikawa, 2000, p. 8)

The silver price in rice is used to calculate the value of the total production of silver expressed in terms of koku of rice in Figure 13. The resulting series shows three peaks above 1,5 million koku. From the 1620's the silver output declined quickly and silver values fell further. By the end of the Tokugawa period the output was worth only 20 to 40 thousand koku. The next step is to calculate the rice value into a GDP percentage using an interpolation of the GDP series from Fukao et al. (2015). The series is extended after 1873 by using silver production value in yen from the LTES (Shinohara, 1972, Table 49), and GDP in yen from Fukao et al. (2015, Table 3.1) Expressed in terms of GDP the output started above 3%, but declined even faster than the rice value, due to the fact that GDP grew from 44 million koku in 1600 to 130 million koku in 1874. During the Meiji period silver output climbed to 128 tonnes in 1909, and to a temporary peak of 223 tonnes in 1917 (not shown in the graph). (Schmitz, 1979, p. 149) Although the 1909 output was 34 tonnes higher that the Tokugawa peak, in the contemporary GDP this only made up 0,1%. As a reference, an additional GDP share series is given of the silver output estimate without the 10% supplement for small mines, i.e. just the output of the 4 large mines.

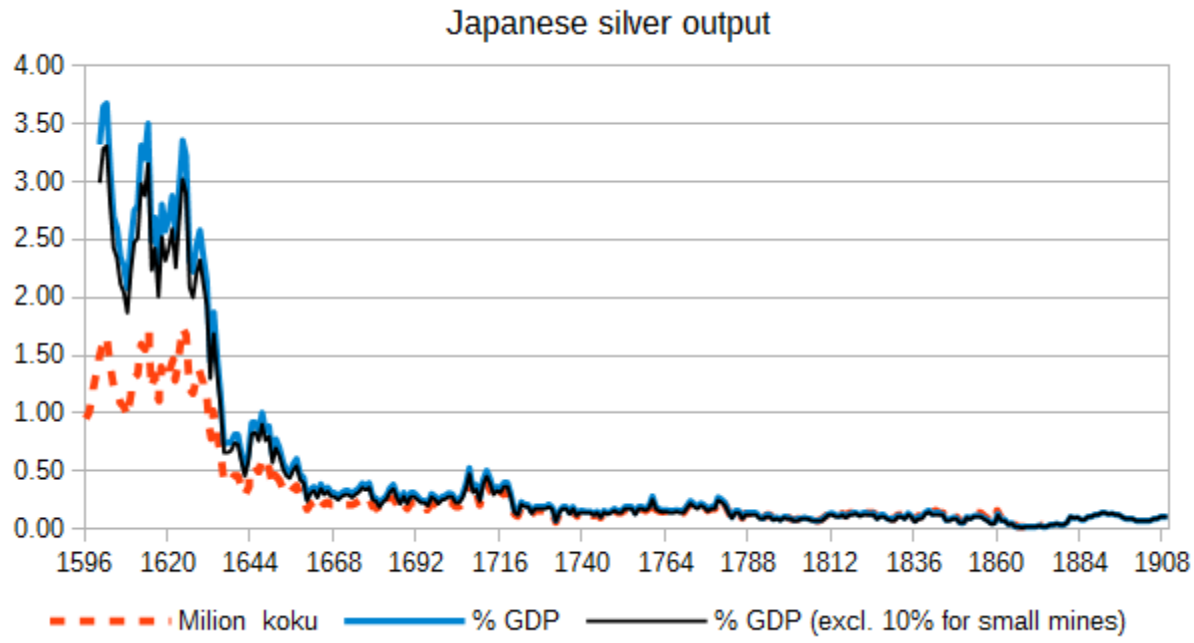

Figure 13: Japanese silver output converted to rice, GDP %

Sources: Production: See Figure 6, 1874-1909, production in yen:(Shinohara, 1972, Table 49) silver/rice price series: See Figure 12; GDP: (Fukao et al., 2015, Tables 3.1, A1.10)

7.1.2. Copper

The best estimate of copper production uses both the supply and use sides from Figure 10. Given the export figures and estimated domestic consumption, the production series before 1700 is likely an underestimation, as discussed in Chapter 5. Therefore the total use of copper – export plus domestic consumption – is adopted to estimate 17th century production. From 1700 the production series is used.

To calculate the copper production share of GDP it is again necessary to express this production in terms of koku of rice. Compared to silver and gold, converting the copper output to a rice amount presents a bigger challenge, however. Rice prices in terms of copper are much less common. The prices that are available are given in *mon*, the unit of copper currency. (see for instance Kin'yūkenkyūkai [Financial research group], 1937, pp. 1–18) The problem with using this unit is that the purity of the copper coins – called *sen* – is not well recorded, and during the second half of the Tokugawa period there were even sen made entirely of lesser materials like iron. As a result the value of 'copper' coins seems to have been fluctuating more in concordance with the issue of the coins than with the supply and demand of the raw material.(Takekoshi, 1930a, p. 448)

It would perhaps be more appropriate to look at the price of copper that was traded as a commodity, instead of as a coin. This trade has been most extensively described in context of its export, but as explained in Chapter 2 the prices recorded in those exchanges were virtual prices, artificially lowered by the Nagasaki traders to keep total trade within the import value restrictions. The domestic price for bulk copper was substantially higher than the official export price.(Gramlich-Oka, 2008, p. 89; Shimada, 2006, pp. 57–58) Domestic market prices for copper sold at the Osaka refineries were set by the bakufu. These consisted of the purchase price from the mine plus a fee for refining and other costs. These prices were given as an amount of silver monme per 100 *kin* (60 kg) of copper. (Imai, 1988, p. 55)

The purchase prices and domestic market prices for copper are available for certain years in the early and mid 18th century, see Table 6 in the appendix. In addition, for 1763 and 1764 there are both purchase and sale prices. In these two years the refinery margin came to around 35 monme per 60 kg of copper. This refinery margin can be used with purchase prices for 1766 – 1774 to estimate domestic sale prices for those years. According to these figures, the value of copper converted to silver climbed from just over 207 units of copper for each unit of silver in 1701, to a peak of 368 to 1 in 1717. After that the ratio dropped to 200-250 in the 1750's and to about 180 in the 1770s.

The domestic copper price expressed in silver can be used in combination with the rice price in silver to calculate a rice price in terms of copper. The results range from 30-40 koku per tonne of copper in the early 17th century to around 50 koku per tonne – with a wide margin – from 1751 to 1774. These years correspond respectively to periods of high and medium output. It is logical that the value of copper is lowest in the period of highest output, when the supply is large and the copper can be extracted with relatively little effort. After production fell below 2000 tonnes in 1775 prices could have risen above 50 koku per tonne. The copper production from Figure 10 (calculated from total use pre-1700) has been converted to a value in koku of rice using three price points based on domestic market prices. The series for prices of respectively 35, 50 and 70 koku of rice per tonne of copper are presented in Figure 14.

Using domestic bulk copper rates has a couple of arguments against it. First of all the years for which prices are available is limited. Secondly, copper exports outweighed domestic copper use by a factor of 2 to 1 during the Tokugawa period. Therefore, the price of copper on the international market might be more relevant. Compared to international rates copper was relatively cheap in Japan (or silver expensive) in those years for which prices are available. Let us first look at a few copper producing countries. In Norway the silver to copper price rate was 104 during 1718-1720,

and it averaged about 114 in the second half of the 18th century. In the UK the ratio dropped from 126 in the 1770s to 87 in the 1790s, possibly influenced by a rising demand for copper due to the UK's involvement in the French revolutionary wars. (based on, respectively, Norwegian and UK copper prices and European silver prices from Schmitz, 1979, pp. 268, 269, 273, 289)

Prices in Amsterdam for Norwegian and Swedish copper are available for many years in the 17th, 18th and mid-19th centuries. Coupled with the silver content of the Dutch Guilder coin the copper to silver price ratio can be calculated for the Amsterdam market. Between 1600 and the 1860s the silver to copper price ratio fluctuated mostly between 80 and 100 to 1, making copper relatively expensive there compared to Norway and the UK. The average of the linearly interpolated series for the period after 1650 to the 1860's is 89,8. (Own calculations based on Posthumus, 1946, Tables V, 173, 174) Prices for Japanese copper sold by the VOC in Amsterdam are also available for certain years during the second half of the 17th century and the first half of the 18th century. During 1689-1712 these prices resulted in an average silver to Japanese copper price ratio of 90,8. In the same years the Scandinavian copper had a ratio of 88,0 meaning Japanese copper was slightly cheaper. (Glamann, 1981, Table V)

Within Europe copper was slightly more expensive in Amsterdam than other markets, like Norway which was a producer country. A balance between prices in copper producing and non-producing countries leads to a silver to copper value rate of in the neighbourhood of 100 for the 17th to mid-19th centuries. This rate can be used to convert the copper production into silver amounts. Through the rice price in units of silver this can in turn be converted to rice amounts. In effect this is the same as using the series of Figure 12 divided by 100 as the copper price. The result is presented in Figure 14, both for the original and a 15 year average. The running average is added to smooth out some of the extreme fluctuations found in the silver rice price. As explained above, the purity of silver in circulation changed periodically, and although it has been corrected for, the process is only an approximation. In the case of copper the period of highest output coincides with a period of big changes to the silver purity (from 64% down to 20% and back up to 80% between 1695 and 1714). In addition there was a famine in 1714 that drove rice prices up sharply. (Miyamoto, 2004b, p. 61)

What is left is to make a choice of which price series to use. During the peak copper production years the international price series yield a similar amount of rice as the higher domestic price series of 70 koku per tonne. This is not unexpected, as international prices tend to be higher than the prices in producing countries. In Japan the restrictions on copper exports would have meant a possible oversupply of copper, which would have resulted in very low prices. In the second half of the Tokugawa period the price of rice falls, which is reflected in the international series as a rise in

the price of copper. This change is not reflected in the domestic rates, as they are fixed at the same price. Due to these circumstances, the international price 15 year running average will be used to convert the copper production value into rice.

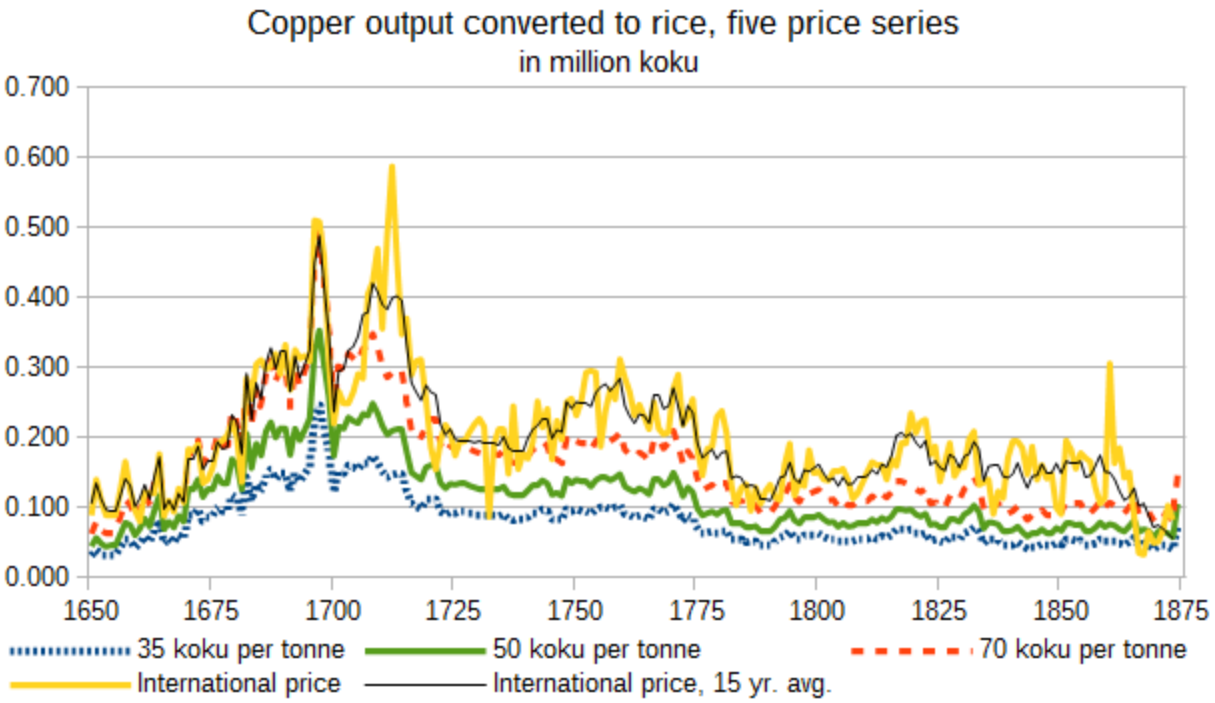

Figure 14: Copper output converted to rice by five price series

Sources: see text

The copper output in terms of rice is converted to a GDP percentage using the same interpolated GDP as described for the silver production. The production after 1873 is again a yen value taken from the LTES. (Shinohara, 1972, Table 49) In comparison with silver, the copper output made up a smaller part of GDP. Starting off around 0,2% of GDP, copper output rose relatively quickly to 0,4% and attained a short-lived peak at 0,6% around 1700. From 1725 production stabilised around 0,25% before dropping to a level of about 0,15% at the end of the 18th century. During the Meiji period, however, copper became a more important sector in the economy, almost reaching 0,9% of GDP in in 1907. Price changes diminished the GDP share again in 1908.

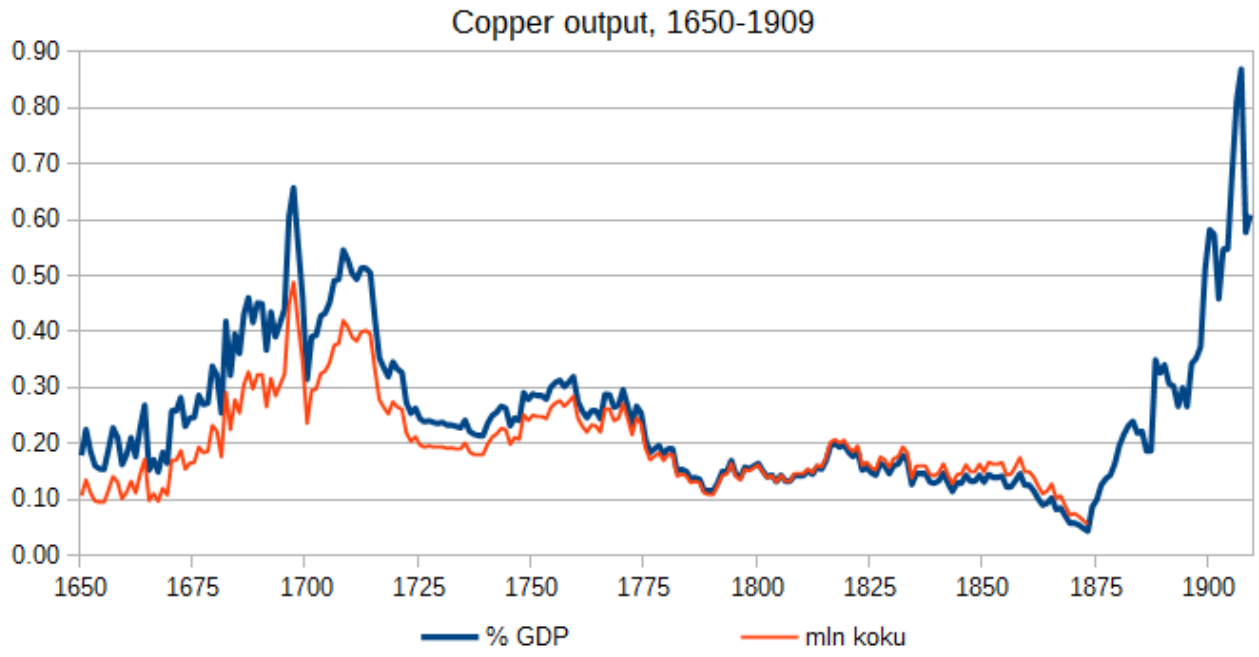

Figure 15: Copper output in terms of rice and GDP %

Sources: 1610-1873: see text, 1874-1909 production value: (Shinohara, 1972, Table 49)

7.1.3. Gold

For gold the same procedure will be followed as above. Production is taken from Figure 11 for 1602 to 1727. This is converted to rice amounts using the available market rates for rice in ryō, a gold coin of a set weight. Similar to the silver currency, these gold coins were of different purity levels, depending on the period. (Miyamoto, 2004b, pp. 60, 61) This has been corrected for, to arrive at the value of a kg of pure gold expressed in koku of rice, see Figure 16. Using this rate the output of gold in a rice equivalent value is calculated and presented in Figure 17. Two variants are shown here, one with the amount added for missing data on mines other than Sado in certain years. The other series does not include this imputation. Both series are further used to calculate a GDP share for the gold production, using the same reference GDP as above. The GDP share was highest in the first few decades of the 17th century, peaking at about 0,35% of GDP. The GDP share fell during the course of the 17th century until recorded output reached zero early in the 18th century.

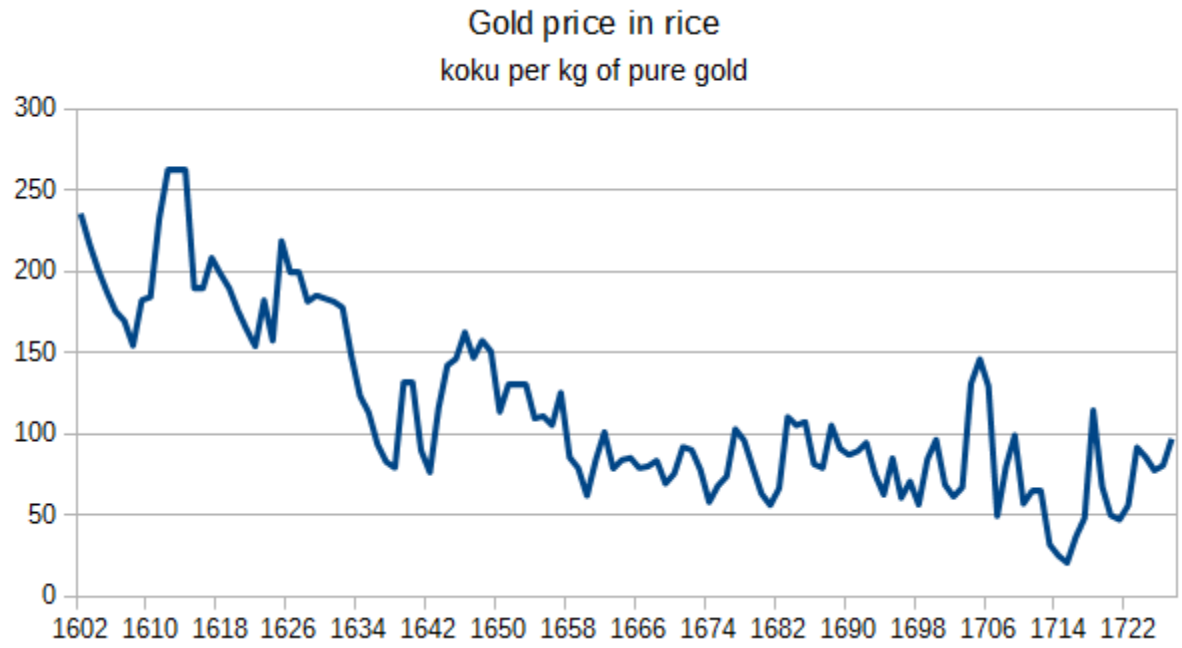

Figure 16: Gold value expressed in rice

Sources: Rice prices in ryō: (Kin'yūkenkyūkai [Financial research group], 1937, pp. 1–18, 6 years interpolated)*, Gold coin purity: (Miyamoto, 2004b, pp. 60, 61)*

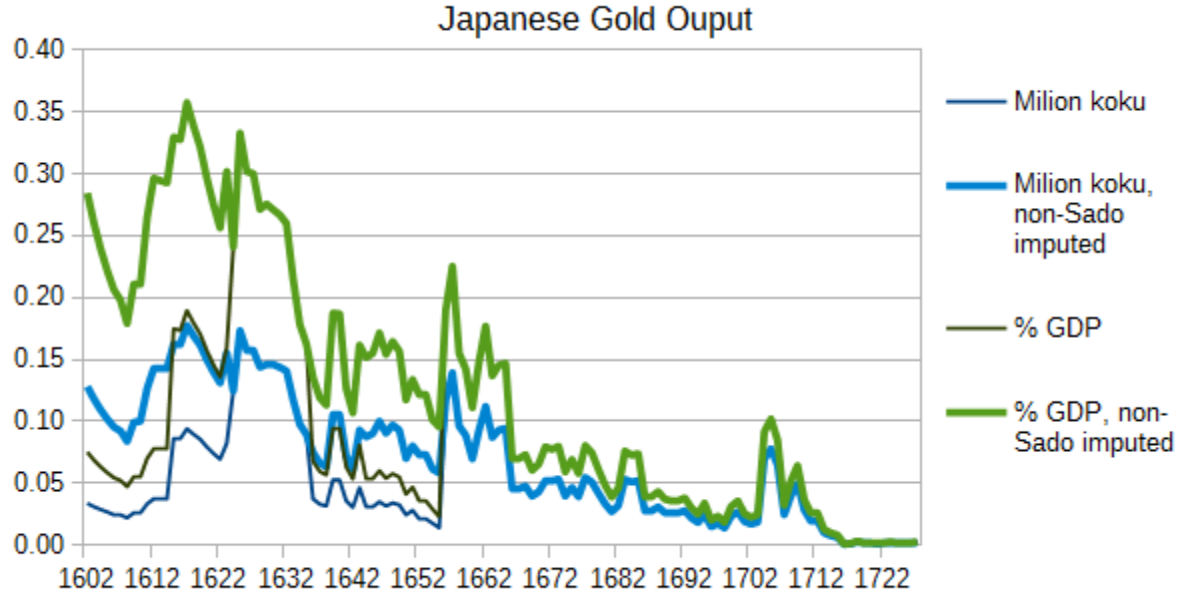

Figure 17: Gold output in terms of rice and GDP %

Sources: See Figure 11, GDP: *(Fukao et al., 2015, Table A1.10)*

7.1.4. Composite GDP share

Gathering the GDP shares for the three precious metals gives an overall picture of the importance of the these activities in the Tokugawa economy. Another point of interest is how these activities compared to the mining activities of the Meiji period. To that end, the GDP shares of coal mining and other mining activities are included from 1874. Figure 18 underscores the extent of the silver boom during the first half of the 17th century. At roughly 3% of GDP at its peak it was 6 times the size of the copper boom as a percentage of total economic activity. Gold production was the smallest sector of the three in terms of share of the economy. The fact that copper was able to fulfil a similar export role as silver, despite its smaller GDP share, is due to a number of factors. Silver had its peak at a time when it was relatively expensive in terms of rice, while copper had its peak when rice was relatively expensive in Japan (see Figure 12). Secondly, the size of the total economy had grown substantially in the time between peak silver production and peak copper production. In 1700 GDP was 69% larger than in 1600.(Fukao et al., 2015, Table A1.10) Another factor is the increasing self-sustainability of the Japanese economy by import substitution, which relieved pressure from the export commodities.

Another interesting point is the comparison between the early Tokugawa mining peak and with the Meiji period mining peak. After the start of the Meiji period mining was one of the booming sectors. By 1909 the entire mining sector made up 2,6% of GDP, a similar share as silver mining had by itself during its peak. However, the Meiji economy by 1909 was a much more industrialised economy. In the post-Tokugawa mining sector the dominant commodity was coal, followed by copper. Demand for Japanese coal by foreign powers was one of the factors that led to the opening up of the country, as mentioned in Chapter 3, so it is not surprising this sector would grow quickly. A detailed account of late Tokugawa period coal production is lacking, but coal output grew from a reported 1,4 million tonnes in the 1820's to 5,7 million tonnes in 1875. (Murakushi, 1980, p. 7; Shinohara, 1972, Table 51) By that later period it made up 0,25% of GDP. It is likely that the coal sector's share of GDP began to rival those of silver and copper sometime around the middle of the 19th century. Of the three metals that are the main focus of this paper, copper is the only one that during the Meiji period surpassed its Tokugawa period peak GDP share. By 1909 copper output volume was at 6,5 times its previous peak, while by the same measure silver production increased only 1,4 times, and gold 3,5.

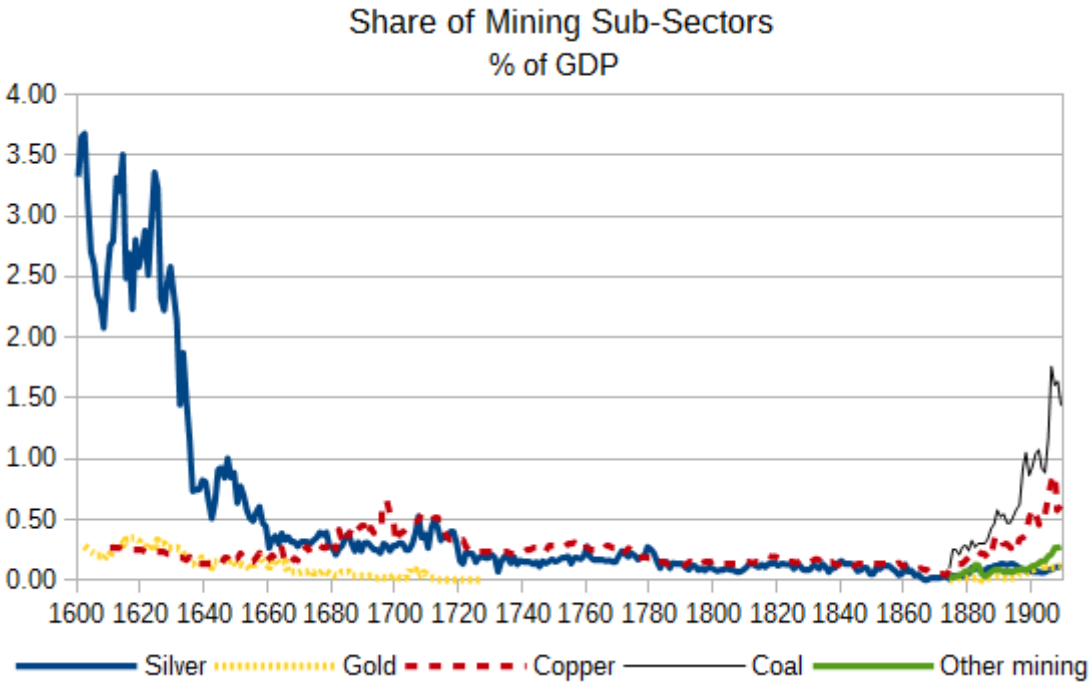

Figure 18: Share of mining sub-sectors in GDP

Sources: 1600-1873: see Figure 13, Figure 15 and Figure 17, 1874-1910: Mining output: (Shinohara, 1972, Table 49), *GDP: (Fukao et al., 2015, Table 3.1)*

It seems obvious that the regime change from Tokugawa to Meiji was the cause for the sudden growth in mining output, with international trade policy a prime suspect for the main catalyst. The exact causal chain is less obvious however. As stated above, exports of precious metals were by the late Tokugawa period not only hampered by trade restrictions and import substitution, the production capacity was also lacking. How then would the trade regulations have influenced production capacity?

There are parallels with the ascendence of Japan as a producer of precious metals in the 16th century. That blossoming of precious metals production was relatively near in time to the first contact with Portuguese traders and exchanges with Korean specialists that brought new refining techniques. Subsequently, silver and gold output increased, as did the attraction of Japan as a trade partner. It is easy to see how a virtuous cycle could set in where trade fosters sharing and advancement of technology, which increases production, which stimulates trade, in turn advancing technologies, and so on. From the 1630s, while the value of Japanese exports was not necessarily reduced, the number of contacts with the rest of the world was curtailed however. This hampered the sharing of technology and possibly slowed down this virtuous cycle. During the Meiji period the cycle would

have regained momentum with the opening up of Japan to more trade partners, and boosted by hiring foreign engineers.

7.2. Employment

Besides the value of the output, from a socio-economic perspective it can be illustrative to look at the jobs the precious metal mining sector provided. Additionally, the information can be used to calculate production per worker, to give some sense of the consistency and plausibility of the production figures. The information on the number of workers is quite scant, however, therefore only a broad impression can be given.

The mining sector of Tokugawa Japan employed a large number of workers, possibly upwards of 100 000 people. Total population at large mining towns during the silver peak in 1620 has been estimated at 180 000.(Innes, 1980, pp. 569–571) Given that total urban population increased from 1 to 3 million in these years, the mining towns would have made up a significant part of the city population. (Bassino et al., 2015, p. 28) Assuming that one third to half of the mining town population was employed in the mines and smelters, this would mean 60 000 – 90 000 people were directly employed in the mining sector. Adding employment at smaller mines, the total workforce could have been 100 000 or more. In the middle of the 17th century the workforce would have shrunk as gold and silver production decreased. As copper production increased, employment would have shifted to his sector. Between 1670 and 1715 employment in the copper sector, including in the Osaka refineries, was an estimated 30 000 – 50 000 thousand workers. The gold and silver sectors might have employed another 25 000 – 30 000 workers. (Innes, 1980, pp. 569–571)

At a national population of 17 million in 1600 and 21,8 million in 1650, 100 000 mining workers would have made up about 0,5% of the total population in the first half of the 17th century. (Fukao et al., 2015, Table A1.2) In the total working population, on which there is no estimate available, the silver workers would have constituted a larger part. Together they produced around 3% of GDP at the peak, or 15 koku of rice per worker. Compared to national income per capita of 2,6 – 2,7 koku this is relatively high, but not implausibly so.(Fukao et al., 2015, Table A1.10) First of all, national income per worker would be slightly higher than per capita income. Secondly, in the years of high production only an estimated 50% of the value of the mining output was used to pay for the mining costs. Additionally, the output would had to pay for certain inputs, like wood and charcoal. It follows that the final compensation per worker would have been only a fraction of that 15 koku, probably 5 koku or less. Given that this was the figure at the peak of the silver boom, it is not unlikely that compensation would have dropped in the later periods.

The copper sector workers would have made up 0,11% to 0,18% of the 28,1 million total population in 1700.(Fukao et al., 2015, Table A1.2) Again, as a share of the working population the percentage would be slightly higher. Copper production was on average 0,45% of GDP during the 30-year span surrounding 1700. This represents about 8 koku per worker, compared to national income per capita of 2,7 koku.(Fukao et al., 2015, Table A1.10) The bakufu did not take a share of the output of copper, but set a price at which copper was bought from the mines. The Osaka refineries also received a compensation and separate prices were in effect for the domestic and export trade. Due to this complicated and non-transparent system it is difficult to assess who ended up with which share of the income from copper. It is safe to say, however, that a worker ended up with substantially less than 8 koku per year.

Besides the direct employment in the mining sector, the trade in precious metals facilitated additional jobs. The traders in Nagasaki for instance, were dependent on silver, copper and gold as the main export products. This trade in turn supplied the Japanese silk weaving industry with raw materials, at least until import substitution took place. At the end of the 17th century the silk industry supported around 70 thousand people. (Innes, 1980, p. 10) Precious metals were of course also used in the domestic market. The size and exact make-up of this market is uncertain, but it would have provided jobs in fields such as minting, copper roofing and other metal crafts. H. Burger, a contemporary Dutch observer, who made a trip from Nagasaki to Edo (present-day Tokyo) in 1826, mentioned in particular the widespread and skilful copper craft that provided many people with a relatively good income. (Burger, 1836, p. 4)

7.3. International comparison

Judging the relative importance of the metal mining activities in Tokugawa Japan can be done not just by comparing it with the rest of the economy, but also with the rest of the world. In this section Japanese output of silver, copper and gold will be compared with the output volumes of prominent producing countries for each commodity. Most data is taken from C.J. Schmitz' *World non-ferrous metal production and prices, 1700-1976* (1979), supplemented with additional sources.

7.3.1. Silver

International silver output before the 18th century is based on *Summarized data of silver production* by C.W. Merrill (1930). He estimated Japanese silver production by looking at exports by Dutch, Portuguese and English traders – not including Chinese traders. By this method he arrives at an

estimate of 2 tonnes per year for the 17th century, less than half the estimate used in this paper. The three largest producers during this period were all Spanish possessions. Among them, Bolivia had the highest output, reaching over 200 tonnes per year from 1601 to 1620. In comparison, Japan during the 20 years around its peak (1611-1630) produced 77 tonnes of silver per year on average. Even by Merrill's underestimated output, Japan was the fourth-largest silver producer during the 17th century. Using the estimates from this paper, Japan might have held on to that ranking for the 18th century as well, although Mexico was by then a very dominant producer with an output of 500 tonnes per year. During the 19th century The United States achieved production on a similar scale as Mexico. After the Meiji period Japan quickly increased production and surpassed the previous peak, reaching 2%-3% of total world output by the 1910's.

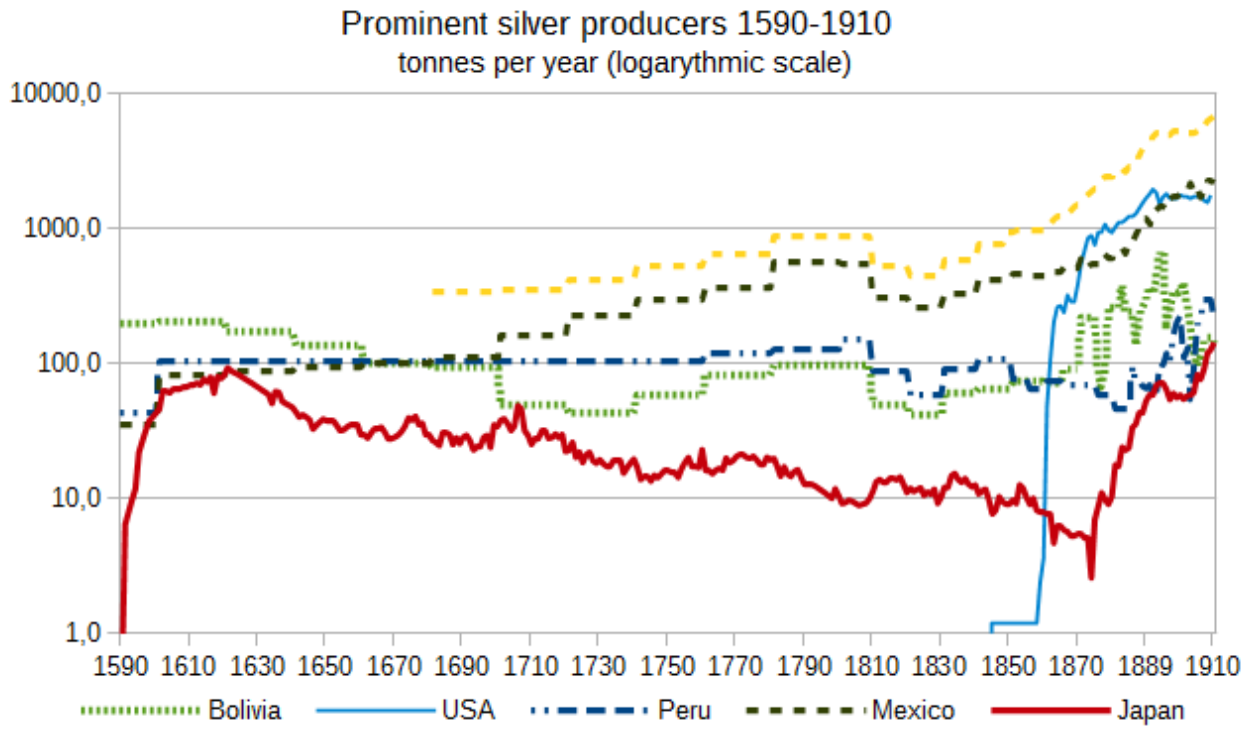

Figure 19: Prominent early modern silver producers

Sources: Japan: 1590-1873: See Figure 6, 1874-1910: (Shinohara, 1972, Table 51), *others:* (Merrill, 1930, pp. 29, 36, 40; Schmitz, 1979, pp. 143–159)

7.3.2. Copper

Copper output is less well described than both silver or gold, possibly due to its not being traditionally counted as a precious metal. For instance, for the period before 1800 Schmitz lacks the data for Japan, Sweden and China. He reports world data from 1726, but at a level lower than the

Japanese output estimated in this paper. From 1801 Schmitz' world output seems to match the rest of the data much better. The pre-19th century discrepancy underscores the lack of aggregated historical data on this topic.

The first big copper source for which detailed production data is available is the Falun mine in Sweden. By the estimates in this paper Japanese copper output surpassed it around 1670, becoming the world's largest copper producing country. Japanese output was suddenly overtaken by China, which reached 6000 tonnes per year around 1740. Output grew to around 7000 tonnes per year, but it is unclear exactly how long this was maintained. Next the UK, as the first industrialised country, took China's crown in the early 19th century. The UK in its turn was overshadowed by Chile and later the United States. After the end of the Tokugawa period Japan rapidly increased its copper production, growing from around 1% of world output to over 6% in 1890. From that date to 1910, despite still growing strongly, Japanese output growth was barely enough to keep up with world output growth.(Schmitz, 1979, pp. 66–69)

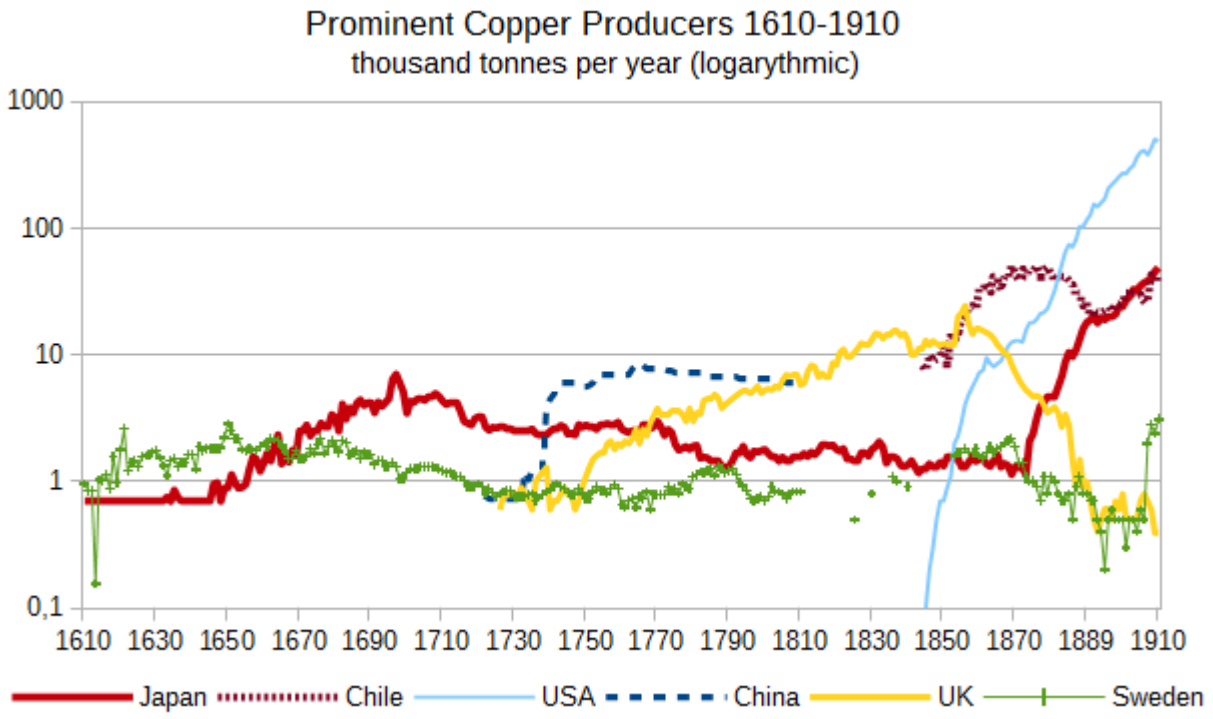

Figure 20: Prominent early modern copper producers

Sources: Japan: 1610-1873: See Figure 8 and Figure 9, 1874-1910: (Shinohara, 1972, Table 51), *China: (Izawa, 2013, p. 16), UK: 1790-1793: (Izawa, 2013, p. 16), 1726-1789, 1794-1910:* (Schmitz, 1979, pp. 61–78) *Sweden: 1610-1810: (Izawa, 2013, p. 1610), 1825-1910:* (Schmitz, 1979, pp. 61–78)*others:* (Schmitz, 1979, pp. 61–78)

7.3.3. Gold

According to the available information, gold production was dominated by Columbia and Brazil during the 17th and 18th centuries. During most of the 17th century Japan was likely the second or third largest producer, beating out Mexico and Peru. At its peak Japanese production might have been over 10% of world production, although world output for that period is highly speculative. During the 19th century Russia, the United States, Australia (not depicted) and South Africa successively became the world's largest producer. When Japan started producing gold again in appreciable amounts, output grew steadily to over 1% of world output in the 1910's.(Ridgway, 1929, p. 48)

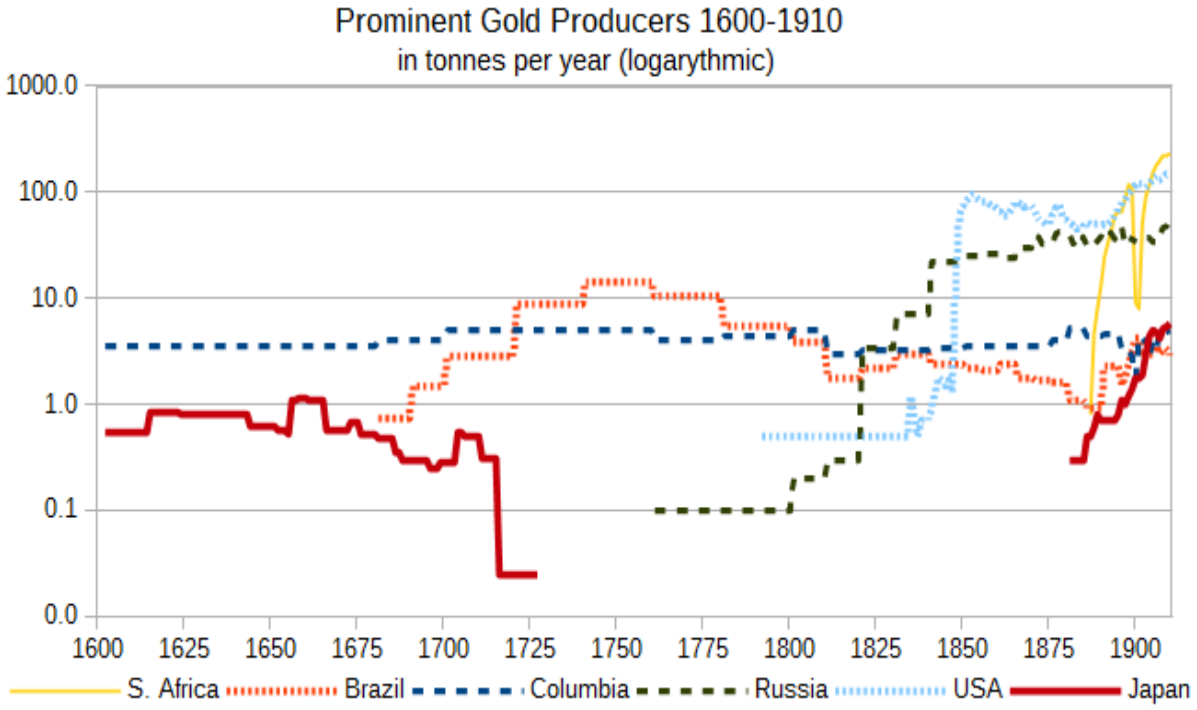

Figure 21: Prominent early modern gold producers

Sources: Japan: 1602-1727: see Figure 11, 1874-1910: (Shinohara, 1972, Table 51)*, others:* (Ridgway, 1929, pp. 34, 36; Schmitz, 1979, pp. 79–91)

8. Conclusion

The main goal of this study is to provide a comprehensive account of the production and economic importance of the precious metals mining sector in Early Modern Japan. Results based on interpolation show that silver production probably peaked around 1630, estimated at over 90 tonnes per year. Trade data corroborates production levels of this order of magnitude, in contrast to much higher trade figures suggested by Iwao (1966), Kobata (1965), Yamamura & Kamiki (1983) and others. In my opinion these are likely to be overestimations, due to the use of data from unrepresentative years. The higher values have been used to estimate a peak silver export value equal to 10% of *agricultural* output. This study finds that the peak value of silver production was equal to about 3% of GDP and falling quickly after 1630. Gold production peaked around he same time at an estimated value of about 0,35% of GDP. Copper production grew to an estimated peak of about 0,5% of GDP around the year 1700. The outcomes of this study are consistent with both the available supply side and the use side data. However, the domestic use of precious metals – especially outside the money supply – is a matter that is very much underexposed and could benefit from further study.

Compared to other production regions around the world, in its peak years the Japanese silver and copper mines were among the biggest producers in the world. Silver output was comparable to the main production centres in the Americas, and Japan lead the world in copper output for a time.

The production and subsequent trade in precious metals was heavily influenced by trade policy. In contrast to the word 'sakoku', usually used to describe Japanese international policy, Japan was not entirely closed off. Moreover, trade policy and the size and composition of imports and exports changed significantly over time. Previous work by Innes (1980) shows that for the first half of the Tokugawa period total foreign trade did not markedly decrease after the restriction of Nagasaki trade to the Chinese and Dutch. The precious metals production share of GDP did, however, show a sharp decrease after the 1630s, and copper mining did not achieve anywhere near the GDP share that silver mining had. Several circumstances worked together to cause this divergent development of foreign trade and mining GDP share. Partly this is a price effect caused by the early 17th century decreasing value of precious metals versus rice, which was the main agricultural product and the measurement unit used for GDP. In addition, the Japanese GDP grew by 69% between 1600 and 1700. (Fukao et al., 2015, p. 246)

Confrontation of supply and use side data also shows that there was often a delay between the production and export of precious metals, especially in the case of silver and gold. Production of silver peaked in the early 1620s, while exports peaked in the late 1630s and again around 1660. Copper on the other hand, had a more direct connection from mine to export. This combination of a delay in silver export, a short period of gold exports, and a relatively quick pick-up of copper exports, partly insulated total export values from supply shocks. This is another reason why foreign trade was sustained at a high level throughout the 17th and early 18th centuries. From the 18th century new export quotas reduced the export of copper, although over time supply failed to meet even these lower maximum amounts. This coincided with increasing import substitution, first of silk and later of sugar.

In the early Meiji period the mining mining industry experienced a boom. This was most pronounced for copper and coal, but silver and gold output also surpassed their Tokugawa period peaks. This boom period seems a response tot the opening up of the country. The sakoku trade restrictions primarily reduced the number of trade partners. Although volume or value restrictions were in place at times, these were frequently higher than production capacity. Consequently, the process through which the opening of the country would have stimulated the growth of mining production is more likely to be related to the increase in number of trade partners than a relaxation in trade volume restrictions. In my opinion a plausible mechanism is a virtuous cycle in which trade stimulates the spread of knowledge and technology, which increases production potential, in turn stimulating trade. This cycle ties together the main themes of this paper: the international trade policy of Tokugawa Japan, the technological and institutional setting of the precious metal sector, and the production and trade of silver copper and gold.

Appendix 1: Silver Mine Production Model

Table 5: Silver royalty estimates under assumption of 3-stage development

Mine/Stage	Type of change	Period	Royalty level at end of period	Observation
Sado				
Boom	Exponential growth	1614-1621	23 865	Royalty payment
Decline	Exponential decay	1622-1647	4 292	Royalty payment
Tail	Linear decay	1648-1867	349	Royalty payment
Ōmori				
Boom	Exponential growth	1589-1596	13 500	Royalty payment
Decline	Exponential decay	1597-1673	387	Production level
Tail	Linear decline	1674-1857	40	Production level
Ikuno				
Boom	Exponential growth	1591-1598	10 040	Royalty payment
Decline	Exponential decay	1599-1632	1 806	
Tail	Linear decline	1633-1863	617	Royalty payment*
Innai				
Boom	Exponential growth	1605-1612	10 040	
Decline	Exponential decay	1613-1638	1 806	
Tail	Linear decline	1639-1875	296	Production level

*Average of final two observations

The following equations describe the model for development of royalty payments:

Sado: $Y_{peak} = 23\ 865$ kg

Boom (t=0;7): $Y_t = 0{,}15604 * Y_{peak} * (1+0{,}30392)^t$ (2)

Decline (t=8;33): $Y_t = Y_{peak} * (1-0{,}06386)^{t-7}$ (3)

Tail (t=34;253): $Y_t = 0{,}17984 * Y_{peak} * (1-0{,}00418 * (t-33))$ (4)

Ōmori: $Y_{peak} = 13\ 500$

Boom (t=0;7): $Y_t = 0{,}15604 * Y_{peak} * (1+0{,}30392)^t$ (5)

Decline (t=8;84): $Y_t = Y_{peak} * (1-0{,}04509)^{t-7}$ (6)

Tail (t=85;268): $Y_t = 0{,}02865 * Y_{peak} * (1-0{,}00487 * (t-84))$ (7)

Ikuno: $Y_{peak} = 10\ 040$

Boom (t=0;7): $Y_t = 0{,}15604 * Y_{peak} * (1+0{,}30392)^t$ (8)

Decline (t=8;33): $Y_t = Y_{peak} * (1-0{,}06386)^{t-7}$ (9)

Tail (t=34;272): $Y_t = 0{,}17984 * Y_{peak} * (1-0{,}00276 * (t-33))$ (10)

Innai: $Y_{peak} = 10\ 040$

Boom (t=0;7): $Y_t = 0{,}15604 * Y_{peak} * (1+0{,}30392)^t$ (11)

Decline (t=8;33): $Y_t = Y_{peak} * (1-0{,}06386)^{t-7}$ (12)

Tail (t=34;270): $Y_t = 0{,}17984 * Y_{peak} * (1-0{,}00353 * (t-33))$ (13)

Royalty/Production relationship:

Royalty share of production in period t: $R_t = 0{,}25 + 0{,}25 * Y_t / Y_{peak}$ (14)

Appendix 2: Copper Prices

Table 6: Copper domestic bulk prices

Year	Purchase price monme/60 kg	Costs monme/60 kg	Domestic sale price monme/60 kg	Copper/ silver ratio	Koku rice per tonne copper
1701			121	206,6	29,8
1708			103,5 – 136	267,2	31,8
1709			101 – 136	270,0	37,0
1710			104,6 – 132,8	269,6	30,4
1711			121,3 – 194,4	316,8	37,9
1712			191,5 – 251,5	361,2	38,8
1717			195 – 240	367,8	29,0
1718	175 – 268	24 – 37	212 – 295,6	315,2	35,3
1738			270	128,8	51,0
1751			130 – 145	253,0	36,4
1752			130 – 146	252,0	42,6
1753			139 – 145	244,9	46,4
1754			143 – 197	204,6	51,5
1755			150 – 176	213,4	30,8
1756			153 – 164	219,4	37,7
1757			150 – 160	224,4	43,1
1758			150 – 153	229,6	38,8
1759			150 – 194	202,2	52,1
1760			160 – 195	196,0	55,8
1761			190 – 240	161,8	65,2
1762			194 – 248	157,4	59,9
1763	165 – 259		233 – 258	141,7	68,2
1764	209,5 – 234,5		242 – 276	134,3	68,7
1766	160,8	35	195,8	177,6	50,2
1767	158,4	35	193,4	179,9	42,1
1768	160,4	35	195,4	178,0	43,7
1769	159,5	35	194,5	178,8	42,7
1770	158,5	35	193,5	179,7	50,1
1771	157,8	35	192,8	180,4	59,3
1772	156,6	35	191,6	181,6	51,7
1773	159,1	35	194,1	179,2	49,5
1774	152,6	35	187,6	185,4	56,2

Sources: (Gramlich-Oka, 2008, p. 89; Imai, 1988, pp. 53, 55, 62, 65; Kobata, 1980, pp. 106–07; Shimada, 2006, pp. 57–58)*, 1766-1774 refinery costs and domestic sale prices: own estimate, based on 1763-1764 prices, copper/silver ratio corrected for silver coin purity.*

Appendix 3: Data supplement

This section contains the main descriptive statistics and outcomes for the three precious metals, in order, silver, copper and gold. For a detailed description of the sources, see the main text.

Table 7: Silver data

Year	Export	Money supply absorption	Import	Production	Price	Production	GDP share	GDP
	Tonne pure	Tonne pure	Tonne pure	Tonne pure	Koku per kg of pure	Million koku	%	Million koku
1596	23,3			26,7	35,8	0,95		
1597	23,3			31,9	31,7	1,01		
1598	23,3			37,7	32,1	1,21		
1599	23,3			40,2	33,3	1,34		
1600	23,3	4,9		43,1	34,3	1,48	3,33	44,5
1601	23,3	4,9		46,2	35,4	1,63	3,65	44,8
1602	23,3	4,9		63,7	26,0	1,66	3,68	45,1
1603	23,3	4,9		62,2	22,8	1,42	3,13	45,4
1604	23,3	4,9		60,8	20,3	1,24	2,70	45,7
1605	23,3	4,9		65,3	18,3	1,20	2,60	46,0
1606	23,1	4,9		65,4	16,7	1,09	2,35	46,3
1607	23,1	4,9		65,8	16,1	1,06	2,27	46,6
1608	23,1	4,9		66,5	14,7	0,98	2,08	46,9
1609	23,1	4,9		67,5	17,3	1,17	2,48	47,2
1610	23,1	4,9		68,8	19,0	1,31	2,75	47,5
1611	48,2	4,9		70,3	19,0	1,34	2,79	47,8
1612	48,2	4,9		72,0	22,2	1,60	3,32	48,1
1613	48,2	4,9		69,9	22,2	1,55	3,20	48,4
1614	48,2	4,9		77,0	22,2	1,71	3,51	48,7
1615	48,2	4,9		73,2	16,7	1,22	2,49	49,0
1616	47,7	4,9		79,8	16,7	1,33	2,69	49,3
1617	47,7	4,9		60,5	18,3	1,11	2,23	49,6
1618	47,7	4,9		80,3	17,5	1,40	2,81	49,9
1619	47,7	4,9		77,7	16,7	1,30	2,58	50,3
1620	47,7	4,9		82,2	16,6	1,36	2,70	50,6
1621	53,3	4,9		93,7	15,6	1,47	2,88	50,9
1622	53,3	4,9		88,7	14,5	1,29	2,51	51,2
1623	53,3	4,9		86,0	17,6	1,52	2,95	51,5
1624	53,3	4,9		83,5	20,8	1,74	3,36	51,8
1625	53,3	4,9		80,6	20,8	1,68	3,22	52,1
1626	37,5	4,9		77,7	15,6	1,22	2,32	52,4
1627	37,5	4,9		74,9	15,6	1,17	2,22	52,7
1628	37,5	4,9		72,1	18,0	1,30	2,45	53,0
1629	37,5	4,9		69,4	19,8	1,38	2,58	53,3

Year	Export	Money supply absorption	Import	Production	Price	Production	GDP share	GDP
1630	37,5	4,9		66,7	18,9	1,26	2,36	53,6
1631	64,1	4,9		64,1	18,0	1,16	2,14	53,9
1632	64,1	4,9		61,6	12,7	0,78	1,45	54,2
1633	64,1	4,9		59,2	17,3	1,02	1,87	54,5
1634	64,1	4,9		50,8	15,9	0,81	1,48	54,8
1635	64,1	4,9		62,4	10,3	0,64	1,16	55,1
1636	92,2	4,9		61,5	6,6	0,41	0,73	55,4
1637	92,2	4,9		52,7	7,8	0,41	0,74	55,7
1638	92,2	4,9		50,8	8,3	0,42	0,75	56,0
1639	92,2	4,9		49,2	9,4	0,46	0,82	56,3
1640	92,2	4,9		47,5	9,7	0,46	0,81	56,6
1641	38,9	4,9		44,0	8,5	0,37	0,65	56,9
1642	38,9	4,9		40,2	7,3	0,29	0,51	57,2
1643	38,9	4,9		42,0	8,8	0,37	0,64	57,5
1644	38,9	4,9		40,2	13,1	0,53	0,91	57,8
1645	38,9	4,9		38,5	14,0	0,54	0,93	58,2
1646	31,0	4,9		32,8	15,1	0,49	0,85	58,5
1647	31,0	4,9		34,9	16,9	0,59	1,01	58,8
1648	31,0	4,9		37,0	13,6	0,50	0,85	59,1
1649	31,0	4,9		38,9	13,6	0,53	0,89	59,4
1650	31,0	4,9		38,4	9,9	0,38	0,64	59,7
1651	32,3	4,9		37,9	12,3	0,47	0,78	60,0
1652	32,3	4,9		37,5	11,3	0,42	0,70	60,3
1653	32,3	4,9		34,7	10,2	0,35	0,58	60,6
1654	32,3	4,9		31,9	9,8	0,31	0,51	60,9
1655	32,3	4,9		32,5	9,2	0,30	0,49	61,2
1656	55,2	4,9		34,1	10,2	0,35	0,56	61,5
1657	55,2	4,9		35,6	10,5	0,38	0,61	61,8
1658	55,2	4,9		35,4	8,3	0,29	0,47	62,2
1659	55,2	4,9		34,9	8,0	0,28	0,45	62,5
1660	55,2	4,9		29,4	5,7	0,17	0,27	62,8
1661	60,5	4,9		29,7	7,3	0,22	0,34	63,1
1662	60,5	4,9		28,1	8,3	0,23	0,37	63,4
1663	60,5	4,9		30,7	6,3	0,19	0,30	63,7
1664	60,5	4,9		33,1	7,5	0,25	0,39	64,0
1665	60,5	4,9		33,5	6,3	0,21	0,33	64,3
1666	14,7	4,9		33,9	6,9	0,23	0,36	64,6
1667	14,7	4,9		31,1	6,6	0,20	0,31	65,0
1668	14,7	4,9		28,2	7,2	0,20	0,31	65,3
1669	14,7	4,9		27,4	6,7	0,18	0,28	65,6
1670	14,7	4,9		28,5	7,2	0,21	0,31	65,9
1671	19,4	4,9		29,6	7,2	0,21	0,32	66,2
1672	19,4	4,9		31,7	6,8	0,22	0,32	66,5
1673	19,4	4,9		34,7	5,8	0,20	0,30	66,8
1674	19,4	4,9		39,9	5,6	0,22	0,33	67,1
1675	19,4	4,9		38,2	6,2	0,24	0,35	67,4
1676	21,6	4,9		40,9	6,6	0,27	0,40	67,7

Year	Export	Money supply absorption	Import	Production	Price	Production	GDP share	GDP
1677	21,6	4,9		35,4	7,2	0,25	0,37	68,1
1678	21,6	4,9		36,4	7,5	0,27	0,40	68,4
1679	21,6	4,9		29,4	6,6	0,19	0,28	68,7
1680	21,6	4,9		29,6	6,2	0,18	0,27	69,0
1681	21,6	4,9		27,0	5,4	0,15	0,21	69,3
1682	21,6	4,9		26,2	6,9	0,18	0,26	69,6
1683	21,6	4,9		24,8	8,1	0,20	0,29	69,9
1684	21,6	4,9		31,3	8,0	0,25	0,36	70,2
1685	21,6	4,9		30,6	8,9	0,27	0,39	70,5
1686	8,7	4,9		29,9	7,1	0,21	0,30	70,9
1687	6,1	4,9		25,2	6,8	0,17	0,24	71,2
1688	7,5	4,9		28,3	8,0	0,23	0,32	71,5
1689	6,0	4,9		25,6	6,8	0,17	0,24	71,8
1690	6,7	4,9		28,6	7,8	0,22	0,31	72,1
1691	8,2	4,9		29,5	7,6	0,23	0,31	72,4
1692	7,3	4,9		26,9	7,6	0,21	0,28	72,7
1693	6,8	4,9		22,9	8,0	0,18	0,25	73,0
1694	7,7	4,9		24,5	7,5	0,18	0,25	73,3
1695	7,3	4,9		24,3	6,8	0,17	0,22	73,6
1696	7,3	24,8		28,5	7,9	0,23	0,31	74,0
1697	6,2	24,8		29,5	7,2	0,21	0,29	74,3
1698	3,4	24,8		24,0	7,5	0,18	0,24	74,6
1699	4,8	24,8		35,3	5,9	0,21	0,28	74,9
1700	3,8	24,8		34,2	6,3	0,22	0,29	75,2
1701	6,6	24,8		38,1	6,2	0,24	0,31	75,4
1702	4,3	24,8		39,1	5,9	0,23	0,30	75,6
1703	1,8	24,8		36,0	5,4	0,20	0,26	75,9
1704	3,2	24,8		32,0	5,9	0,19	0,25	76,1
1705	2,6	24,8		34,6	6,6	0,23	0,30	76,3
1706	3,1	24,8		48,9	6,1	0,30	0,39	76,5
1707	2,3	24,8		46,5	8,7	0,41	0,53	76,7
1708	2,4	24,8		31,8	8,5	0,27	0,35	77,0
1709	2,3	24,8		29,5	10,0	0,29	0,38	77,2
1710	1,5	24,8		25,3	8,2	0,21	0,27	77,4
1711	1,9	-21,9		27,7	12,0	0,33	0,43	77,6
1712	1,6	-21,9		28,1	14,0	0,39	0,51	77,8
1713	2,9	-21,9		31,7	10,7	0,34	0,43	78,1
1714	5,9	-21,9		31,4	8,2	0,26	0,33	78,3
1715	4,7	10,8		28,0	10,3	0,29	0,37	78,5
1716	4,2	10,8		28,4	9,7	0,27	0,35	78,7
1717	4,1	10,8		30,2	10,7	0,32	0,41	79,0
1718	2,9	10,8		28,3	11,1	0,31	0,40	79,2
1719	1,7	10,8		29,9	8,0	0,24	0,30	79,4
1720	2,3	10,8		22,3	5,8	0,13	0,16	79,6
1721	3,4	10,8		22,9	4,8	0,11	0,14	79,9
1722	4,9	10,8		26,2	7,2	0,19	0,24	80,1
1723	4,5	10,8		20,2	8,5	0,17	0,22	80,3

Year	Export	Money supply absorption	Import	Production	Price	Production	GDP share	GDP
1724	2,1	10,8		22,2	7,7	0,17	0,21	80,6
1725	1,2	10,8		18,6	6,6	0,12	0,15	80,8
1726	2,1	10,8		21,1	7,2	0,15	0,19	81,0
1727	3,8	10,8		22,1	7,2	0,16	0,20	81,3
1728	3,3	10,8		19,1	7,9	0,15	0,19	81,5
1729	4,1	10,8		18,3	8,5	0,16	0,19	81,7
1730	4,4	10,8		19,5	9,0	0,17	0,21	82,0
1731	4,8	10,8		18,2	8,5	0,15	0,19	82,2
1732	3,0	10,8		17,4	3,4	0,06	0,07	82,5
1733	2,1	10,8		17,1	7,6	0,13	0,16	82,7
1734	2,3	10,8		19,3	8,5	0,16	0,20	83,0
1735	2,9	10,8		19,0	8,1	0,15	0,19	83,2
1736	1,3	10,8		19,3	6,2	0,12	0,14	83,5
1737	1,5	4,7		15,5	10,5	0,16	0,19	83,7
1738	2,3	4,7		16,9	6,6	0,11	0,13	83,9
1739	1,8	4,7		18,4	7,5	0,14	0,16	84,2
1740	2,7	4,7		19,6	6,8	0,13	0,16	84,4
1741	2,3	4,7		17,1	7,4	0,13	0,15	84,7
1742	1,4	4,7		13,8	9,5	0,13	0,15	84,9
1743	0,3	4,7		14,8	7,7	0,11	0,13	85,2
1744	1,5	4,7		14,6	9,0	0,13	0,15	85,4
1745	0,8	4,7		13,5	7,1	0,10	0,11	85,7
1746	0,8	4,7		14,9	9,2	0,14	0,16	85,9
1747	0,8	4,7		14,3	8,5	0,12	0,14	86,2
1748	0,3	4,7		15,2	8,9	0,13	0,16	86,4
1749	0,9	4,7		16,1	9,5	0,15	0,18	86,7
1750	0,6	4,7		16,3	8,3	0,13	0,15	86,9
1751	0,3	4,7		15,7	9,2	0,14	0,17	87,1
1752	0,0	4,7		15,6	10,7	0,17	0,19	87,4
1753		4,7		14,4	11,4	0,16	0,19	87,6
1754		4,7		16,7	10,5	0,18	0,20	87,8
1755		4,7		18,6	6,6	0,12	0,14	88,0
1756		4,7		20,2	8,3	0,17	0,19	88,3
1757		4,7		17,3	9,7	0,17	0,19	88,5
1758		4,7		17,6	8,9	0,16	0,18	88,7
1759		4,7		17,0	10,5	0,18	0,20	88,9
1760		4,7		23,1	10,9	0,25	0,28	89,2
1761		4,7		16,4	10,5	0,17	0,19	89,4
1762		4,7		16,3	9,4	0,15	0,17	89,6
1763		4,7	2,7	15,3	9,7	0,15	0,16	89,8
1764		4,7	2,7	16,2	9,2	0,15	0,17	90,1
1765		4,7	2,7	16,8	8,9	0,15	0,17	90,3
1766		4,7	2,7	16,2	8,9	0,14	0,16	90,5
1767		4,7	2,7	20,0	7,6	0,15	0,17	90,8
1768		4,7	2,7	18,5	7,8	0,14	0,16	91,0
1769		4,7	2,7	19,1	7,6	0,15	0,16	91,2
1770		4,7	2,7	20,5	9,0	0,18	0,20	91,4

Year	Export	Money supply absorption	Import	Production	Price	Production	GDP share	GDP
1771		4,7	2,7	21,0	10,7	0,22	0,24	91,7
1772		4,7	2,7	21,2	9,4	0,20	0,22	91,9
1773		4,7	2,7	20,2	8,9	0,18	0,19	92,1
1774		4,7	2,7	19,9	10,4	0,21	0,22	92,3
1775		4,7	2,7	20,7	9,2	0,19	0,21	92,6
1776		4,7	2,7	19,4	8,2	0,16	0,17	92,8
1777		4,7	2,7	18,2	10,0	0,18	0,20	93,0
1778		4,7	2,7	18,2	9,9	0,18	0,19	93,2
1779		4,7	2,7	20,3	12,7	0,26	0,28	93,5
1780		4,7	2,7	19,4	12,5	0,24	0,26	93,7
1781		4,7	2,7	20,0	10,6	0,21	0,23	93,9
1782		4,7	2,7	17,3	8,5	0,15	0,16	94,2
1783		4,7	2,2	14,7	6,6	0,10	0,10	94,4
1784		4,7	3,2	17,3	8,3	0,14	0,15	94,6
1785		4,7	2,8	15,3	9,3	0,14	0,15	94,8
1786		4,7	3,3	14,6	6,5	0,09	0,10	95,1
1787		4,7	2,9	15,9	8,7	0,14	0,15	95,3
1788		4,7	3,4	16,4	8,0	0,13	0,14	95,5
1789		4,7	2,9	14,4	9,3	0,13	0,14	95,7
1790		4,7	1,9	13,0	10,0	0,13	0,14	96,0
1791		4,7	1,4	13,0	7,8	0,10	0,11	96,2
1792		4,7	2,1	12,9	6,6	0,09	0,09	96,4
1793		4,7	2,0	12,5	9,5	0,12	0,12	96,6
1794		4,7	2,0	12,0	10,1	0,12	0,12	96,9
1795		4,7	1,7	11,5	7,2	0,08	0,08	97,1
1796		4,7	0,8	11,0	8,9	0,10	0,10	97,3
1797		4,7	1,3	10,5	7,5	0,08	0,08	97,5
1798		4,7	0,9	10,0	10,6	0,11	0,11	97,8
1799		4,7	1,4	11,8	8,5	0,10	0,10	98,0
1800		4,7	1,7	10,5	8,5	0,09	0,09	98,2
1801		4,7	1,9	9,2	8,4	0,08	0,08	98,5
1802		4,7	2,2	9,4	8,8	0,08	0,08	98,9
1803		4,7	2,0	9,8	9,5	0,09	0,09	99,2
1804		4,7	2,2	9,5	10,6	0,10	0,10	99,5
1805		4,7	2,0	9,2	9,9	0,09	0,09	99,8
1806		4,7	2,1	8,9	9,6	0,08	0,08	100,1
1807		4,7	2,2	9,1	7,7	0,07	0,07	100,5
1808		4,7	1,0	9,3	7,6	0,07	0,07	100,8
1809		4,7	1,7	10,0	8,6	0,09	0,08	101,1
1810		4,7	1,2	11,3	9,6	0,11	0,11	101,4
1811		4,7	1,1	13,3	9,9	0,13	0,13	101,7
1812		4,7	1,6	13,9	10,2	0,14	0,14	102,0
1813		4,7	2,1	13,4	9,3	0,13	0,12	102,4
1814		4,7	1,9	13,1	8,6	0,11	0,11	102,7
1815		4,7	1,2	14,1	9,6	0,14	0,13	103,0
1816		4,7	1,2	13,9	8,1	0,11	0,11	103,3
1817		4,7	1,9	13,8	9,7	0,13	0,13	103,6

Year	Export	Money supply absorption	Import	Production	Price	Production	GDP share	GDP
1818		4,7	1,9	14,5	10,0	0,15	0,14	103,9
1819		-3,8	1,9	12,7	12,1	0,15	0,15	104,3
1820		-3,8	0,0	11,1	11,4	0,13	0,12	104,6
1821		-3,8	2,0	12,0	12,7	0,15	0,15	104,9
1822		-3,8	1,9	11,3	12,3	0,14	0,13	105,2
1823		-3,8	2,0	11,7	11,6	0,14	0,13	105,5
1824		-3,8	2,2	12,1	12,2	0,15	0,14	105,9
1825		-3,8	1,9	10,6	9,5	0,10	0,09	106,2
1826		-3,8	2,1	11,2	11,4	0,13	0,12	106,5
1827		-3,8	2,6	10,8	11,4	0,12	0,12	106,8
1828		-3,8	1,8	11,8	8,7	0,10	0,10	107,1
1829		-3,8	2,6	9,2	9,9	0,09	0,08	107,4
1830		-3,8	2,3	10,3	8,7	0,09	0,08	107,8
1831		-3,8	1,5	12,2	10,4	0,13	0,12	108,1
1832		-3,8	1,8	12,1	10,1	0,12	0,11	108,4
1833		-18,0	1,4	14,7	7,0	0,10	0,10	108,7
1834		-18,0	1,6	15,4	9,7	0,15	0,14	109,0
1835		-18,0	1,9	13,9	8,9	0,12	0,11	109,3
1836		-18,0	1,4	13,2	5,8	0,08	0,07	109,7
1837		-18,0	1,8	14,2	8,1	0,11	0,10	110,0
1838		-18,0	1,4	12,8	8,4	0,11	0,10	110,3
1839		-18,0	1,7	12,3	13,1	0,16	0,14	110,6
1840		-18,0		12,6	14,3	0,18	0,16	110,9
1841		-18,0		10,8	13,3	0,14	0,13	111,3
1842		-18,0		11,4	14,1	0,16	0,14	111,6
1843		-18,0		11,8	12,6	0,15	0,13	111,9
1844		-18,0		9,8	14,7	0,14	0,13	112,2
1845		-18,0		7,7	11,1	0,09	0,08	112,5
1846		-18,0		8,2	11,6	0,10	0,08	112,8
1847		-18,0		10,3	10,9	0,11	0,10	113,2
1848		-18,0		9,5	11,5	0,11	0,10	113,5
1849		-18,0		9,2	7,0	0,06	0,06	113,8
1850		-18,0		9,1	6,8	0,06	0,05	114,1
1851		-18,0		9,8	12,7	0,12	0,11	114,8
1852		-18,0		9,2	11,6	0,11	0,09	115,4
1853		-18,0		12,7	10,4	0,13	0,11	116,1
1854		-18,0		11,9	11,6	0,14	0,12	116,8
1855				10,2	13,1	0,13	0,11	117,4
1856				9,1	12,5	0,11	0,10	118,1
1857				10,1	9,1	0,09	0,08	118,8
1858				8,2	6,7	0,05	0,05	119,5
1859				7,9	7,9	0,06	0,05	120,1
1860				8,1	20,0	0,16	0,13	120,8
1861				7,8	11,0	0,09	0,07	121,5
1862				7,6	13,4	0,10	0,08	122,1
1863				4,7	10,8	0,05	0,04	122,8
1864				6,2	10,3	0,06	0,05	123,5

Year	Export	Money supply absorption	Import	Production	Price	Production	GDP share	GDP
1865				6,2	5,4	0,03	0,03	124,1
1866				5,8	2,7	0,02	0,01	124,8
1867				5,7	2,3	0,01	0,01	125,5
1868				5,4	4,9	0,03	0,02	126,1
1869				5,2	4,4	0,02	0,02	126,8
1870				5,4	3,9	0,02	0,02	127,5
1871				5,5	5,3	0,03	0,02	128,1
1872				5,2	8,1	0,04	0,03	128,8
1873				5,0	7,2	0,04	0,03	129,5

Table 8: Copper data

Year	Export	Domestic consumption	Production	International price, 15 year average	Production	GDP share
	Tonne	Tonne	Tonne	Koku per kg of copper	Million koku	%
1610		700	122	0,188	0,132	0,277
1611		700	122	0,185	0,129	0,270
1612		700	122	0,182	0,128	0,265
1613		700	122	0,181	0,127	0,262
1614		700	122	0,180	0,126	0,259
1615		700	122	0,179	0,126	0,256
1616		700	122	0,181	0,127	0,257
1617		700	122	0,184	0,129	0,259
1618		700	122	0,185	0,129	0,259
1619		700	122	0,183	0,128	0,254
1620		700	122	0,178	0,125	0,247
1621		700	122	0,176	0,123	0,242
1622		700	122	0,174	0,122	0,238
1623		700	122	0,175	0,123	0,239
1624		700	122	0,176	0,123	0,238
1625		700	122	0,173	0,121	0,232
1626		700	122	0,173	0,121	0,231
1627		700	122	0,172	0,120	0,229
1628		700	225	0,168	0,118	0,222
1629		700	225	0,162	0,113	0,213
1630		700	225	0,157	0,110	0,206
1631		700	225	0,151	0,106	0,196
1632		700	225	0,144	0,100	0,185
1633	58	700	225	0,136	0,103	0,189
1634		700	225	0,131	0,092	0,168
1635	157	700	225	0,126	0,108	0,196
1636	51	700	225	0,120	0,090	0,162
1637	11	700	225	0,115	0,082	0,147
1638		700	225	0,112	0,078	0,140
1639		700	225	0,110	0,077	0,137
1640		700	225	0,113	0,079	0,139
1641		700	225	0,110	0,077	0,136
1642		700	225	0,109	0,076	0,133
1643		700	225	0,108	0,076	0,132
1644		700	225	0,112	0,079	0,136
1645		700	225	0,114	0,080	0,138
1646	257	700	225	0,116	0,111	0,189
1647	286	700	225	0,116	0,114	0,195
1648		700	225	0,116	0,081	0,137
1649	189	700	225	0,117	0,104	0,175
1650	197	700	225	0,119	0,107	0,179
1651	439	700	225	0,119	0,135	0,225
1652	278	700	225	0,115	0,113	0,187

Year	Export	Domestic consumption	Production	International price, 15 year average	Production	GDP share
1653	187	700	225	0,110	0,097	0,160
1654	204	700	225	0,104	0,094	0,155
1655	254	700	225	0,099	0,094	0,154
1656	549	700	225	0,094	0,117	0,191
1657	871	700	225	0,090	0,141	0,228
1658	803	700	225	0,087	0,131	0,211
1659	509	700	225	0,084	0,101	0,162
1660	704	700	465	0,081	0,113	0,180
1661	988	700	465	0,079	0,133	0,211
1662	760	700	1 390	0,077	0,112	0,176
1663	1 229	700	1 390	0,075	0,145	0,228
1664	1 649	700	1 390	0,073	0,172	0,269
1665	683	700	1 390	0,071	0,098	0,152
1666	901	700	1 390	0,069	0,111	0,171
1667	732	700	1 390	0,068	0,097	0,149
1668	1 069	700	1 390	0,068	0,120	0,184
1669	900	700	1 390	0,067	0,108	0,165
1670	1 850	700	1 780	0,067	0,170	0,258
1671	1 822	700	1 780	0,068	0,170	0,258
1672	2 103	700	1 780	0,067	0,188	0,282
1673	1 606	700	1 780	0,067	0,154	0,231
1674	1 803	700	1 874	0,066	0,165	0,246
1675	1 817	700	2 007	0,066	0,167	0,247
1676	2 205	700	1 984	0,067	0,194	0,286
1677	2 014	700	2 323	0,068	0,184	0,270
1678	2 007	700	2 408	0,069	0,186	0,272
1679	2 682	700	2 527	0,069	0,232	0,339
1680	2 528	700	2 446	0,069	0,222	0,322
1681	1 814	700	2 393	0,070	0,176	0,254
1682	3 410	700	2 594	0,071	0,292	0,419
1683	2 427	700	2 486	0,072	0,225	0,322
1684	3 125	700	2 238	0,073	0,278	0,396
1685	2 790	700	2 292	0,073	0,255	0,361
1686	3 471	700	2 287	0,073	0,306	0,432
1687	3 737	700	2 287	0,074	0,328	0,461
1688	3 307	700	2 250	0,074	0,298	0,417
1689	3 568	700	2 250	0,076	0,324	0,452
1690	3 561	700	2 015	0,076	0,325	0,450
1691	2 808	700	2 038	0,076	0,266	0,367
1692	3 555	700	2 524	0,074	0,317	0,435
1693	3 227	700	2 662	0,073	0,285	0,391
1694	3 529	700	2 729	0,072	0,305	0,415
1695	3 843	700	2 831	0,071	0,324	0,441
1696	5 732	700	3 192	0,070	0,448	0,606
1697	6 363	700	3 520	0,069	0,488	0,658
1698	5 364	700	3 698	0,068	0,414	0,556
1699	4 439	700	3 703	0,067	0,346	0,462

Year	Export	Domestic consumption	Production	International price, 15 year average	Production	GDP share
1700	3 040	700	3 477	0,068	0,237	0,315
1701	3 191	700	4 315	0,068	0,295	0,391
1702	3 190	700	4 251	0,070	0,298	0,394
1703	3 304	700	4 576	0,071	0,325	0,428
1704	4 256	700	4 474	0,074	0,330	0,433
1705	4 034	700	4 413	0,078	0,345	0,452
1706	3 947	700	4 678	0,080	0,376	0,491
1707	3 916	700	4 628	0,082	0,379	0,494
1708	4 408	700	4 975	0,085	0,420	0,546
1709	3 989	700	4 705	0,087	0,409	0,529
1710	3 871	700	4 332	0,090	0,390	0,504
1711	3 117	700	4 085	0,094	0,383	0,494
1712	2 185	700	4 193	0,095	0,399	0,513
1713	2 911	700	4 249	0,095	0,402	0,515
1714	2 994	700	4 220	0,094	0,396	0,506
1715	1 135	700	3 598	0,093	0,334	0,425
1716	1 242	700	2 998	0,093	0,278	0,353
1717	2 273	700	2 900	0,091	0,265	0,335
1718	3 424	700	2 803	0,090	0,253	0,319
1719	2 222	700	3 153	0,087	0,275	0,346
1720	2 563	700	3 214	0,083	0,265	0,333
1721	2 860	700	3 239	0,081	0,261	0,327
1722	2 001	700	2 703	0,081	0,219	0,273
1723	2 255	700	2 551	0,080	0,204	0,254
1724	1 051	700	2 681	0,079	0,212	0,264
1725	2 037	700	2 655	0,074	0,197	0,244
1726	2 644	700	2 690	0,072	0,194	0,239
1727	2 727	700	2 709	0,072	0,196	0,241
1728	1 583	700	2 624	0,074	0,194	0,238
1729	2 072	700	2 578	0,075	0,193	0,236
1730	2 426	700	2 534	0,077	0,195	0,238
1731	2 433	700	2 532	0,076	0,192	0,233
1732	2 757	700	2 547	0,075	0,192	0,233
1733	2 450	700	2 523	0,076	0,191	0,231
1734	2 220	700	2 499	0,076	0,189	0,228
1735	2 060	700	2 605	0,077	0,201	0,242
1736		700	2 399	0,077	0,185	0,222
1737		700	2 342	0,077	0,181	0,217
1738		700	2 355	0,076	0,179	0,214
1739		700	2 366	0,077	0,181	0,216
1740		700	2 489	0,080	0,199	0,236
1741		700	2 615	0,081	0,212	0,250
1742		700	2 663	0,082	0,217	0,256
1743		700	2 779	0,082	0,227	0,267
1744		700	2 690	0,084	0,225	0,264
1745	1 748	700	2 369	0,084	0,199	0,232
1746	1 867	700	2 425	0,087	0,211	0,246

Year	Export	Domestic consumption	Production	International price, 15 year average	Production	GDP share
1747	2 091	700	2 331	0,089	0,208	0,241
1748	1 666	700	2 828	0,089	0,251	0,291
1749	1 548	700	2 697	0,090	0,241	0,279
1750	1 548	700	2 798	0,090	0,251	0,289
1751	1 548	700	2 741	0,090	0,248	0,285
1752	1 548	700	2 730	0,092	0,250	0,286
1753	1 548	700	2 599	0,094	0,244	0,279
1754	1 737	700	2 782	0,095	0,264	0,301
1755	1 778	700	2 848	0,096	0,272	0,309
1756	1 773	700	2 879	0,096	0,277	0,314
1757	1 685	700	2 781	0,096	0,267	0,301
1758	1 705	700	2 854	0,096	0,275	0,310
1759	2 155	700	2 959	0,096	0,285	0,320
1760	1 765	700	2 609	0,094	0,245	0,275
1761	2 128	700	2 518	0,092	0,231	0,258
1762	1 697	700	2 456	0,090	0,220	0,246
1763	1 793	700	2 555	0,091	0,233	0,260
1764	1 726	700	2 490	0,093	0,231	0,257
1765	1 346	700	2 376	0,093	0,220	0,244
1766	1 738	700	2 810	0,093	0,261	0,288
1767	1 316	700	2 815	0,093	0,261	0,287
1768	1 330	700	2 634	0,092	0,241	0,265
1769	1 601	700	2 723	0,090	0,245	0,269
1770	1 535	700	2 999	0,090	0,271	0,296
1771	1 652	700	2 711	0,091	0,245	0,268
1772	1 202	700	2 325	0,093	0,216	0,235
1773	1 613	700	2 580	0,095	0,246	0,267
1774	1 739	700	2 445	0,096	0,236	0,255
1775	1 313	700	1 977	0,097	0,192	0,207
1776	1 657	700	1 777	0,096	0,171	0,184
1777	1 284	700	1 837	0,097	0,178	0,191
1778	1 478	700	1 893	0,097	0,183	0,197
1779	1 496	700	1 803	0,094	0,170	0,181
1780	1 392	700	1 909	0,094	0,179	0,191
1781	1 351	700	1 939	0,093	0,180	0,192
1782	919	700	1 535	0,092	0,142	0,150
1783	1 219	700	1 566	0,093	0,145	0,154
1784	1 741	700	1 539	0,093	0,142	0,151
1785	1 504	700	1 440	0,090	0,130	0,137
1786	1 776	700	1 468	0,090	0,132	0,139
1787	1 548	700	1 473	0,088	0,130	0,137
1788	1 844	700	1 316	0,085	0,112	0,117
1789	1 551	700	1 323	0,084	0,111	0,116
1790	1 056	700	1 327	0,083	0,110	0,115
1791	782	700	1 460	0,086	0,125	0,130
1792	1 128	700	1 666	0,086	0,143	0,148
1793	1 109	700	1 707	0,085	0,145	0,150

Year	Export	Domestic consumption	Production	International price, 15 year average	Production	GDP share
1794	1 068	700	1 903	0,086	0,164	0,170
1795	911	700	1 637	0,086	0,142	0,146
1796	421	700	1 544	0,087	0,135	0,139
1797	729	700	1 745	0,088	0,154	0,158
1798	483	700	1 715	0,088	0,151	0,155
1799	753	700	1 753	0,089	0,157	0,160
1800	906	700	1 797	0,090	0,162	0,165
1801	1 023	700	1 676	0,089	0,149	0,151
1802	1 171	700	1 578	0,088	0,139	0,140
1803	1 087	700	1 595	0,089	0,143	0,144
1804	1 178	700	1 453	0,090	0,131	0,131
1805	1 086	700	1 563	0,092	0,144	0,144
1806	1 118	700	1 463	0,091	0,133	0,133
1807	1 181	700	1 475	0,091	0,134	0,134
1808	542	700	1 577	0,092	0,145	0,144
1809	904	700	1 579	0,092	0,145	0,143
1810	662	700	1 575	0,092	0,145	0,143
1811	602	700	1 665	0,093	0,154	0,152
1812	843	700	1 579	0,094	0,148	0,145
1813	1 115	700	1 710	0,095	0,162	0,158
1814	1 008	700	1 634	0,097	0,158	0,154
1815	662	700	1 749	0,100	0,175	0,170
1816	662	700	1 977	0,103	0,203	0,196
1817	1 041	700	1 975	0,105	0,207	0,200
1818	1 027	700	1 919	0,105	0,201	0,194
1819	1 027	700	1 948	0,106	0,206	0,198
1820		700	1 809	0,107	0,193	0,185
1821	1 088	700	1 745	0,106	0,185	0,177
1822	1 028	700	1 830	0,107	0,196	0,186
1823	1 088	700	1 509	0,107	0,161	0,152
1824	1 208	700	1 542	0,108	0,167	0,157
1825	1 051	700	1 452	0,108	0,157	0,148
1826	1 148	700	1 437	0,106	0,153	0,143
1827	1 426	700	1 678	0,105	0,176	0,165
1828	966	700	1 662	0,103	0,171	0,160
1829	1 391	700	1 597	0,098	0,157	0,146
1830	1 220	700	1 809	0,096	0,173	0,161
1831	803	700	1 890	0,093	0,177	0,164
1832	993	700	2 064	0,094	0,194	0,179
1833	740	700	1 885	0,097	0,183	0,169
1834	867	700	1 402	0,099	0,138	0,127
1835	1 017	700	1 584	0,100	0,159	0,145
1836	755	700	1 566	0,103	0,161	0,147
1837	1 002	700	1 520	0,106	0,161	0,147
1838	785	700	1 345	0,108	0,145	0,131
1839	906	700	1 313	0,109	0,143	0,129
1840			1 358	0,109	0,148	0,134

Year	Export	Domestic consumption	Production	International price, 15 year average	Production	GDP share
1841			1 460	0,112	0,164	0,147
1842			1 307	0,110	0,144	0,129
1843			1 175	0,109	0,128	0,114
1844			1 274	0,114	0,145	0,129
1845			1 261	0,116	0,146	0,130
1846			1 383	0,117	0,162	0,144
1847			1 293	0,116	0,150	0,133
1848			1 289	0,115	0,149	0,131
1849			1 422	0,115	0,163	0,143
1850			1 337	0,111	0,149	0,131
1851			1 546	0,108	0,166	0,145
1852			1 572	0,103	0,162	0,140
1853			1 499	0,109	0,163	0,141
1854			1 529	0,109	0,166	0,142
1855			1 303	0,110	0,144	0,122
1856			1 328	0,110	0,146	0,123
1857			1 423	0,112	0,159	0,134
1858			1 577	0,111	0,175	0,147
1859			1 446	0,104	0,151	0,126
1860			1 533	0,098	0,150	0,125
1861			1 487	0,095	0,141	0,116
1862			1 380	0,090	0,124	0,101
1863			1 322	0,084	0,110	0,090
1864			1 466	0,079	0,115	0,094
1865			1 637	0,078	0,128	0,103
1866			1 306	0,078	0,102	0,082
1867			1 387	0,077	0,106	0,085
1868			1 338	0,066	0,089	0,070
1869			1 140	0,063		
1870			1 299	0,058		
1871			1 302	0,054		
1872			1 270	0,049		
1873			1 153	0,049		

Table 9: Gold data

Year	Export	Production[20]	Price	Production	GDP share
	Kg pure gold	Kg pure gold	Koku/kg pure gold	Million koku	%
1602		544	236	0,128	0,285
1603		544	217	0,118	0,260
1604		544	201	0,110	0,240
1605		544	188	0,102	0,222
1606		544	176	0,096	0,206
1607		544	170	0,092	0,198
1608		544	155	0,084	0,179
1609		544	183	0,099	0,210
1610		544	185	0,100	0,211
1611		544	233	0,127	0,265
1612		544	262	0,143	0,296
1613		544	262	0,143	0,295
1614		544	262	0,143	0,293
1615		851	190	0,162	0,330
1616		851	190	0,162	0,328
1617		851	209	0,178	0,358
1618		851	199	0,169	0,339
1619		851	190	0,162	0,322
1620		851	176	0,150	0,297
1621		851	165	0,140	0,275
1622		851	154	0,131	0,256
1623		851	183	0,155	0,302
1624		792	158	0,125	0,241
1625		792	219	0,173	0,333
1626		792	200	0,158	0,302
1627		792	200	0,158	0,300
1628		792	182	0,144	0,272
1629		792	185	0,147	0,276
1630		792	184	0,145	0,271
1631		792	182	0,144	0,267
1632		792	178	0,141	0,260
1633		792	148	0,117	0,216
1634		792	124	0,098	0,179
1635		792	113	0,090	0,163
1636		801	94	0,075	0,136
1637		801	83	0,067	0,119
1638		801	79	0,064	0,113
1639		801	132	0,106	0,188
1640		801	132	0,106	0,187
1641		801	90	0,072	0,127
1642		801	77	0,061	0,107
1643		801	116	0,093	0,162
1644		616	142	0,088	0,152

20 Gold production includes an imputation for the non-Sado mines in applicable years. For detail see the text.

Year	Export	Production	Price	Production	GDP share
1645		616	146	0,090	0,155
1646		616	163	0,100	0,172
1647		616	147	0,091	0,154
1648		617	158	0,097	0,165
1649		617	151	0,093	0,157
1650		617	114	0,070	0,118
1651		617	130	0,080	0,134
1652		563	131	0,074	0,122
1653		563	131	0,074	0,122
1654		563	110	0,062	0,101
1655		527	111	0,059	0,096
1656		1 111	106	0,117	0,191
1657		1 111	126	0,139	0,226
1658		1 125	86	0,096	0,155
1659		1 125	79	0,089	0,142
1660		1 125	62	0,070	0,111
1661		1 108	84	0,093	0,148
1662		1 108	101	0,112	0,177
1663		1 108	79	0,087	0,137
1664		1 108	84	0,093	0,146
1665	36	1 108	85	0,095	0,147
1666	460	572	79	0,045	0,070
1667	666	572	80	0,046	0,071
1668	1 704	572	84	0,048	0,073
1669	1 522	572	70	0,040	0,061
1670	1 161	572	76	0,043	0,066
1671	1 596	572	92	0,053	0,080
1672	1 037	572	90	0,052	0,078
1673	1 053	686	78	0,054	0,080
1674	747	686	58	0,040	0,059
1675	600	686	68	0,047	0,069
1676	302	532	74	0,039	0,058
1677	441	532	103	0,055	0,081
1678	375	532	96	0,051	0,075
1679	309	532	79	0,042	0,062
1680	111	532	63	0,034	0,049
1681	245	481	56	0,027	0,039
1682	0	481	67	0,032	0,046
1683	201	481	111	0,053	0,076
1684	613	485	105	0,051	0,073
1685	6	485	108	0,052	0,074
1686	6	347	82	0,028	0,040
1687	160	347	79	0,027	0,039
1688	224	294	105	0,031	0,043
1689	37	294	91	0,027	0,037
1690	181	294	87	0,026	0,036
1691	326	294	89	0,026	0,036
1692	64	294	95	0,028	0,038
1693	254	294	75	0,022	0,030

Year	Export	Production	Price	Production	GDP share
1694	151	294	63	0,019	0,025
1695	75	294	85	0,025	0,034
1696	129	247	61	0,015	0,020
1697	10	247	71	0,018	0,024
1698	75	247	57	0,014	0,019
1699	23	280	85	0,024	0,032
1700	255	280	97	0,027	0,036
1701	20	280	69	0,019	0,026
1702	212	280	61	0,017	0,023
1703	195	280	67	0,019	0,025
1704	28	533	131	0,070	0,092
1705	92	533	146	0,078	0,102
1706	57	501	129	0,065	0,085
1707	203	501	50	0,025	0,032
1708	208	501	80	0,040	0,052
1709	208	501	99	0,050	0,065
1710	154	501	57	0,029	0,037
1711	6	314	65	0,020	0,026
1712	264	314	65	0,020	0,026
1713	156	314	32	0,010	0,013
1714	284	314	25	0,008	0,010
1715	273	314	21	0,007	0,008
1716	88	24	37	0,001	0,001
1717	63	24	48	0,001	0,001
1718	71	24	115	0,003	0,004
1719	18	24	68	0,002	0,002
1720	87	24	50	0,001	0,002
1721	107	24	47	0,001	0,001
1722	58	24	56	0,001	0,002
1723	189	24	92	0,002	0,003
1724	53	24	86	0,002	0,003
1725	114	24	78	0,002	0,002
1726	49	24	81	0,002	0,002
1727	151	24	97	0,002	0,003
1728	142		108		
1729	134		145		
1730	82		121		
1731	31		113		
1732	117		65		
1733	84		68		
1734	75		100		
1735	87		102		
1736	60		114		
1737	0		119		
1738	0		72		
1739	4		81		
1740	1		74		
1741	1		77		
1742	1		91		

Year	Export	Production	Price	Production	GDP share
1743	1		46		
1744	31		92		
1745	19		90		
1746	8		80		
1747	37		91		
1748	14		86		
1749	1		91		
1750	14		92		
1751	0		97		
1752	2		112		
1753	0		132		

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