Should the Government of the Kyrgyz Republic Impose a Tax on Gold Ores and Concentrates?

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Contents

Summary

Government officials in the Kyrgyz Republic are considering levying a tax on the final production of gold ore and concentrate.[1] They hope this will help add value to the country's mineral production, which in turn might supply minerals to industry, create jobs and generate revenue. They also hope that locating processing within the country will prevent companies misreporting the value of their ore and concentrate exports to reduce their tax payments.

Part of the potential benefit of a value addition policy is to ensure that the mining industry continues to produce enough concentrate to feed smelters, refineries and other downstream industry, enough revenue to support the government budget, continue to employ the thousands of workers, and along with all this limit the damage to the country's environment. However, the mining industry in the Kyrgyz Republic is at a critical juncture. Most of the country's mineral production is forecast to cease in 2026 unless there is new investment. New companies such as Jerooy could replace some of this production, but perhaps not all.[2] This makes understanding the impact of a value addition policy important. If a policy substantially increases industry costs, it may deter investment and lower production, thus reducing the amount of concentrate fed to processing plants, and the many benefits the country currently enjoys.

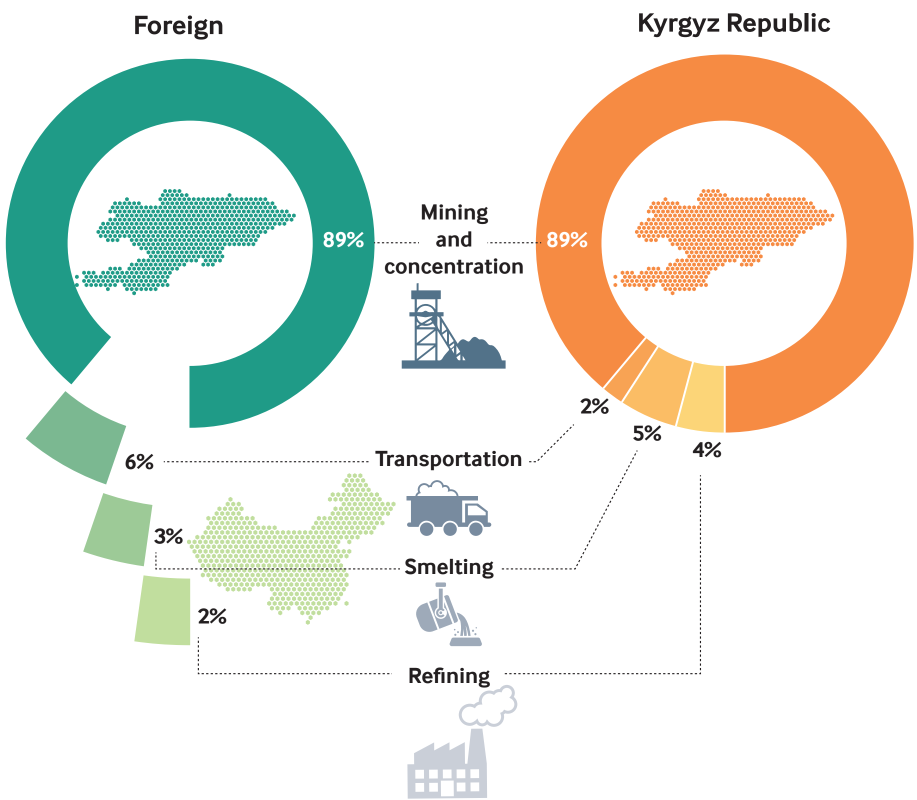
In applying a value addition policy, it is useful to understand that processing some concentrates in the Kyrgyz Republic is more viable than other types of concentrate each requiring different processing technologies In fact, a single mine may require multiple facilities—some domestic, some abroad—depending on how its concentrate production changes over time.

In the Kyrgyz Republic, most mines already process concentrate from within the country because they have ores that allow for a cyanide leaching (a hydrometallurgical technique). In these cases, a tax on the production of ores and concentrates is redundant, since the mines already undertaken most of the processes in extracting minerals domestically. Some mines with the same types of ores still export their ores and concentrates. In these cases, a tax might encourage them to locate their processing in the Kyrgyz Republic, but the costs of doing so may be particularly high which may force some to close or there may be environmental restrictions. Other mines require different, more expensive and environmentally risky pyrometallurgical technology (e.g., smelting and roasting). Probably because of these costs, these mines process their concentrate in foreign smelters (mainly in China and Kazakhstan). A high enough tax may be sufficient to encourage some of these mines to process their concentrates in the Kyrgyz Republic, although again, the costs may be so high as to close some mines, while government officials may wish to compare what benefits they expect to derive from domestic processing against the possible environmental costs. Indeed, in some of these mines, their ores contain impurities for which complicates treatment, and poses substantial

1 Depending on its form, such a tax could contravene the trade rules of the Eurasian Economic Union. We assume in this analysis that the government can levy a tax that accords with these rules.
2 EY, *Non-ferrous metals production and processing. The sector's contribution to the economy of the Kyrgyz Republic and the effects on it of fiscal initiatives.* International Business Council, (2018). http://ibc.kg/en/analysis/surveys/3202_the_research_of_ernstampyoung_quotcontribution_of_gold_mining_to_the_economy_of_the_kr_and_the_effects_of_fiscal_initiativesquot

environmental risks. In these cases, government officials might wish to avoid having these mines processing their concentrate in the country altogether, particularly officials worry that environmental authorities cannot effectively regulate company behavior. In this case, applying a value addition tax might not be appropriate.

Given this diversity, while some mines might successfully respond to a tax and relocate where they process and treat their products, others might not be able to respond. Applying a tax across the whole industry may result in some mines closing, and deterrence of some future investment. This may be acceptable for authorities if they think that the benefits outweigh these costs, but as our report suggests this approach is somewhat questionable—principally because the value added by processing is rather small, while better monitoring of mineral content might be a cheaper method to combat misreporting.



Proportion of value created at each stage in the value chain when concentrate is processing in the Kyrgyz Republic and abroad, based on the modeling exercise

Because of the different technologies employed by Kyrgyz mines to extract gold and other minerals, it is difficult to model the impact of a tax on ore and concentrate production across the whole industry. Instead we focused on the segment of the industry for which applying a tax is most likely to change behavior and result in net benefits for the country: those mines producing gold-copper concentrates that are processed by smelting. By focusing on this segment we can understand the potential increase in value that the Kyrgyz Republic might enjoy, whether this policy might deter investment in the country, and how high a tax would have to be to encourage these types of mines to change their processing location. To do this, we built an economic model and, where data were available, compared the results with third-party estimates. Based on this analysis, we find that:

- Contrary to some expectations, and depending on the mine, most of the value of gold and other minerals comes from the mining and concentration of the ore, with some from reducing transport costs and a small remainder from smelting and refining itself. Locating processing in the Kyrgyz Republic, assuming no misreporting, is likely to only increase value added in the country by about 5 percent. Nor is this likely to gain the government much extra revenue as the costs of processing domestically are likely to be high
- Smelter profitability requires economies of scale. Since Kyrgyz gold-copper production is low, a gold-copper smelter-refinery plant in the Kyrgyz Republic is likely to lose money. Based on the currently available technology without government subsidies, a plant in the Kyrgyz Republic would make a substantial loss. Based on our assumptions, around KGS 14 billion, equivalent to USD 201 million.
- Higher production of gold-copper concentrate would make a smelter-refinery plant more viable, but, paradoxically, imposing a tax might deter investment, thus preventing the industry from increasing its production capacity sufficiently to take advantage of scale economies.
- Gold-copper mining companies would only use a Kyrgyz plant if the government levied a tax of at least 15 percent on the gross value of concentrate. If companies could not avoid this tax by processing their concentrate domestically, they would probably carry one of the highest tax burdens among mineral producing countries.
- Similarly, the high charges necessary to keep the smelter profitable would likely deter investment, as well as reduce employment and government revenue.
- If the government funded a plant either directly or indirectly via tax incentives and subsidies, it would need to fund the KGS 14 billion loss, diverting money from other uses that could benefit the country.

In addition to the doubtful financial benefits of locating these activities within the country, encouraging more processing, treating and refining of ores in the Kyrgyz Republic is likely to increase risks of environmental damages. Making the possibility that the country enjoying a net benefit even more doubtful.

Furthermore, while we do not directly analyze misreporting of mineral content and the government's capacity to audit companies, our analysis suggests that encouraging mines to locate their processing in the country to stop potential misreporting is probably a very expensive approach. Good practice in other countries is to develop sufficient capacity to work with third-party referees to check the mineral content of exports and the content sent to foreign processing plants. Such capacity would be required even if processing was done domestically, and would probably be far cheaper than developing a new processing plant.

We recognize that the government faces a particularly difficult challenge in both attracting sustainable, environmental friendly mining companies and taxing these companies sufficiently to fund broader development in the country. Further, company misreporting of mineral values is a common yet critical challenge that many governments currently face. However, our analysis suggests that imposing a tax is not an appropriate response to these challenges.

Some techniques to extract minerals from ores, particularly leaching using cyanide or a similar reagent, are already viable, so some companies have already or may in the future develop processing plants without the need for a tax to encourage them. Instead, government officials might consider shifting from a tax to developing a governance structure that facilitates this development while protecting the country from misreporting and environmental damages. Rather than imposing a tax on exports, the government could consider other policies:

1. *Manage the value added by the mining industry*. Recognize that many mines already process and treat their production in the Kyrgyz Republic and consider how to take advantage this, including ensuring these activities comes under effective environmental regulation.[3]

2. *Address potential misreporting*. Ensure that the government can hire and work with third-party referees to effectively monitor the performance of foreign smelters, understand the true content of mineral exports, and understand the different technologies used depending on the ore type.

3. *Raise revenues and attract investment*. Evaluate the mining tax regime to sustainably increase government revenue without significantly deterring investment.[4]

3 Natural Resource Governance Institute, *Improving Resource Governance in the Kyrgyz Republic: 12 Priority Issues for the Mining Sector*, 2017.

4 David Manley, *An economic evaluation of gold mining tax regimes in the Kyrgyz Republic*, (Natural Resource Governance Institute, 2018)

Introduction

Countries who export predominately raw materials are often the least developed, while countries that process and manufacture raw materials are frequently wealthier, industrialized countries. This perception has driven governments in many resource-rich developing countries to increase the processing and manufacturing of raw materials.[5] In the Kyrgyz Republic, government officials are considering whether to restrict the export of gold ore and concentrate in the hope that mining companies will instead process these metals inside the country. Officials hope this will lead to a greater supply raw material for the development of new industries. By encouraging companies to process more metal in the Kyrgyz Republic, the government aims to increase the value of the metals companies sell, thus generating additional tax revenue for the country. Government officials also suspect that some foreign mining companies may be misreporting the value of their exports; by moving processing home, officials hope that government inspectors will be able to keep track of what the mines export.

The government has outlined its plans in two documents. The first is the draft National Sustainable Development Strategy 2018–2040, which identifies the need for "beneficiation" and "value addition" with regard to the country's minerals. The second is the five-year "Kyrk Kadam" program, which considers the assessment of economic, social and environmental factors of metallurgical hubs construction, and a three percent surcharge on the Revenue Tax levied on the value of any ore and concentrate produced by mining companies. It is this Revenue Tax surcharge or a similar tax on ore and concentrate exports that we evaluate in this report.

In developing their plans, officials will carefully evaluate the context, given the contentious nature of such policies. While governments in other countries often implement value addition policies, few researchers find evidence that they benefit countries. Indeed, the evidence shows that these policies frequently hurt the implementing country.[6] One recent study on the effects of the ban of nickel exports in Indonesia concluded that it was a risky gamble that just about paid off, but that would not likely be replicable by other countries.[7] This reinforces a principle of value addition policies: their appropriateness depends on the specific context in each country. If companies have chosen not to build processing plants like smelters and refineries, it is likely because it is not profitable enough to do so. A government restriction on exports forces mines to pay for a domestic processing plant, thereby

5 Organisation for Economic Co-operation and Development (OECD), Export Restrictions in Raw Materials Trade: Facts, Fallacies and Better Practices, (2014), 9 - 11. And Colombia Centre for Sustainable Investment. *Linkages to the Resource Sector: The Role of Companies, Government and International* (2016), 35.

6 Various studies indicate that for a country whose mineral production does not determine global prices, an export restriction, such as a tax on concentrate exports, is likely hinder rather than help the domestic economy. See K.C. Fung and Jane Korinek, "Economics of Export Restrictions as Applied to Industrial Raw Materials," OECD Trade Policy Paper no. 155 (2013), 1–33; Ricardo Hausmann, Bailey Klinger and Robert Lawrence, "Examining Beneficiation," Faculty Research Working Papers Series (Harvard Kennedy School, 2008); Nathan Associates, E*conomic Effects of Indonesia's Mineral-Processing Requirements for Export* (2013); Organisation for Economic Co-operation and Development, *Export Restrictions in Raw Materials Trade: Facts, Fallacies and Better Practices* (2014); Olle Östensson and Anton Löf, "Downstream Activities: The Possibilities and the Realities," UNU-WIDER Working Paper no. 113 (2017).

7 Kris Terauds, "Using Trade Policy to Drive Value Addition: Lessons from Indonesia's Ban on Nickel Exports," *Background document to the Commodities and Development Report, United Nations Conference on Trade and Development* (2017).

losing money for mining companies, reducing the tax base (by reducing taxable sales) and reducing the supply of raw materials available to downstream industry in the Kyrgyz Republic.

An export restriction may also violate trade laws. The Kyrgyz Republic is a member of the Eurasian Economic Union (EEU), which prohibits member states from imposing taxes on trade within the union. This is one reason why in October 2017, the parliament narrowly voted against levying an export duty. Therefore, the government may have to consider other options to implement a value addition policy, which would affect trade between the Kyrgyz Republic and Kazakhstan (both member states of the EEU). Policies in support of value addition that government officials may consider include offering a tax incentive for mining companies, directly funding a smelter or imposing an outright ban on the export of unprocessed metals.

Therefore, before levying taxes and other restrictions, it is important to understand the projected cost of processing in the Kyrgyz Republic, its potential effects on the mining industry, and its wider impacts on government revenue, industrialization and jobs. In an effort to aid the government in its decision-making, this paper evaluates mining and mineral processing in the Kyrgyz Republic.

1. The Kyrgyz mining industry is at a critical juncture

Because restricting concentrate exports can impose significant costs on mining companies, a first principle to consider when developing a value addition policy is to ensure that mining companies continue to produce concentrate. Ignoring this principle risks companies closing mines or reducing the amount of concentrate they are willing to produce. Over time the industry could shrink, thus producing less concentrate for value-added processing[8]. This would hurt downstream processing plants and other industries dependent on this production; further, it would reduce the substantial benefits the country gains from the upstream mining sector. A successful value addition policy must ensure that the upstream mining sector is large enough to support the downstream processing plants.

Therefore, a careful evaluation of potential value addition policies is needed. Indeed, the Kyrgyz Republic is at a critical juncture: its mining sector is projected to decline, and government debt is rising. At this moment, a plunge in mining revenue would be catastrophic.

The gold mining industry is an important part of the Kyrgyz economy. Depending on the source, mines employ between 1 to 3 percent of employment, 5 to 10 percent of tax revenue and 45 percent of the country's exports.[9] Most of these benefits come from one mine: Kumtor Gold Company, which contributes about two-thirds of all extractive industries' payments to the government.[10] If additional reserves are not found by currently conducted exploration works, Kumtor's management predicts that the company will cease production in 2026 when the open-pit mine closes. For the mining sector to continue supporting the Kyrgyz economy, this potential loss must be replaced.

8 We use the terms "processing" in this report to refer to all activities related to transforming ores to final products, including milling and concentration (often referred as mineral processing), treatment and refining.

9 Kyrgyzstan Extractive Industries Transparency Initiative. Website: eiti.org/kyrgyz-republic#tax-and-legal-framework- and EY. *Non-ferrous metals production and processing. The sector's contribution to the economy of the Kyrgyz Republic and the effects on it of fiscal initiatives. International Business Council*, 2018. http://ibc.kg/en/analysis/surveys/3202_the_research_of_ernstampyoung_quotcontribution_of_gold_mining_to_the_economy_of_the_kr_and_the_effects_of_fiscal_initiativesquot

10 Authors' calculation from Extractive Industries Transparency Initiative. *EITI Complete Summary Data Table*. eiti.org/api/v1.0/summary_data. Accessed via www.resourcedata.org.

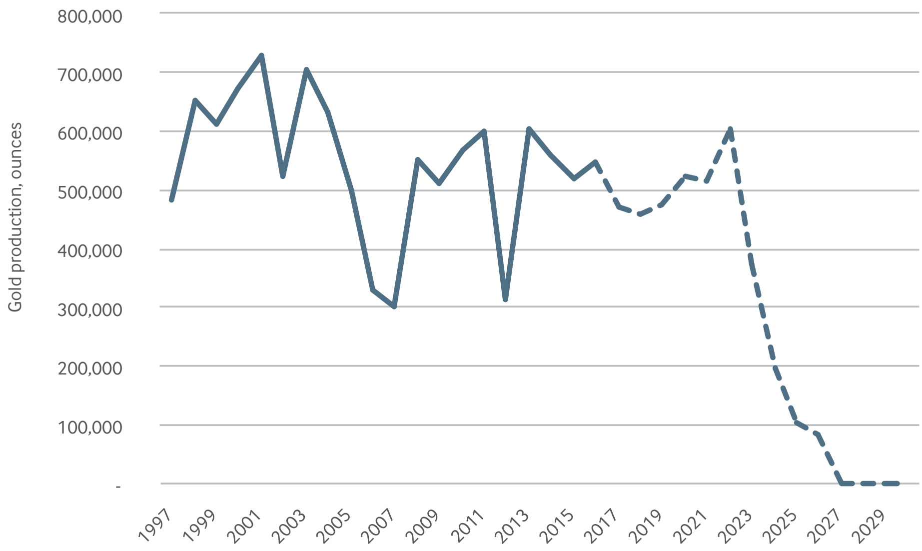


Figure 1. Gold production data and projections from the Kumtor Gold Company, 1997–2029

Source: Kumtor Gold Company, "Production Data 1997–2016," accessed 30 January 2018, www.kumtor.kg/en/deposit/production-figures; Centerra Gold Inc., Technical Report on the Kumtor Mine, Kyrgyz Republic (2015), 1–19.

Kumtor's decline could be partly replaced by some promising new mines. An export restriction that reduces the profitability of these mines could result in some mines reducing their production or even closing completely, and investors diverting capital to other countries. Paradoxically, a policy to add value to the country's metals could destroy existing value. The projected decline in gold production comes at a difficult time for the government. It is projected that highest public debt payments will take place during 2024-2031[11]. In 2016-2017, total public debt service accounted for 15.8 and 13.8[12] percent of total government revenue accordingly. . If the government were to borrow more, the country may receive a "high risk of debt distress" rating, encouraging creditors to increase the interest rates on their loans. Policies to generate significant revenue from the mining industry are therefore vital.

The next section considers which mines already process their concentrates in the Kyrgyz Republic, and which process abroad.

11 Sputnik news agency. "Interview of the minister of finance, A. Kasymaliev. "Accessed 14 May, 2018. ru.sputnik.kg/Radio/20161221/1030904886/s-2024-goda-budem-vyplachivat-po-gosdolgu-okolo-300-mln.html

12 Ministry of Finance of the Kyrgyz Republic. "Public Debt Service data", Accessed 14 May, 2018. minfin.kg/ru/novosti/mamlekettik-karyz/obsluzhivanie-gosudarstvennogo-dolga.html

2. The type of ore determines the type of processing

To understand the effects of levying a tax on concentrate and ore final production, we first considered which mines currently export concentrate and why. Mines in the Kyrgyz Republic, as elsewhere, produce different types of ores that require different techniques to extract minerals from these ores. Ore bodies are not homogenous and contain varying qualities of ore which differ in an economic sense in relation to their proximity to the surface, the content of deleterious materials, rock hardness and ease of mining, and—importantly—the concentration of main-, co- and by-product metals or "grade."[13] Shipments of ore or concentrate might be sent from one mine to different extraction and refining plants.

In general, there are two main groups of ores: the first group includes gold-quartz, gold-pyrite primary or oxide ores that require hydrometallurgical techniques. The second group includes refractory ores that require pyrometallurgical techniques. (Appendix 1 provides further details on the processes applied to each type.)

Gold-quartz, gold-pyrite primary, or oxide ores (Kumtor, Kuranjailoo, Makmal, part of Ishtamberdy, part of Taldybulak levoberezhny, Jerooy, Shambesai and part of Chaarat)

The first type are ores whence gold can be extracted using cyanide (a type of hydrometallurgical technique). This separates the very small proportion gold and other valuable minerals from the rest of the rock, so mines are able to save transport costs by transporting a much smaller weight of product. Globally, most mines with these ores therefore conduct gold extraction near to the mine site. However, some forms of this process, such as heap leaching using cyanide poses environmental risks if the cyanide leaks in to the local water system.

In the Kyrgyz Republic, several mines have these ores and process at least some of their concentrate in the country. Kumtor and Makmal produce doré that is then refined into bullion at the Kara-Balta refinery. Ishtamberdy and Taldybulak levoberezhny process some of their concentrate domestically and produce doré. Owners of other mines in development, like Jerooy, Shambesai and Chaarat, may also decide to process domestically.

However, ores of this type are becoming less common. Many mines in the Kyrgyz Republic, and potentially more in the future, have a second type of ore. Concentrates from these ores require other technologies, typically pyrometallurgical techniques (e.g., smelting or roasting), that are usually more expensive than cyanide leaching. Because of these higher costs, processing plants employing these methods typically must be large enough to create scale economies.

13 Havard Halland, Martin Lokanc, Arvind Nair and Sridar Padmanabhan, The Extractive Industries Sector: Essentials for Economists, Public Finance Professionals, and Policy Makers, (World Bank, 2015), 15.

Gold-copper (Bozymchak, Kuru-Tegerek, part of Taldybulak levoberezhny, Karakazyk) and gold-antimony ores (Terek)

Extracting gold from refractory ores is more difficult. Ores containing associated mineral in commercial scale, such as copper typically using pyrometallurgical technologies such as smelting or roasting, submitting concentrate to very high temperatures. These plants typically require large-scale economies to be economically viable, so many mines in the world with these ores export their concentrate to smelters that can aggregate large quantities of ores. However, this processing is also environmentally risky, potentially releasing significant amounts of sulphur oxide in to the air.

Gold-arsenic ores (Perevalnoye, Terekkan, Unkurtash, part of Ishtamberdy)

Arsenic in concentrate significantly complicates processing. Gold-arsenic ores typically require roasting, which is expensive, and produces poisonous gases. Because of the high environmental risks, few countries allow mines to process these types of concentrate. In some cases, smelters refuse to process gold-arsenic concentrates where the percentage of arsenic and other impurities is high and percentage of metals is low. Mines with such ores often have to mix their concentrates with concentrate with much lower arsenic proportions, sometimes from mines from other countries.

The required diversity of techniques requires to process different ores and concentrates, and the need to mix different concentrates to ensure the right level of elements such as arsenic, suggest that an efficient mining industry is one that has reasonable freedom in choosing where to process its ore and concentrate production. The greater the restrictions, taxes and costs involved in this, the less easily companies can find the required technologies process their production.

Table 1. Known gold mines operating and in development in the Kyrgyz Republic

Assumed ore type	Minerals	Operating status	Name of mine	Owner (HQ country)	Actual or expected processing location
Mostly processes or plans to process in the Kyrgyz Republic					
Gold-quartz	Gold, Silver	Operating	Jamgyr	Vertex Gold Company LLC	Exports ores to Kazakhstan and re-imports gold bullion to Kyrgyzstan; plans to build a gold-processing plant
Gold-quartz	Gold,	Operating	Makmal	Kyrgyzaltyn	Produces doré domestically.
Gold-quartz	Gold, Silver	Developing	Jerooy	Vostok Geoldobycha (Russia)	Will probably produce doré domestically.
Gold-arsenic oxide	Gold, silver, arsenic	Operating	Ishtamberdy	Full Gold Mining (China)	70% of concentrate is processed domestically using hydrometallurgical technology, 30% (containing arsenic) is exported, since it requires pyrometallurgy.
Oxide	Gold	Developing	Shambesai	Guizhou Geological and Mineral Resources Development Co. (China)	Plans to produce doré domestically
Oxide initially (Sulphide zone to be developed later)	Gold, Silver, antimony	Developing	Chaarat	Chaarat Gold Holdings (British Virgin Islands)	Plans to produce doré domestically
Gold-pyrite primary	Gold, Silver	Operating	Kumtor	Centerra (Canada) and Kyrgyzaltyn	Produces doré domestically.
Mostly processes or plans to process abroad					
Gold-pyrite primary	Gold, Silver	Operating	Kuran Jailoo	CJSC "TK Geo Resource"	Exports concentrate.
Copper-gold primary	Gold, Copper, silver	Operating	Bozymchak	KAZ Minerals (Kazakhstan)	Exports concentrate to Kazakhstan
Copper-gold primary	Gold, Copper, silver	Operating	Karakazyk	Unknown	Exports concentrate to China
Gold-copper pyrite-primary	Gold, Copper, silver	Operating	Taldybulak Levoberejnyi	Zijin (China), Kyrgyzaltyn	Exports some concentrate to China
Copper-gold primary	Gold, Copper, silver	Developing	Kuru-Tegerek	China National Gold Corp., Kyrgyzaltyn	Plans to export concentrate to China
Gold-antimony	Gold, Antimony	Developing	Terek		Probably requires pyrometallurgical technology so likely to export concentrate
Gold-arsenic	Gold, Arsenic	Developing	Terekkan, Perevalnoye		Probably requires pyrometallurgical technology so likely to export concentrate
Gold-quartz arsenic-antimony	Gold, Arsenic, antimony	Developing	Unkurtash	Highland Gold (Russia)	Probably requires pyrometallurgical technology so likely to export concentrate

Source: Consultation with various industry experts; State Committee of Industry, Energy and Subsoil Use; S&P Global SNL Mines and Minerals; Chaarat, "Gold mining in the Kyrgyz Republic," accessed 30 January 2018, www.chaarat.com/kyrgyz-republic/gold-mining-kyrgyz-republic; U.S. Geological Survey, 2014 Minerals Yearbook: Kyrgyzstan (2017).

3. Imposing a value addition policy risks closing mines, reducing revenue and losing jobs

Since the majority of mines with oxide, gold-pyrite primary and gold-quartz ores already or plan to process in the Kyrgyz Republic, a policy to locate more processing in the country must consider the mines with other types of ores. Processing of ores with arsenic might be particularly expensive and carry substantial environmental risk, so the government may wish to avoid attracting this sort of processing. That leaves those mines that require smelting techniques—principally those producing a gold-copper concentrate.

Since the companies operating these mines have decided to process their concentrate abroad, domestic smelting is unlikely to be economically feasible at present. However, applying a tax might be sufficient to encourage them to relocate. To analyze the impact of this, we built an economic model of the Kyrgyz gold-copper mining industry and asked five questions. Table 2 outlines our questions and a summary of the results of our analysis.

Table 2. Research questions and summary results

Questions	Summary results of our analysis
1. How much value would smelting and refining add to gold-copper concentrate?	Not much. Most of the value of a bar of gold is created in the mining and concentration process, which is already undertaken in the Kyrgyz Republic. Smelting and refining add about 9 percent. Meanwhile, transport accounts for 20 percent of the value. Our analysis of third-party estimates corroborates this result. But as we will explain, this does not translate into additional tax revenues.
2. Would a smelter be commercially viable given the current amount of gold-copper concentrate produced?	No. Companies would collectively save on transport costs, but to reduce its losses the smelter would have to charge higher fees, wiping out the benefits for companies. Even then, over the assumed 20-year lifetime of a smelter, the industry could lose about KGS 14 billion (USD 201 million).
3. Could increasing industry concentrate production reduce these losses?	Partially. Running the smelter at its assumed maximum capacity of 150,000 tonnes of concentrate a year would cost the industry less money, but would still create a loss valued at about KGS 11 billion (USD 152 million. However, this would entail a significant increase in the size of the industry. Furthermore, if the government imposed a heavy tax, this might discourage companies investing and increasing production.
4. How high would a tax on concentrate have to be to encourage mining companies to use the smelter and refinery?	Fifteen percent. But this would not result in a long-term increase in revenue, and therefore, a high cost could close mines and deter investment.
5. How would a tax affect government revenues and employment?	Severely. The tax burden (the "average effective tax rate") on Kyrgyz mines would become the highest in the Kyrgyz Republic's peer group. But avoiding this tax by building a smelter would instead impose an equivalent burden on companies. While the revenue tax base might increase in the short term, profits would decrease substantially, risking mine closures and deterring investment. In the long term, this would lose revenue for the government. Furthermore, mine closure would lead to job losses in the Kyrgyz Republic, because mining gold concentrate employs many more people than smelting and refining.
6. What are the implications of the government funding the smelter itself?	The government could either develop and operate the smelter and refinery itself, or subsidize the industry. Either way, it would take on the losses, diverting money from other public needs. Equivalent to four times the cost of the government's planned national innovation centres.

MODEL AND ASSUMPTIONS

Our model, which we have posted on the website that accompanies this report[14], focuses on the actions of the four mines in the Kyrgyz Republic that produce gold-copper concentrate: Bozymchak, Taldybulak Levoberezhny, Karakazyk, and the soon-to-open Kuru-Tegerek.

The four mines in our model produce 83,000 tonnes of concentrate a year. Wee based this assumption on their production in 2016. For Kyru-Tegerek, which is yet to start production, we assumed it would produce as much as Bozymchak. For simplicity, we assumed that all four mines will process their concentrate at one smelter. However in practice gold-copper mines may require several types of smelters depending on the concentrates produced at any point in time. This assumption therefore makes our results optimistic in terms of the viability of a domestic smelter.

Mine	**Concentrate (tonnes)** (Based on 2016 data where available)
Bozymchak	34,000
Taldybulak Levoberezhny	10,000
Karakazyk	5,000
Kuru-Tegerek	34,000 (No data available, so assumed to be same as Bozymchak)
Total	83,000

Table 3. Assumed annual production of sulphide concentrate to feed the smelter

Source: Authors.

Each tonne of concentrate contains some gold and some copper. While in reality the metal content of this concentrate differs, not only between mines but even within the same mine, for simplicity, we assumed the entire amount sent to the smelter has the same grade: 20 grams of gold per tonne and 30 percent copper. In reality grades can be quite different to this, and indeed change over time. However, as shown in Appendix 4, the results are not sensitive to this assumption.

In building our model, we imagined that a company constructs a smelter and refinery in the Kyrgyz Republic and charges mining companies to treat their concentrate. Because the mines have a gold-copper concentrate, this smelter smelts the concentrate to separate the gold and copper, and then refines the copper. Companies then refine the gold elsewhere, which is usually the case with sulphide smelters. For simplicity and clarity, we refer to this plant as a "smelter," rather than a "smelter and refinery."

All four mines face a choice. They either continue to export their concentrate to a foreign smelter and refinery, paying the transport cost to do so, and the foreign treatment and refining charges. Or they pay the Kyrgyz smelter to process the concentrate and refine the copper, paying only to transport the gold doré and copper to the downstream market. We assumed that that the distance from the mine to the Kyrgyz smelter would be negligible, so we did not calculate this. We also imagined that there would not be a large domestic market for these metals; all their processed production is exported.

14 www.resourcedata.org/dataset/Kyrgyz-Republic-mining-tax-analyses

As we explain in appendix 2, smelters and refineries use one of two types of pricing arrangements: a tolling arrangement (charging treatment and refining charges) or a sales contract (buying the concentrate from mining companies, then selling the processed products to downstream buyers). Economically, the arrangements are equivalent. So for simplicity, and because it is easier to compare treatment and refining charges, we have chosen the tolling arrangement in this model

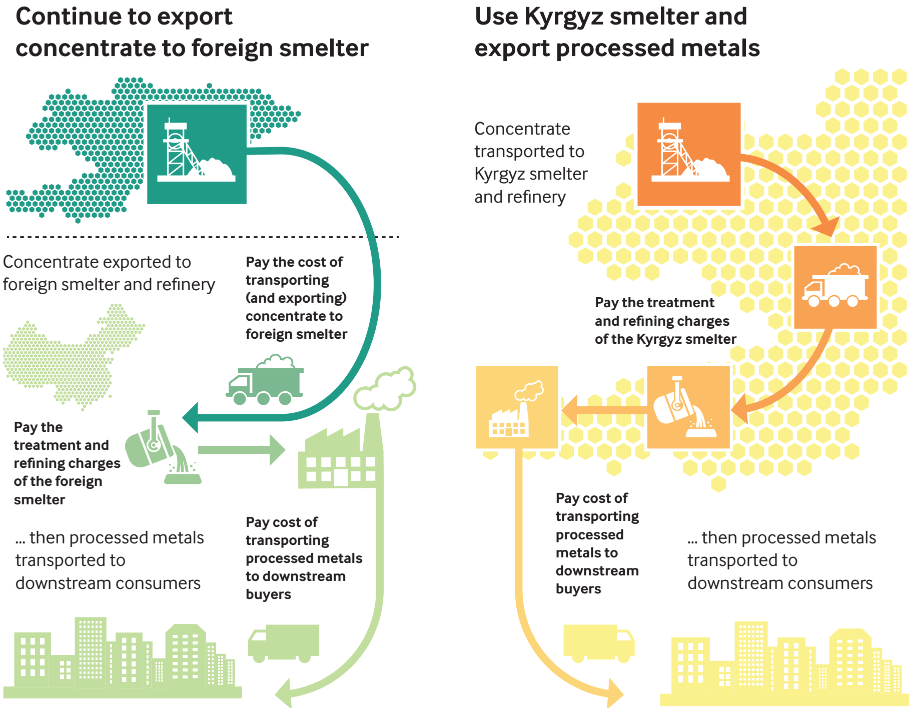


Figure 2. Options for smelting and refining faced by mining companies in our model

Source: Created by the authors, using graphics from: commons.wikimedia.org/wiki/File:Industry_icon.gif; pixabay.com/en/pithead-mine-coal-extract-fuel-40620; commons.wikimedia.org/wiki/File:Factory_icon.svg.

In our model, the mines collectively chose the most profitable option. The costs relevant to this decision are the treatment and refining charges and transport costs, borne by the mining companies. But the Kyrgyz Republic as a whole would bear others costs, the two most important being the environmental costs of smelting and the additional demand on the national power supply, because smelters and refineries consume a lot of electricity. Companies do not consider these costs, but they are important in deciding whether a policy is good for a country. Economists call these sorts of costs “externalities”—they are external to the decision of the company, but are nonetheless important—and we discuss these two externalities in section four.

We assumed the mines make their decision collectively and all send their concentrate to the same smelter: either the foreign or Kyrgyz smelter. In reality, the situation would be more complicated. For example, Bozymchak sends its concentrate to Kazakhstan, while others send theirs to places in China. Mining companies also usually send their concentrate to more than one smelter, based on factors such as the location of the downstream buyer for the particular shipment, spare smelting capacity at the time and specific elements in the concentrate that require specialized treatments.

We assumed that the treatment and refining charges (TC/RC) of the foreign smelter is equal to the average TC/RC reported across the world. While the transport costs are determined by our assumption of where the foreign smelter is and the unit cost of transportation. However, the TC/RC of the Kyrgyz smelter are determined within the model. In our model, the Kyrgyz smelter sets its TC/RC to maximize its profits (or minimize its losses). In setting these charges, it is competing with foreign smelters for the mining companies' business. So it has to set TC/RC that are competitive. It need not set the same TC/RC as foreign smelters. In fact, it can set higher TC/RC because of the great distance between the mines and competing smelter, and thus the savings they can make on the cost of transporting concentrate to the Kyrgyz smelter. Specifically, the Kyrgyz smelter sets its TC/RC so that it is just slightly cheaper for the mines to choose to use the Kyrgyz smelter than the foreign smelter. One way to see this pricing decision is with an equation.

Transport cost of concentrate to foreign smelter + TC/RC of foreign smelter + transport cost to downstream market > **TC/RC of Kyrgyz smelter + transport cost to downstream market**

Specifically, in our model, the smelter maximizes its profits by setting TC/RC (underlined in the equation) that are as high as possible while keeping the right-hand side of this equation (the costs involved in option 2) just less than the left-hand side (the costs involved in option 1).

Table 4 shows all our assumptions together. Little data is available on the Kyrgyz mining industry, so in some cases our assumptions are simplistic. When a lack of data led us to doubt our assumptions, we chose values and amounts that were optimistic from the perspective of a proponent of a value addition policy. In other words, we used assumptions that would make the model produce a result that was favorable for a value addition policy as likely as possible. We did this to be more confident in our results. If the results show that a value addition policy would not benefit the country, even after optimistic assumptions, then we can be confident in the results. In addition, we could be more confident in the results despite a lack of data, as we are calculating how much the smelter profitability changes for a given change in each assumed value. We describe the results of changing the location of the foreign smelter and the concentration production of the mining industry below. For the other assumptions, we found that the results were most sensitive to the cost of developing the smelter, and somewhat sensitive to the cost of operating the smelter, the cost of transporting a tonne per kilometer and the discount rate. However, no reasonable change in any one of these values resulted in a profitable smelter.

In all but one case—the assumption of the development cost of a smelter—the results of our analysis are not sensitive to these assumptions. In other words, changing these assumptions did not significantly change the results. Appendix 4 contains full results of this sensitivity analysis.

Table 4. Assumptions used to model a smelter

Item	Value	Notes and sources
Capacity	150,000 tonnes of concentrate	Following the Tanzania Minerals Audit Agency (TMAA, 2011) study we took 150,000 to be a reasonable capacity of a smelter costing $300million With the cost being optimistic, see note on Development cost below. Further the TMAA (2011) note: "no commercial-scale proven technologies exist which are suitable for small scale Copper Concentrate smelting of less than 100,000 tonnes per year".
Total concentrate throughput	83,000 tonnes of concentrate	This is the total expected production of sulphide concentrate once Kuru-Tegerek starts. See Table 3.
Grade	30% copper, 20 g/ tonne gold	Based on expert consultation.
Development cost	USD 300 million	Split evenly across four years. While development cost depends to an extent on capacity. Other studies show a range of USD 370 million to USD 1.2 billion. TMAA (2011) gives a range from USD 370 million to USD 750 million for a 150k capacity smelter. We chose USD 300 million for two reasons: to remain optimistic about the chances of a value addition policy working, and because of the possibility of the smelter being built on the same site as the Kara Balta refinery, which may reduce costs slightly (brownfield development is slightly cheaper than green field).
Net operating costs	USD 115 per tonne of concentrate	Equivalent to TC/RC in the foreign smelter and refinery. Effectively, this assumes the global market has brought TC/RC down to the average cost of production. The spot price for TC/RC should be relatively close to the operating costs, given the fact that there has been persistent excess capacity at this stage for a long time and that a lot of toll smelting happens at the margin in smelters that have some spare capacity.
Life time of smelter	20 years of production	Based on expert consultation.
Transport costs	USD .11 per tonne, per kilometer	This is based on the cost of rail transportation in Africa. This might be more expensive than costs in central Asia, and so leads to an optimistic result from the perspective of value addition policy proponents. (Source: Olle Östensson, Caromb Consulting)
Distance to foreign smelter	1,450 km	Companies send concentrate to various smelters in China and Kazakhstan. As a starting assumption, we took the average of the approximate distance between a mine in the Kyrgyz Republic and a smelter in Kazakhstan (400 km) and the distance from the mine to a smelter in China (2,500 km). We show the effect of varying this assumption below.
Treatment and refining charge	USD 70 per tonne of concentrate, 7 cents per lb of copper cathode,	This is equivalent to USD 115 per tonne of concentrate with 30 percent of copper. Based on the average spot TC/RCs over the period from 2000 to February 2016. (Source: Olle Östensson, Caromb Consulting)
Gold refining charge	USD 6 per ounce of gold	Source: Olle Östensson, Caromb Consulting)
Metal prices	Gold – USD 1,300 per ounce; Copper – USD 6,000 per tonne	
Tax rate on smelter and refinery	0%	This is a highly simplifying assumption, but since in almost all cases a smelter is not viable, its tax base would be zero in any case.
Discount rate	10%	This is a typical discount rate used in analyzing mining projects, including the IMF's Fiscal Analysis of Resource Industries model.[15]

15 International Monetary Fund, *Fiscal Regimes for Extractive Industries: Design and Implementation* (2012), 35.

RESULT 1: MOST OF THE VALUE OF EACH OUNCE OF GOLD COMES FROM THE EXTRACTION AND CONCENTRATION OF THE ORE, SOME FROM REDUCING TRANSPORT COSTS, AND LITTLE FROM SMELTING AND REFINING ITSELF.

We first calculated how much value domestic smelting adds. Figure 3 illustrates the results. By "value" we mean the difference in prices for each intermediary product. For example, in our model a tonne of concentrate contains about $2,534 of gold and copper. The mining company must pay treatment and refining charges for various processing companies, and pay to transport the metals to these processing companies. In total this amounts to $278. This is the value for all these stages in the production. Which means that most of the value of the gold and copper is taken by the mining company.

If the mining company instead uses a domestic smelting facility, it can save a great deal on transport costs. Instead of paying $160 per tonne of concentrate it pays just $46 per tonne.[16] The Kyrgyz smelter can charge more than a foreign smelter, so it takes more of the value of the concentrate. This means that some more of the total value of the concentrate is taken by companies within the Kyrgyz Republic, but the difference it not a great amount. In other words, most of the value of the concentrate is already created in the Kyrgyz Republic whether or not a smelter is located in the country or abroad.

To confirm these results from the economic modelling, we also calculated the value added using estimates from the SNL Mining and Mineral database. This includes estimated TC/RCs and transport costs for Bozymchak and most of the global mining industry in general.[17] These estimates are comparable to our modelling results. SNL states that Bozymchak's TC/RCs and transport costs are 9 percent of total cash costs, of which most is from TC/RCs. This is equivalent to 5 percent of gold value when assuming a gold price of $1,300. The global weighted average for transport and TC/RC as a proportion of the gold value is 2 percent. So our modelling estimates might be optimistic in terms of potential value added.

16 In Appendix 2, we explain this pricing in detail.
17 SNL covers about 60 percent of all gold production in these estimates.

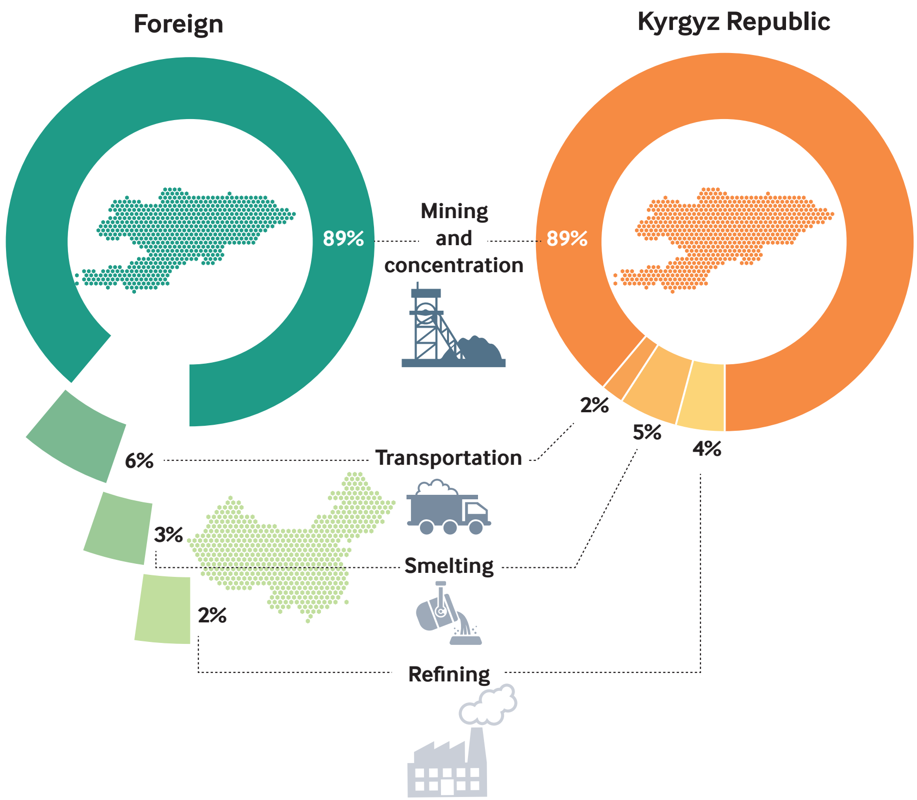


Figure 3. The proportion of value created at each stage in the value chain when concentrate is processing in Kyrgyzstan or abroad

This result may surprise readers who might expect that smelting and refining add significant value. It is true that for some minerals, processing *does* add significant value to the raw material, but this is not true for gold-copper concentrates.[18]

However, while smelting and refining add comparatively little value to concentrate, by smelting concentrate in the Kyrgyz Republic, mining companies *do* save on transport. Savings on transportation is often the primary reason why companies decide to build smelters close to mine sites. For mines that are far from their downstream markets, these savings may be sufficient to make domestic smelting feasible. We therefore calculated whether these savings are enough to support processing in the Kyrgyz Republic.

RESULT 2: A SMELTER WOULD MAKE A SUBSTANTIAL LOSS EVEN ACCOUNTING FOR THE TRANSPORT COST SAVINGS.

In our model, the smelter could charge higher TC/RCs than the global average because locating a smelter in the Kyrgyz Republic would save the mining industry the cost of transporting concentrate abroad. These higher charges mean the industry collectively has to pay USD 19 million a year, USD 9 million more than they have to pay to the foreign smelter. This means the transport savings are wiped out by higher TC/RCs. The mines themselves do not benefit.

However, despite being able to charge higher TC/RC and remain competitive with the foreign smelter, they are still not enough for the smelter to make a profit. In fact, it would lose KGS 14 billion (USD 201 million) over its lifetime. This

18 Hausmann, Klinger and Lawrence, "Examining Beneficiation."

is the "present value" of the income and losses the smelter receives over its 20-year operating lifetime, discounted by our assumed discount rate. Faced with this prospect, a smelting and refining company would not want to operate without significant government assistance, or without obtaining exemptions on regulation such as environmental rules.

The result is based on the competing smelter being 1,450 kilometers away. We chose this distance as about the average of the distance between the two nearest existing smelters in China and Kazakhstan. What if the nearest competing smelter was nearer or further away? For example, in Kazakhstan, or in western China. Table 5 shows that the net present value of smelter losses increases or decreases if the nearest competing smelter is closer or further away. Even if the nearest available smelter was on the east cost of China, 4,000 kilometers away, the smelter would still lose USD 96 million over its lifetime.

Nearest competing smelter to Kyrgyz Republic	Approximate distance in kilometers	Net present value of lifetime smelter loss
Kazakhstan	400	USD 244 million
Western China	2,500	USD 157 million
Eastern China	4,000	USD 96 million

Table 5. Modeled net present value of lifetime smelter loss based on the distance to the nearest smelter neighboring the Kyrgyz Republic

Source: results of our model.

RESULT 3: CURRENT KYRGYZ MINING PRODUCTION IS TOO SMALL TO GENERATE SUFFICIENT ECONOMIES OF SCALE; BUT INCREASING PRODUCTION WOULD HELP.

Thus far, we have based these results on four mines producing 83,000 tonnes of sulphide concentrate. We know that economies of scale are important in smelting, so a larger mining industry might make a smelter viable. Despite the difficult future ahead for the Kyrgyz industry, over time it may grow and be large enough to support smelting. How much larger does it have to be?

Running the smelter at its maximum capacity of 150,000 tonnes of concentrate a year would still lose money, KGS 11 billion (USD 153 million), but less than if production were 83,000 tonnes. A smelter with an even larger capacity might be profitable. Although we did not model a situation with more than one smelter or a much larger smelter, it seems unlikely Kyrgyz mines could produce enough concentrate to run a larger smelter at capacity. In fact, it would require almost doubling total gold-copper concentrate in the country, and we understand that there are no plans to develop gold-copper resources to increase current production to 150,000 tonnes.

Over time, the mining industry could become large enough, but growth would have to be significant. Policies that deter investment into the Kyrgyz mining industry, like imposing an export duty or surcharge on the revenue tax, would slow the growth of production making it even less likely that the industry could achieve the economies of scale required to make smelting profitable. This is a critical point: a successful value addition policy should not kill the goose that lays the golden eggs.

RESULT 4: MINING COMPANIES WOULD ONLY USE A KYRGYZ SMELTER IF THERE WERE A TAX ON THE GROSS VALUE OF CONCENTRATE OF AT LEAST 15 PERCENT, PROBABLY TOO HIGH TO ENCOURAGE INNOVATION.

The first three results suggest that no company would operate a smelter in the Kyrgyz Republic since it would lose money. To make a profit, the smelter would have to charge rates more than five times higher than the foreign smelter charges. Because the extra charges that a Kyrgyz smelter would impose on mining companies would be so high, it seems unlikely that companies could sufficiently innovate to find ways to reduce costs and make the smelter viable. Instead, with such high charges, mines would all choose to use foreign smelters.

Depending on the trade rules of the Eurasian Economic Union, the Kyrgyz government could change this situation by taxing companies whose final production is ore or concentrate. For example, in reality, the government has considered a surcharge on the revenue tax of three percent. In our model, this would not be anywhere near high enough to encourage mining companies to switch from sending their concentrate to foreign smelters to sending it to the Kyrgyz smelter. In fact, the government would have to levy a rate (on the gross sales value of concentrate) of at least 15 percent. But as our next result shows, this would not be good for the Kyrgyz Republic.

RESULT 5: THE HIGH COSTS OF THE SMELTER WOULD LIKELY DETER INVESTMENT, AND REDUCE EMPLOYMENT AND GOVERNMENT REVENUE.

Our first result showed that smelting and refining add little value, but savings on transportation could, depending on the distance to the nearest smelter with spare capacity. However, this should not be confused with extra revenue the government might receive in tax. Why? Because it does not include the significant costs of producing each intermediary product. It is true that adding value to concentrate might increase the gross sales value accounted for by companies in the country and in doing so increase the tax base for the two main taxes levied on Kyrgyz mines: the royalty and the revenue tax. However, the extra costs involved would severely reduce company profits and might cause some mines to close, leading to losses in tax revenue.

We calculated the impact on mining companies' profitability from either paying a 15 percent export tax or the equivalent cost in higher TC/RCs. We did this by measuring the average effective tax rate (AETR) for a representative mine, while treating the higher TC/RCs like a tax payment. The AETR is the present value of all tax paid by a company over its lifetime divided by the present value of the company's income over its lifetime. AETR is a common measure used by analysts, such as the International Monetary Fund, to evaluate tax regimes.[19] Other measures are important, but the AETR is enough to show how imposing a 15 percent export tax increases the burden of tax on a mining company in the Kyrgyz Republic.

19 Philip Daniel, Brenton Goldsworthy, Wojciech Maliszewski, Diego Mesa Puyo and Alistair Watson, "Evaluating Fiscal Regimes for Resource Projects: An Example from Oil Development," in *The Taxation of Petroleum and Minerals: Principles, Problems and Practice*, ed. Philip Daniel, Michael Keen and Charles McPherson (London and New York: Routledge, 2010), 187–240.

As Figure 5 shows, imposing a tax of 15 percent would make the overall tax burden on Kyrgyz mines that continue to export concentrate the highest in the Kyrgyz Republic's peer group. Companies could avoid this tax by using the Kyrgyz smelter, but they would then have to pay much higher TC/RC than before. Effectively, avoiding the export tax would impose an equivalent burden of higher TC/RC on companies. In either case, based on our models, a value addition policy would change the Kyrgyz Republic from one of the lowest tax regimes in its peer group to one of the highest. Imposing the export tax (or the equivalent costs of the smelter) would make the Kyrgyz Republic one of the least attractive countries for gold and copper mining investment.

This result shows the damage of applying a tax across all mining companies. While it could be possible that some mines produce suitable concentrates to develop smelting facilities, others might not. Yet these other mines would still have to pay the export tax.

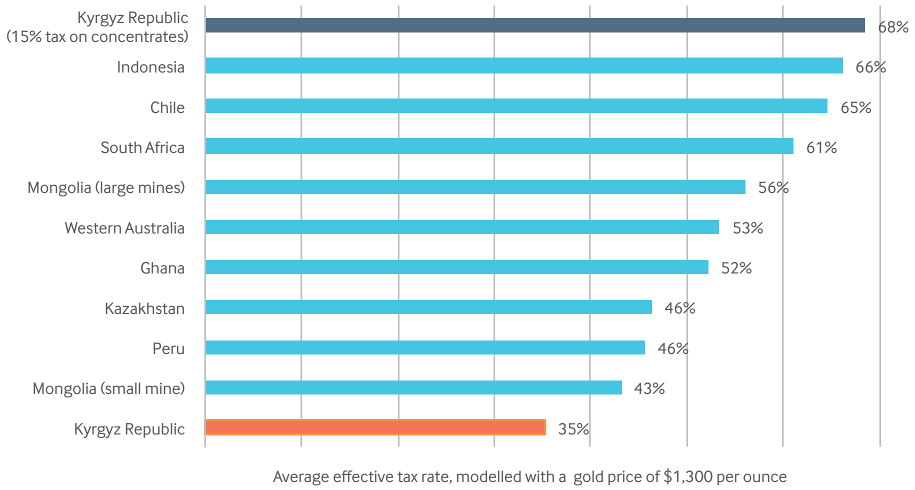


Figure 5. Average effective tax rate over the life cycle of a typical mine when the gold price is USD 1,300

Source: Natural Resource Governance Institute, NRGI Gold Mining Tax Model v1, 2018.

Note: The graph illustrates the change in AETR due to paying a tax on concentrate. The International Monetary Fund (2012) suggests: "reasonably achievable ranges of discounted AETRs will be 40–60 percent for mining." However, the results are very sensitive to a range of assumptions. They illustrate how imposing the export tax significantly changes the tax burden for companies. The reader should not draw conclusions about the overall tax burden on Kyrgyz mining companies from the current tax regime on. See our companion report for an evaluation of the tax regime, details on how we modelled the average effective tax rate, and precautions in interpreting these estimates. David Manley, An economic evaluation of gold mining tax regimes in the Kyrgyz Republic, (Natural Resource Governance Institute, 2018)

For many companies this could force them to close mines, lay off workers and stop production. It might also deter investors from investing in the country either to expand existing mines or explore for new resources. This has three implications. First, it would reduce the chances of the smelter reaching a commercially viable level of production. Second, it would reduce government revenue both by reducing production now and in the future. Third, forcing mine closure and deterring investment could result in fewer jobs for Kyrgyz people, since a smelter would employ far fewer people than most mines employ. For example, Kumtor employs 3,500 workers in the mine compared with 80 at Kara-Balta refinery, while a smelter with a 150,000 tonne capacity might employ between 100 and 200 people only.[20] Likewise, in Indonesia, the gold and copper mine, Grasberg, employs 32,000 people, while the smelter that processes the mine's concentrate employs only 800 people.

20 Kumtor Gold, "Contribution to the Economy," accessed 4 February 2018, www.kumtor.kg/en/media-relations/contribution-to-the-kyrgyz-economy.

RESULT 6. IF THE GOVERNMENT FUNDED A SMELTER (EITHER DIRECTLY OR INDIRECTLY VIA TAX INCENTIVES AND SUBSIDIES) THE COST WOULD BE KGS 14 BILLION (USD 201 MILLION), DIVERTING MONEY FROM OTHER USES.

Rather than imposing such a heavy cost on mining companies, the government might consider funding the smelter and refinery costs itself, or give substantial tax incentives to companies to encourage them to use the smelter. This is common in countries whose governments have insisted on following a value addition policy. Indonesia, for example, gives incentives to companies on top of banning the export of concentrate.[21] But given our estimated loss of USD 201 million over the 20 years of production, it would be a heavy price to pay for a policy that was intended in the first place to increase government revenue.

21 Östensson and Löf, "Downstream Activities: The Possibilities and the Realities."

4. Four factors determine the viability of domestic processing

The results of our modeling cast a dim view on the prospects of a value addition policy in the Kyrgyz Republic. They are driven, predominantly, by three main factors—global treatment and refining charges, economies of scale, and the cost of transport. We did not model a fourth factor—power consumption and environmental impact of smelting and refining—because it is an externality and difficult to quantify. However, these costs only add to the costs that a value addition policy would impose on the country.

These factors combine to make smelter develop in the Kyrgyz Republic commercial unviable. These factors are unlikely to change in the foreseeable future.

A. TREATMENT AND REFINING CHARGES

Treatment and refining charges (or TC/RC) across the world are so low that few smelters and refineries make a profit without financial support from governments. This is because there are too many smelters and too little concentrate produced. Here we discuss the current conditions in the processing of sulphide concentrate and copper. While the Kyrgyz republic produces mostly gold, the factors here are still relevant.

Considering the smelting of concentrate with copper (such as the sulphide concentrate produced in the Kyrgyz Republic), in 2002, the world contained 122 smelters, with a combined capacity of over 14 million tonnes a year. Since then, capacity has grown considerably, and by 2019, it is projected to be about 22 million tonnes of concentrate a year.[22] Much of this expansion has come from China, which has increased its capacity by 10 percent a year.[23] The Chinese government may limit this expansion because of the massive amounts of power their smelters and refineries are consuming, and because of the increasing air pollution in Chinese cities, but there are still plans to increase capacity for the time being.[24]

These new smelters add to the stock of older smelters that previously treated the output of a nearby mine whose reserves have now been depleted. These old smelters have since recovered their original investment. So, in order to remain viable, these smelters are available to smelter concentrate from other mines, increasing the total capacity on the market. Further, these smelters only have to set TC/RC to cover their operating costs. This allows them to set lower TC/RC than a new mine that has to also recover the money invested in development. The aggregate effect is to further reduce TC/RC past the point of profitability for most new smelters.

22 "Copper production growing by 1 million tonnes a year," *Mining.com*, 26 July 2016, www.mining.com/copper-production-growing-1m-tonnes-year.
23 Nathan Associates, *Economic Effects of Indonesia's Mineral-Processing Requirements for Export*, 12.
24 CRU International, "Chinese smelter capacity to continue growing despite a tightening copper concentrates market," posted 1 August 2016, www.crugroup.com/knowledge-and-insights/insights/chinese-smelter-capacity-to-continue-growing-despite-a-tightening-copper-concentrates-market.

This capacity increase has not been matched by an increase in global concentrate production. Even in 2011, there was an excess capacity of 7 million tonnes, about 51 percent of total concentrate output.[25] This excess capacity has driven down TC/RC for processing concentrate by 60 percent in the past 15 years.[26] Such low TC/RC ensures that few smelters make significant profits, and few new smelters are commercially viable unless supported by a government or unless a mine is far enough away from downstream markets that savings in transport costs become important—the third factor will we discuss soon.

In addition to the fall in TC/TC, the cost to develop new smelters has risen—from 2008 to 2014 by 70 percent. This is particularly the case for new smelters ("greenfield development"). Costs have increased less for the expansion of existing smelters ("brownfield development"). For instance, Kazakhstan's recently built copper smelter by Kazzinc will process 370,000 tonnes of concentrate, but this is a brownfield development as part of a larger existing metallurgical complex producing lead and zinc.[27]

Building greenfield smelters is rarely viable outside China. In China, development costs for greenfield smelters remain about half those in the rest of the world. But replicating the factors that contribute to lower costs in China are difficult and perhaps less desirable for other countries. China has lower land acquisition fees, provides special tax treatment for locating in special industrial zones (since their large industries benefit from having smelters close by), has low construction costs (because of low labor costs and low-interest loans, supported by state banks), large markets for by-products such as acid and metals, abundant electricity and infrastructure to support metal processing, and a weak protection of local communities and the environment.[28] These factors help Chinese greenfield copper smelters to break even.[29]

Finally, many smelters, depending on their contract with mining companies, can earn additional income from selling by-products found in concentrate, but these are often still not enough to make most potential smelters viable.[30] In addition, these by-products often require exportation to specialized plants. For copper, it is still often the case that the anode slime produced during smelting has to be processed in a different specialized facility. For instance, Indonesia's Gresik smelter sells the anode slime it produces to a plant in Japan for further processing.

25 Nathan Associates, *Economic Effects of Indonesia's Mineral-Processing Requirements for Export*, 14.
26 *Ibid.*, 12.
27 Glencore International, "Kazzinc Commissions Copper Smelter at New Metallurgy Project, Further Strengthening a World-Class Polymetallic Operation," posted 13 September 2011, www.glencore.com/assets/media/doc/news/2011/201109130800-Kazzinc-commissions-copper.pdf.
28 Nathan Associates, *Economic Effects of Indonesia's Mineral-Processing Requirements for Export*, 14.
29 *Ibid.*
30 *Ibid.*, 12.

B. ECONOMIES OF SCALE AND COSTS

Developing a smelter for sulphide concentrate currently costs a lot: hundreds of millions to billions of dollars. Much more than the processes of oxide concentrates. Smelting technology is slowly changing which may reduce the size of smelters, and reduce their costs, environmental wastes and energy use. As these technologies develop, the economics of gold and copper smelting in the Kyrgyz Republic may change. But for now, development costs remain high.

To pay off these costs a smelter must process large amounts of concentrate, and operate as close to its capacity as possible. If a smelter can be guaranteed a large volume of concentrate over its lifespan, its average costs per unit will be low, and the charges it can set to remain profitable can also be low. Because the average per unit cost of the smelter falls as production rises, we can say the smelter has an "economies of scale."

For relatively small mining industries like in the Kyrgyz Republic, economies of scale make developing a new smelter problematic. A study by the Tanzanian Mining Authority showed that a commercially viable smelter required a feedstock of at least 150,000 tonnes of concentrate per year. Tanzania only produced 60,000 tonnes a year, so the authors concluded a smelter would not be viable.[31]

Economies of scale also mean it is crucial to ensure a large and reliable supply of concentrate. If a company builds a smelter for a large mine—like the Gresik smelter in Indonesia that processes copper and gold concentrate from Grasberg, one of the largest mines in the world—then a large throughput can be expected for many years. Alternatively, a company can build a smelter for several mines that can reliably produce a large throughput—like the Nkana smelter in Zambia, a major copper producer. But for countries with a small mining industry, or where the throughput is unreliable (for instance because of disputes between companies and the government that cause shutdowns), achieving the economies of scale necessary to keep costs low can be difficult. Smelters that have been developed only to see the available throughput decline have to seek concentrate from other countries. For example, even in Zambia, the country now has too much smelting capacity, forcing the Nkana smelter to buy concentrate from as far away as Chile to keep its production high enough.[32] Kazakhstan faces a similar problem with their gold refineries. Kazakhstan's mines were not sending enough production to feed the country's refineries. In response, the government imposed rules to encourage mining companies to use the existing gold refinery rather than export their doré, but at a high cost to the Kazakh mines that were using cheaper foreign refineries.[33]

31 Tanzania Minerals Audit Agency, *A Study on Viability to Construct a Copper Concentrate Smelter in Tanzania*, (2011).

32 "KCM Explains Why it is Importing Copper Concentrate from Chile," *Lusaka Times*, 28 June 2015, www.lusakatimes.com/2015/06/28/kcm-explains-why-it-is-importing-copper-concentrate-from-chile; "Zambia Orders Vedanta Unit to Get Rid of Chilean Copper," *Mining.com*, 14 September 2015, www.mining.com/zambia-orders-vedanta-unit-to-get-rid-of-chilean-copper.

33 Michael Wilson and Elena Lee, "Kazakhstan's Gold Mining Sector and the New Regulation on Gold Sales," *Alchemist*, no. 66 (2012).

Economies of scale also explain why smelters in places like China, South Korea and Japan can operate without substantial losses. Much of the world's concentrate production from surrounding small producers aggregates in these countries.

Is this situation likely to change in the future? It does not seem likely, unless new smelting technologies make it possible to smelt small quantities of concentrate without a high cost of development. Based on our consultation with industry experts, no such technology appears commercially viable or efficient at present.

C. TRANSPORT COSTS

The primary advantage of building a smelter in the Kyrgyz Republic is that it would save mining companies substantial costs in transportation. For instance, smelting a gold-copper concentrate removes about two-thirds of the weight that has to be transported. This is why smelters in Zambia, over 9,000 kilometers from China, can operate profitably.

In the Kyrgyz Republic, mines produce about 49,000 tonnes of sulphide concentrate a year and export this concentrate to smelters in Kazakhstan and China. About half of copper exports go to China. China has a large and growing smelting capacity, but much of it is in the eastern half of the country. Based on data from 2002, the nearest smelters to the Kyrgyz Republic are 2,500 kilometers away. On the other hand, the distance to downstream industries in the manufacturing regions of China is much less. In addition to the smelters shown in Figure 6, three new smelters in western China are due to be built in the next three years with a combined capacity of 300,000 tonnes.[34] The remaining concentrate is exported to Kazakhstan which has two large smelters with have a combined capacity of about 395,000 tonnes of concentrate, although it is unclear how much capacity is spare after processing Kazakhstan's own production. These two smelters are about 470 to 720 kilometers away from Bishkek. There is another smelter in Uzbekistan also about 470 kilometers from Bishkek. Although this smelter has a capacity of 140,000 tonnes, no Kyrgyz concentrate is exported here.

This situation is unlikely to improve. China's One Belt, One Road initiative—which aims to build roads, rail and other infrastructure throughout central Asia—could make transporting concentrating to China cheaper, making developing smelters in the Kyrgyz Republic less viable.

34 CRU International, "Chinese smelter capacity to continue growing despite a tightening copper concentrates market," posted 1 August 2016, www.crugroup.com/knowledge-and-insights/insights/chinese-smelter-capacity-to-continue-growing-despite-a-tightening-copper-concentrates-market.

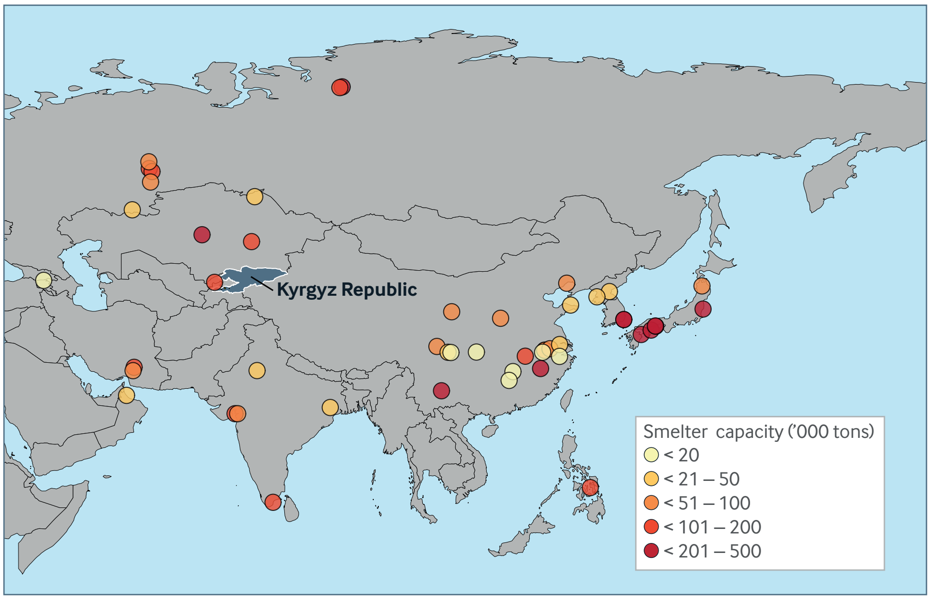


Figure 6. Copper smelters close to the Kyrgyz Republic, 2002

Source: NRGI illustration using data from U.S. Geological Survey, "World Copper Smelters," accessed 30 January 2018, Ehttps://mrdata.usgs.gov/mineral-resources/copper-smelters.html.

Note: The map shows smelters and their capacity in 2002. Not shown on the map are three new smelters being built in the west of China. Capacity is in tonnes of concentrate. We do not know how much of this capacity is spare, but we do know that globally about 50 percent of smelting capacity is currently unused.

These factors have driven the trend in which less copper ore is smelted within the country of origin. Table 6 shows that in 2000, 66 percent of copper ore was smelted in its country of origin. By 2014, this was down to 55 percent. This is as true for high-income countries as for low-income countries: in the United States, 100 percent of copper ore was smelted in the country, but by 2014, it was 62 percent.

	2000	2005	2010	2014
Peru	86%	45%	29%	24%
Chile	45%	42%	47%	35%
Australia	54%	47%	48%	50%
United States	100%	89%	89%	62%
Russia	100%	99%	84%	88%
China	100%	100%	100%	100%
India	100%	100%	100%	100%
Zambia	100%	82%	100%	100%
Japan	100%	n/a	n/a	n/a
South Korea	n/a	100%	n/a	n/a
Total	66%	63%	59%	55%

Table 6. The proportion of copper smelted in the country from which was extract has fallen over time, except in countries far from industrial centers.

Source: Östensson and Löf, "Downstream Activities: The Possibilities and the Realities."

Note: Copper ore smelted within country of origin as percent of total copper ore produced within the same country.

Another factor that drives the concentration of smelting capacity in areas such as eastern China and Japan is the short distance to downstream customers. Industrial users of raw materials today expect speedy delivery and a broad product range from their suppliers. Many downstream products such as semi-fabricates of steel and nonferrous metals are produced in a wide range of qualities and are used by a variety of industries; smelter and refineries that can deliver metals at short notice and to the correct specification gain a strong competitive advantage. Given this demand from customers, producers far away from downstream industry are disadvantaged. It is no coincidence that semi-manufacturing of nonferrous products has migrated from Europe and North America to East Asia at the same rate as the production of manufactured products.

D. POWER CONSUMPTION AND ENVIRONMENTAL RISK

Our modeling results indicate that a smelter and refinery in the Kyrgyz republic would likely lose money. But in addition to this loss, more smelting and refining would also impose other costs on the country. One is the vast amount of power that smelting and refining require. In some cases, companies build their own power station to supply the smelter and refinery, but this would add to the development cost. Further, this adds to the importance of maintain a reliable feed of concentrate to keep the power station operating. One option is to allow the power station is sell spare power back to the national grid, although this requires reliable in-country buyers.

Otherwise, the power needs of smelting and refining are supplied from the country's own power plants. If there is insufficient capacity, this can lead to shortages. This risk has led Zambia to avoid building refineries in the country. In Zambia, the mining industry consumes about 50 percent of the nation's power, with a large portion of that going to smelters. The lack of power means that while Zambia can smelt most of its copper concentrate, much less can be refined in the country, a process that requires even more power. This is also the case in Chile. While Zambia and Chile smelt much of their own concentrate, the amount they refine internally has fallen, from 89 percent to 65 percent, and 74 percent to 55 percent, respectively. [35] In some countries, like the Democratic Republic of Congo, the demand for power is so great compared to the acute shortage of power, the government has abandoned plans to smelt and refine cooper in the country.[36]

We did not explicitly measure power capacity in the Kyrgyz Republic, nor the added demand from building smelters and refineries. The Kyrgyz Republic has potentially sufficient amounts of electricity if it developed its hydroelectric resources, but until that happens, people rely on mostly coal and diesel generation, which is polluting the local air.

Smelting and refining also create pollution if companies do not expertly manage these processes. For example, smelting sulphide concentrate produces sulphur dioxide, which, if released, causes acid rain that damages forests and farms. Similarly, some substances in concentrate are difficult to process and dispose of safely. For example, because of this difficult, few governments allow the processing of concentrate containing arsenic in their countries.

35 Östensson and Löf, "Downstream Activities."
36 *Ibid.*

Lessons and recommendations for the government

On whether to levy a tax:

It is unlikely that encouraging more domestic process of gold ores and concentrates will result in a large net benefit for the Kyrgyz Republic.

Some types of ores require pyrometallurgical techniques (smelting) for which locating in the Kyrgyz Republic is probably less feasible than other types of pres. Levying a tax on these ores and concentrates may push some mines out of business and deter investment. In itself, this is not problematic, except that our analysis and corroborating estimates suggest that the added value from smelting and the associated net benefits for the country are unlikely enough to warrant pushing some mines out of business. Likewise, a government funded smelter would lose the public billions of Kyrgyzstani som that could be used elsewhere, without any clear benefit.

Different types of gold ore require different types of processing, and some processes carry environmental risks.

A number of mines in development may process their concentrate in the country, without the need for the government to impose a value addition policy. However, in addition to losing money on gold-copper concentrate processing, the government may not want to encourage concentrate processing involving hazardous substances like arsenic.

On developing an alternative value addition policy:

Strong regulation and monitoring of any processing plants will help minimize environmental damages.

Some processing is most likely viable in the Kyrgyz Republic, and companies may decide to build these plants. Even so, there is a significant risk of environmental damage from mineral processing that needs to be controlled. Strict rules on environmental impact assessments, consultations with local communities and effective monitoring are all useful. A full list of environmental protections can be found in *Natural Resource Charter Benchmarking Framework, Precept 5*.[37]

37 Natural Resource Governance Institute, *Natural Resource Charter Benchmarking Framework* (2017), 60 – 70, resourcegovernance.org/sites/default/files/documents/natural-resource-charter-benchmarking-framework-report-2017-web_0.pdf.

A larger mining industry would increase the likelihood that smelting plants will be commercially viable.

A discussion paper by the Natural Resource Governance Institute—*Improving Resource Governance in the Kyrgyz Republic: 12 Priority Issues for the Mining Sector*—details some of these alternative policies.[38] An evaluation of the mining tax regime would also be useful—see the companion report—*An Economics Evaluation of Gold Mining Tax Regimes in the Kyrgyz Republic.*[39]

On generating more revenue from the mining industry:

Changing the gold mining tax regime will probably yield greater benefits than encouraging more domestic processing.

Careful evaluation can help in government officials and other stakeholders to understand how to best design the mining tax regime. The tax reform program led by the Ministry of Economy is a useful initiative to increase revenue from the mining industry, and our accompanying report—An economics evaluation of gold mining tax regimes in the Kyrgyz Republic—provides an evaluation of the tax regime

Following leading practices in monitoring the mineral content of gold exports will help government metallurgists reduce company misreporting.

Government officials are concerned that mining companies are not declaring the true value of the concentrate they export. However, building a smelter in the Kyrgyz Republic would be an expensive way to address this concern. Further, there is no guarantee that a Kyrgyz smelter will be more efficient than other smelters. Whatever the country might gain from monitoring companies in this way, it may lose from a less efficient smelting process and the added cost of the smelter itself. A good practice used in many countries in the world is to insist that mining companies and foreign smelters provide the government and its designated "referees" with samples of the concentrate being smelted. While the government m ay be worried it cannot maintain an effective metallurgy department, it could at least ensure sufficient capacity to work with these referees. Once this system is established, the government could ensure that its metallurgists have sufficient expertise to evaluate the referee reports and choose suitable referees, regularly assess referee performance and replace them when necessary. Further, if the government and its referees find that a foreign smelter appears to be extracting relatively little metal from concentrate, it could just whether this is because mining companies and smelters have common interests or beneficial owners. In such cases, the government might consider imposing rules to prevent such relationships between foreign smelters and Kyrgyz mining companies. Appendix 3 details this system.

38 Natural Resource Governance Institute, *Improving Resource Governance in the Kyrgyz Republic: 12 Priority Issues for the Mining Sector* (2017), resourcegovernance.org/sites/default/files/documents/nrgi_discussion_paper.pdf.

39 Available at www.resourcegovernance.org/analysis-tools/publications/economics-evaluation-gold-mining-tax-regimes-kyrgyz-republic.

Appendices

This report contains four appendices. Appendix 1 explains the physical process of turning gold ore into gold bullion, and the processing of copper, a common substance found in sulphide ore in the Kyrgyz Republic. Appendix 2 explains how treatment and refining charges are calculated based on the concentrate's metal content. Appendix 3 explains the typical approach governments take to monitor smelters and the mineral content of sales. Appendix 4 explains the sensitivity analysis we undertook to ensure our results were not highly sensitive to our assumptions.

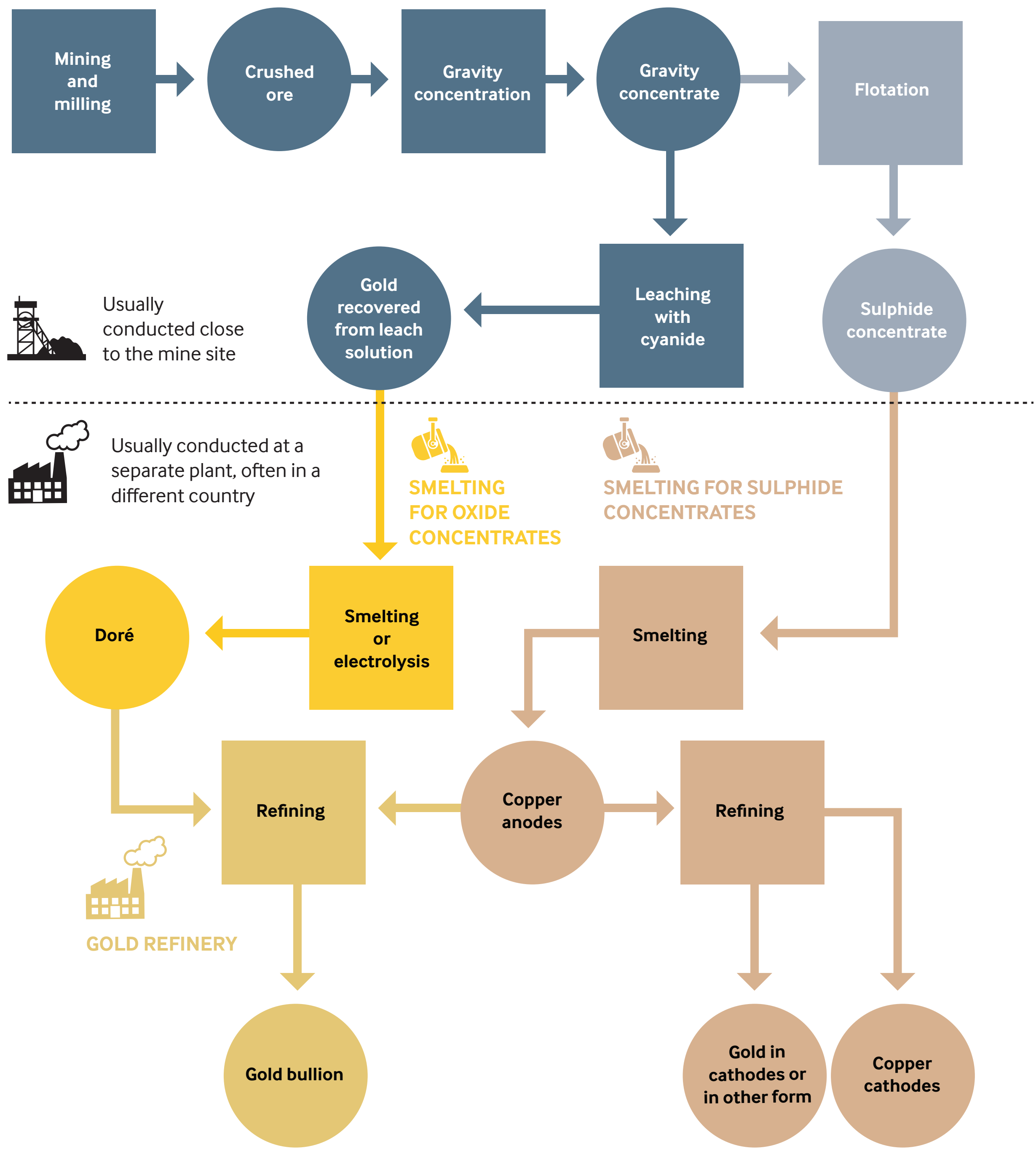
A1. PROCESSING GOLD ORES[40]

Miners are always adding value to their product. What policy-makers refer to as "value addition" focuses on only one part of a long series of processes. In this section, we review this series, explaining what processes are typically undertaken at the mine site, and what is typically done elsewhere. We also explain how processes differ depending on the composition of the ore available. Figure A1 below shows the different process chains. The specific processes involved change in different cases, this section illustrates the process for a typical gold and copper value chain.

All processing starts with miners extracting ore, and crushing and milling the ore to produce *milled ore*. This reduces the ore's particle size so that it can be subjected to further processing. Miners then transform the milled ore into *concentrate* removing much of the waste rock in the process. For example, on average, concentration increases the gold content by a factor of 10 from the content of the ore. At this point, for example, the concentrate might have 5 grams of gold per tonne. This is the first part of mineral processing, which nearly all mines in the world do at the mine site. What happens next depends on whether the type of ore.

40 Encyclopaedia Britannica, "Gold Processing," last modified 11 May 2001, www.britannica.com/technology/gold-processing.

Figure A1. Processing gold and gold-copper ores



Processing oxide and quartz ore

To process concentrate from oxide ore, miners *leach* the minerals using cyanide to create *leach solution*. For low grade ores miners typically use *heap leaching*, for high grade ores *vat leaching*. These processes produce *doré*, a gold and silver alloy, which may also contain other metals.

Up to this point processing is almost always done close to the mine site. This is because of the high cost of transporting the bulky ore and concentrate and the relative cheapness of processing the gold concentrate into doré. In the few cases when mining companies choose to export their ore, they probably do so because the concentration process requires specialist techniques that can be done more cheaply elsewhere. For instance, processing ore containing arsenic usually require a more expensive form of processing technique compared to other types of oxide ore. This means that for mines with oxide ore, almost all processing will be done in the Kyrgyz Republic, unless specialized techniques are required.

Processing refractory ores (sulphide, gold-copper ores)

Refractory ore is more difficult to process than oxide ore. For refractory ore, after gravity concentration, miners process the gravity concentrate using *flotation*—a technique that removes much of the waste rock. Flotation usually occurs close to the mine site. But once much of the waste has been removed, the concentrate is valuable enough for miners to transport by rail, road or barge to another processing plant. The gold content of a flotation concentrate may vary widely, but in gold-copper ores the copper can be between 20 to 35 percent of the concentrate.[41]

Further processing removes sulphides from the concentrate using either a *roasting* or *smelting* technique. *Roasting* involves submitting the concentrate to extremely high temperatures; however, roasting makes it difficult to recover the sulphur, which is released to the atmosphere, becoming a serious pollutant. To avoid this, most concentrate will instead be *smelted* in a smelter. For ore containing copper, this process produces *copper anodes,* which often contain other metals such as gold. To separate the copper and gold, copper anodes are refined, usually by *electrolysis*. Both smelting and refining of copper are often done in the same processing complex, but often separate to mine sites.[42]

Refining gold

Whether from the doré produced from oxide ore or the copper anodes produced from refractory ore, gold bullion is extracted using a separate refining process. This separates other elements, such as silver, to produce gold bullion. Likewise, some elements like platinum require specialized refining techniques and therefore specialized refineries. Furthermore, only a few countries in the world operate gold refineries. The Kyrgyz Kara-Balta gold refinery can process the output from the Kumtor and Makmal, it might not be able to process the output from other mines in in the future. The need for specialist techniques means that specific refineries refine gold from across the world.

41 This assumes copper is the main value metal. Flotation is also used on ore of other metals that exist as sulphides, for instance, lead and zinc. These ore often contain some copper as well.
42 Nathan Associates, *Economic Effects of Indonesia's Mineral-Processing Requirements for Export,* 12.

A2. CALCULATING TREATMENT AND REFINING CHARGES, AND VALUE ADDED

In section three we argued that smelting and refining adds relatively little value to gold concentrate. Value addition is calculated by comparing the prices of each product in the value chain. Therefore, we need to understand how concentrate is priced, and the prices charged by smelters and refineries.

There are two arrangements by which these prices are set, both of which are equivalent for our purposes. The first is the buyer-seller arrangement. In this arrangement, the miner sells concentrate to the smelter, the smelter then processes this concentrate and sells the output at a marked-up price. The mark-up is the smelter's income. The second arrangement is tolling. The miner retains legal hold of the product but pays the smelter and refinery a set of charges, called treatment and refinery charges, or "TC/RC." The value added by the smelter and refinery is therefore the mark-up in prices under the first arrangement, and the TC/RC under the second arrangement. The two arrangements are economically equivalent, but because tolling is more common, we focus on this second arrangement here.

To set the treatment and refinery charge as part of a tolling arrangement, a mining company and a smelting and refining company first calculate the value of the concentrate to be processed. These calculations have to account for associated minerals like copper often found in the concentrate. Table A2 shows the information used to calculate the price. This replicates the assumption we made in the modeling exercise described in section three.

Table A2. Assumptions to calculate the value added to gold concentrate

Assumption	Gold	Copper
Gold content, grade (grams/tonne of concentrate, %)	0.002%	30%
Payable metal	95%	96.65%
Gold Price (USD/oz)	1,300	
Copper Price (USD/tonne)		6,000
Copper Price (USD/lb)		3.18
Smelting (Treatment) charge (USD/tonne of concentrate)	70	70
Gold Refining charge (USD/oz)	6	
Copper Refining charge (cents/lb)		7
Transport cost (USD/tonne/kilometer)	0.11	0.11
Distance from mine to smelter in Kazakhstan (kilometer)	400	400

Note: see the accompanying Excel spreadsheet model for the full calculations. www.resourcedata.org/dataset/Kyrgyz-Republic-mining-tax-analyses

In this example, a mining company produces concentrate containing gold and copper. The mine, smelter, an independent referee and a government inspector jointly establish the copper and gold content in the concentrate. In this example 20 grams per tonne (0.002%) of concentrate is gold and 30 percent of the concentrate is copper. Smelting processes never recover the full amount of metal from concentrate; much depends on the ore types and efficiency of the smelting process, so the standard practice is for the smelter and mining company to agree the proportion of metal that will be officially recovered, which is termed the "payable metal content" for each mineral. In our example, this is 95 percent for gold and 96.65 percent of the assayed content for copper. The mining company and smelter then establish the price of gold and copper. In this example, the contract uses the London Bullion Fix of USD 1,300 per troy ounce for gold and the London Metal Exchange of price USD 6,000 per tonne of copper.

To calculate the value of concentrate before treatment and refining is charged, the parties would use a formula similar to this one:

Gold content in concentrate (grams/tonne) x Payable metal content (%) x London fix, gold price, converted to grams (USD/grams)

\+

Copper content in concentrate (%) x Payable metal content (%) x LME copper price (USD/tonne)

= Value of concentrate before TC/RC

For the following calculations we round to the nearest significant number. For more accurate results, refer to the spreadsheet model.

Combining this formula with the information from Table A2 above, the value of the concentrate is USD 2,534:

20 g/tonne x 95% x USD 1,300/ounce/31 +
30% x 96.65% x USD 6,000/tonne Cu
= USD 2,534

(Since gold prices are quoted in troy ounces, but gold content is quoted in grams, in this example, the gold price is converted into grams by dividing by 31.)

Having established the value of the tonne of concentrate, the smelting company can then calculate the treatment and refinery charges. The standard practice is to set treatment charges in dollars per tonne of concentrate, and to set refining charges in cents per pound of copper and dollars per ounce of gold. In our example, the treatment charge for 1 tonne of concentrate is USD 70.[43] For refining charges, the calculation is more complicated because there are separate charges for each metal and because fees are traditionally quoted in different units to tonnes.

Copper refining charge: 30% x 96.65% x (0.07 x 2,204) **= USD 45**

Gold refining charge: 20 g/tonne x 95% x 6/31 **= USD 4**

43 In some cases, a smelter would include a deduction on the amount the mining company receives, to keep the model tractable we have left this out. The overall result is similar in either case.

Putting all this together gives the value of a tonne of concentrate that the mining company receives.

USD 2,534 – USD 70 – USD 45 – USD 4 = **USD 2,416**

Therefore, in this example, the amount the smelting and refining companies receive, or the value added of all this processing is USD 70 + USD 45 + USD 4 = USD 118 (values are rounded to the nearest whole number). Meanwhile, the mining company receives USD 2,416. The mining company creates almost all of the value.

If the smelter is 1,450 kilometers away in Kazakhstan from the mine and the cost of rail transport is 11 cents per tonne per kilometer, the cost of transporting a tonne of concentrate is USD 160. Therefore, the actual amount the mining company receives, after paying for rail transport, is:

USD 2,416 – USD 160 = **USD 2,256**

In other words, in this example, the mining and concentration process creates 89 percent of the final value, transportation creates 6 percent of the value and smelting and refining creates only 5 percent.

Smelting, however, significantly reduces the mass of product that has to be transported. If the concentrate was instead smelted in the Kyrgyz Republic, and then the processed gold and copper were transported the same distance to China, a mining company could save USD 31 per tonne of concentrate. Locating a smelter close to the mines allows some more of the value to be created in the Kyrgyz Republic, but most of the value is still created by the initial processing of mining and concentration.

A3. MONITORING METAL AND MINERAL CONTENT IN CONCENTRATE

Mining and concentrating create most of the value of gold and copper. However, there is no guarantee that this value will be correctly reported to the government. This is a common concern for governments across the world. Tanzania, for example, banned the export of unprocessed concentrate and ore partly because they suspected that a mining company, Acacia Mining, was underdeclaring the mineral content of their concentrate sales.

Although a domestic smelter and refinery may provide better access for government inspectors, following established practices used in many other countries can provide the same information. Usually these systems involve taking several samples of the mineral concentrate to be processed, analyze them and distributing these samples between the mining company, buyer, government departments and referees. This system already exists in the Kyrgyz Republic, where samples are taken and analyzed by Alex Stewart International. Referees—like Alex Stuart, Bureau Veritas and SGS—are asked to arbitrate if the other parties disagree over the mineral content. The government could potentially hire to different third-party verifiers ancd cross check their results. The government could allow two different firms to take samples and compare the results. This system is necessary even if the government were to insist on domestic smelting and refining, since mining companies and metal buyers would require the same set of sampling and independent checks by referees, and because the government would also need to audit and monitor smelters and refineries in the country to ensure taxes are paid correctly. In addition, the government may want to ask foreign smelters to send the government reports on metal content of concentrates they receive for processing. By comparing the results from various sources, this system usually identifies if one party is cheating. Unless the buyer, seller and smelter are related, each party will have an interest in ensuring that the other parties do not cheat.

However, this system may fail a government in at least two ways. One is if the government does not correctly follow the process and fails to systematically cross-check assay reports.

Another risk is if a mining company uses a smelter and refinery, and sells to a buyer that are related parties, and government inspectors and independent firms cannot get proper access to their operations. In these cases, the interests of the other parties may be aligned against the government, while the referee may not have sufficient information to challenge the other parties. In this case the government could request that the mining company ensure that government inspectors and referees can sample deliveries appropriately. This could be backed by an intention to remove a company’s license to export if it does not comply.

Strengthening the government’s expertise in verifying samples from smelters, as well as the tax authority’s ability to conduct audits on mining companies is the most common way for governments to ensure companies do not underreport.

A4. SENSITIVITY OF THE RESULTS TO THE ASSUMPTIONS

Each of our assumptions is an educated guess about the real world. If the real value of each of our assumptions were different, how would our results change? To provide an indication, we varied the eight most important assumptions and recorded the change in the total NPV gain or loss to the country. For varied each assumption by –75%, –50%, –25%, 25%, 50% and 75%. However, we kept all other variables constant. This is a simplifying assumption to keep our calculations tractable.

Figure A4 illustrates the results. The modeled net present value of lifetime smelter income is mainly sensitive to our development cost assumption, and to a smaller extent to transport cost. Our headline result is most sensitive to the development cost assumption. At an assumed development cost of USD 300 million, we estimate the loss to the country to be USD 201 million. If development cost were only USD 150 million (unlikely based on our consultation with industry experts) the loss to the country would be USD 71 million. The development cost would have to be only USD 68 million for the country to gain from building a smelter (given our other base assumptions).

There is some sensitivity to our operating cost, discount rate and transport costs assumptions, but the qualitative result holds even with large variations.

The sensitivity analysis indicates that our assumptions about the mineral content of ore and mineral prices are not as important as these other assumptions already mentioned.

Figure A4. Sensitivity of the modeled net present value of lifetime smelter income (vertical axis) to main assumptions

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