

RESEARCH ARTICLE

Can large-scale technology raise small-miner income and reduce mercury? Prospects for female waste-rock collectors selling ore to non-mercury processing plants

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Abstract

Artisanal-and-small-scale gold mining supports millions of livelihoods in the Global South but is the largest anthropogenic source of mercury emissions. Many initiatives promote mercury-free technologies that small miners could employ. Few document mercury impacts. We study an alternative: instead of processing themselves, small miners sell their ore to plants employing larger-scale, mercury-free technologies that also raise gold yields. Some ore-selling occurs without policy intervention, yet impacts on incomes and mercury use remain unclear. We assess ore-selling preferences of female waste-rock collectors (*jancheras*) in Ecuador, using a discrete-choice experiment. Results demonstrate that *jancheras* generally are open to ore-selling, yet often reject options similar to a recent pilot intervention. Offers that address formalization hurdles (invoicing), inability to meet quantity minima (given limits upon association, storage, and credit), and constraints on trust (including in plants' ore testing) could increase adoption by tailoring related interventions to the preferences of and challenges for defined populations.

Keywords: ASGM; Ecuador; gender; gold; mercury; mining; ore-selling; poverty

JEL classification: O13; O33; Q56

1. Introduction

Artisanal and small-scale gold mining (ASGM) produced about one fifth of the world's gold output in 2014, with roughly 16–20 million miners operating primarily in low-

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and middle-income countries (Seccatore *et al.*, 2014). ASGM supports the livelihoods of 50 to 150 million people globally (World Bank, 2019; Cheng *et al.*, 2023; Keane *et al.*, 2023; IGF, 2024).

However, ASGM is also the largest anthropogenic source of atmospheric mercury pollution (Seccatore *et al.*, 2014; Esdaile and Chalker, 2018; Martinez *et al.*, 2021). Mercury and its compounds are highly toxic, posing serious risks to human and environmental health (Nevado *et al.*, 2010; Basu *et al.*, 2018; Gerson *et al.*, 2018; Zulaikhah *et al.*, 2020). As ASGM contributes to livelihoods and global pollution, many programs aim to reduce emissions while preserving economic benefits.

The Minamata Convention on Mercury highlights the need for intervention within ASGM (UNEP, 2013). It requires all countries with more than insignificant ASGM sectors to create National Action Plans to eliminate worst practices and to define targets for mercury reduction. The funding for pilot programs to support these efforts has been disbursed by the Global Environmental Facility, through the planetGOLD initiative. Its first phase is just concluding – although it has been reauthorized, notably with over twice the budget (GEF, 2021; planetGOLD, 2024).

Unfortunately, the most common intervention in the planetGOLD program and in ASGM overall, i.e., miner-level gravimetric technology, has yielded little adoption or attributable emissions reductions see reviews in Veiga and Fadina (2020), Veiga and Gunson (2020); Martinez *et al.* (2021), Keane *et al.* (2023), Veiga *et al.* (2025). Miner-level technologies which replace uses of mercury with gravity concentration to extract gold can, in principle – e.g., in lab settings – both reduce mercury use and increase gold yields. Thus, if their adoption costs were low, new technologies could raise income via yield. Yet, miners do not adopt them (or, at the least, it is not documented). Even when mercury use fell, reductions could not clearly be attributed to technologies at the miner level (García *et al.*, 2015).

Reasons for non-adoption are many. Technologies require capital to buy and expertise to operate and optimize. New technologies often have “hidden” costs related to peripheral equipment and consumables (generators, fuel, and clean water). The combined forces of informality, limited tenure stability, and a lack of access to finance make the purchase of new technologies difficult and risky for miner and lender alike. Powerful actors within supply chains benefit from this status quo, as informal financiers and landlords, so they may act to limit small actors’ abilities to adjust (Veiga *et al.*, 2014; Hook, 2019; Smith, 2019; Veiga and Fadina, 2020; Verbrugge *et al.*, 2021; Bugmann *et al.*, 2022; Keane *et al.*, 2023). These constraints make uptake of complex technologies far more difficult. Thus, mercury remains the cheapest, and easiest, way to extract gold (Veiga and Fadina, 2020).¹

Ore-selling provides an alternative mercury-free option that could eliminate these hurdles for the miner and has been employed in Central and South America. Sales of ore between small miners and large-scale processing plants (*plantas de beneficio*) that own and operate mercury-free circuits could raise miners’ incomes by raising gold yields while at the same time reducing mercury use (Veiga and Fadina, 2020;

¹The fact that mercury has been used for generations, in some mining populations, can also generate resistance to alternatives.

Veiga and Gunson, 2020; Martinez *et al.*, 2021; Veiga *et al.*, 2022).² Yet, to our knowledge, rigorous evaluations of ore-selling's impacts on small miners' incomes and mercury use do not exist, despite some ore-selling having already been privately adopted. Based on the available information, it is difficult to know how much miner populations and processing plants benefited from ore-selling and under what conditions – for instance, to what extent benefits vary by ore-selling arrangement or with specific actor types, mineralogy, or legal frameworks (Veiga and Fadina, 2020; Veiga *et al.*, 2022). If any such model is to be promoted as a private or public solution, however, then its requirements and net benefits for miners and processing plants need to be clearer. This motivates our inquiries.

ASGM is quite heterogeneous (Fisher, 2007; Buss *et al.*, 2019; Crespo-Lopez *et al.*, 2023). Historically, larger actors, such as processing plants, gained more from technological advances in the sector (Verbrugge *et al.*, 2021). Keane *et al.* (2023) call to analyze the conditions under which any ore-selling initiatives generate net benefits for specific mining groups, given distinct sub-populations of ASGM with varied output and pollution. International and national government interventions often try to help the most vulnerable groups, often referred to as 'micro-miners' given their limited gold output. These groups may face barriers to adopting non-mercury options, due to a lack of formality and unfavorable power relations with other actors in supply chains, and can be among the most intensive mercury users per unit of ore.

In Ecuador, the female waste-rock collectors (*jancheras*) have been identified as micro-miners, as well as intense users of mercury, within the National Action Plan's baseline study (Ministerio del Ambiente y Agua, 2020). Because many *jancheras* work within this sector due to a lack of other opportunities, they are targeted beneficiaries for a number of public interventions (e.g., Ministerio del Ambiente y Agua, 2020; Ministerio del Ambiente, 2020; Ministerio de Energía y Minas, 2022). The planetGOLD Ore-Selling Strategy evaluated the feasibility of targeting the *jancheras* before discovering participation barriers (see below) that led the program to focus upon other ASGM sub-populations.

We combine field observations, surveys, and a choice experiment with 236 *jancheras* to assess ore-selling's potential for *jancheras*. We drew upon extensive field work to determine survey questions and the hypotheses we test in our experiment. Our choice experiment to elicit *jancheras*' preferences uses qualitative feedback to select the ore-selling dimensions of greatest consequence and to assign locally relevant values. Facing our choice options – presented in a manner efficient for inference – respondents revealed how they traded off across the dimensions in choosing between two randomly generated ore-selling offers versus opting out (taking no offer, thus continuing status quo processing). We estimate statistical models on the choice data to infer willingness to accept offers' components, as well as compute the probabilities of adoption for specific offers, on average and for sub-groups.

We find many *jancheras* are interested in ore-selling yet could not participate in the proposed OSS pilot design due to lack of formality, access to material, and associations

²This 'ore-selling' is driven by mutual economic gains, not joint extraction from the same land as in the 'coexistence' settings in which ASGM occurs where larger mining firms own rights (and may engage to protect operational rights).

to aggregate material. Initiatives' impacts could rise if relevant populations are defined, studied, and targeted earlier. While ore-selling has promise, it will not be viable for some small mining actors without complementary interventions that address the kinds of barriers our preference revelation has identified as critical.

Below, [section 2](#) discusses the background of the ore-selling strategy, the *janchera* population, and the options for mineral processing for ASGM. [Section 3](#) describes the methods for our surveys, with a discrete-choice experiment. [Section 4](#) reports the results of the survey and choice experiment, then [section 5](#) discusses their implications, including the follow-ups that occurred after the project.

2. Background

2.1. Ore-selling strategy

We study an ore-selling strategy (OSS) developed by the Program of National Chemical Management (PNGQ) in Ecuador. PNGQ is a partnership between the United Nations Development Program, Ecuador's Environment and Energy Ministry, and its Non-Renewable Natural Resources Ministry funded by the Global Environment Facility (GEF) in 2017. As it aligns with goals of planetGOLD,³ OSS was adopted into the initial cohort of planetGOLD's mercury-free-solutions pilots for ASGM. Related efforts in Ecuador have since received funding to continue within planetGOLD's Phase 2.

OSS initially required procuring and putting into operation a processing plant (10 tons/day) for demonstrating gravimetric mercury-free processing methods to miners. However, the program evolved over time as program managers discussed options to offer alternatives for ASGM actors:

- (1) The program approached the National Mining Company, ENAMI EP, which said it would only be willing to administer such a processing plant if all the operating costs were covered.
- (2) It next approached a large mining firm, Lundin Gold, which works with artisanal miners on its concession to resolve conflicts and support livelihoods. Lundin expressed concerns about traceability – it is difficult to ensure all ore is from legal sources – and, further, that adopting such an OSS might generate conflict by enticing miners to mine illegally on its concession.
- (3) PNGQ next tried to identify any artisanal group which could directly administer a new plant, but policymakers predicted artisanal groups would dismantle the plant for short-term profits.
- (4) OSS then supported existing processing plants, initially selecting three (two in Camilo Ponce Enriquez and one in Portovelo) to receive valued equipment for their operations, in exchange for agreeing to pilot ore-selling with smaller miners. They also strengthened local independent laboratories.

³This was recently reauthorized. This added a further US\$416m in support for a Phase 2 (<https://www.planetgold.org/planetgold-phase-2>) to the prior US\$180m funding for Phase 1, noting that Ecuador is the only country within both phases.

2.2. Potential target beneficiaries: *jancheras*

A group identified early as potential beneficiaries of this program were *jancheras* – mostly women – who collect waste rock from other operations (Velásquez-López *et al.*, 2020). OSS highlighted them for gender equality and mercury reduction.⁴ Women are excluded from traditional artisanal mining, make less from the same activities, have more family responsibilities, and have less access to finance (Buss *et al.*, 2019; Reichel, 2020).⁵ These factors lock *jancheras* into using mercury when processing waste rock.⁶ While 1000 to 2000 regular members⁷ represents a small population, within Ecuador's ASGM population, *jancheras* are highlighted in Ecuador's National Action Plan due to their mercury usage and vulnerable status as low-income women e.g., Ministerio del Ambiente (2020), Ministerio del Ambiente y Agua (2020), Ministerio de Energía y Minas (2022). They also may face barriers to adopting ore-selling, which would prevent behavior changes of similar groups in Peru, Colombia and elsewhere.

2.3. Gold extraction processing methods for ASGM primary deposits in Ecuador

Mercury is used to concentrate gold. In primary deposits (hard rock), ore is crushed to liberate gold, then processing depends on ore type and grade. Crushed ore may be: gravimetrically concentrated, using a sluice or a centrifuge; further concentrated, using surface chemical methods (amalgamation or flotation); leached, using cyanide; or a combination.⁸ As this can require expensive equipment that is out of reach for artisanal/small-scale miners, private processing plants exist throughout the region.

In 2012, 48 processing plants opened in Camilo Ponce Enriquez, adding to over 80 processing plants in Portovelo-Zaruma (Veiga *et al.*, 2014). As of 2021, 153 processing plants were registered in Azuay and El Oro provinces, the respective locations of Camilo Ponce Enriquez and Portovelo-Zaruma (Delaune and Costa, 2022). These plants vary in how they procure ore. Some have concessions that supply ore, while others rely exclusively upon *jancheras*, artisanal, small-scale, and even medium-scale miners. Some combine material from others and their own concessions or affiliated mining companies.

For ASGM, the two main types of processing plant are mercury-intensive and mercury-free. Common versions of the former in Camilo Ponce Enriquez are *chanchas*, which offer access to ball mills and mercury to grind and process a miner's ore in small batches. As ore is crushed, the liberated gold is inefficiently amalgamated and concentrated, in a process called whole-ore amalgamation. The resulting amalgam can be heated, or 'burned', to evaporate the mercury to reveal 'sponge gold', which can be

⁴See, for instance, Ministerio del Ambiente, Agua y Transición Ecológica and Ministerio de Energía y Recursos Naturales No Renovables (2022).

⁵Gender disparities in ASGM have led to similar groups of women operating in Colombia (*chattarreras*), Peru (*pallequeras*), Burkina Faso, and DRC.

⁶Indeed, *jancheras* often employ the "worst practice" of whole-ore amalgamation at processing plants known as *chanchas*, where processing tends to involve grinding their ore while adding 2–7 parts mercury for each part of gold recovered.

⁷These estimates come from unpublished reports by ESPOL (all sources are available upon request to the authors).

⁸On flotation and cyanidation see, e.g., (O'Connor and Dunne, 1994) and (Veiga *et al.*, 2009, 2014).

sold locally. This grinding and processing can be done relatively quickly, in exchange for a nominal fee, or indeed even for free, yet miners must leave behind their gold-rich, mercury-contaminated tailings.⁹

Such plants often incentivize miners to process at their facilities by paying for ore transport and offering air-conditioned lounges with amenities, as well as the services of technicians to operate machinery and burn amalgams. These plants get little upfront revenue from fees for those services, yet still can reap huge profits because these miners are leaving ~70 per cent of the gold behind, in tailings, which the *chanchas* will then reprocess (Cordy *et al.*, 2011; Veiga *et al.*, 2014). Whole-ore amalgamation and the reprocessing of mercury-contaminated tailings, using cyanide, are deemed “worst practices” by the Minamata Convention (UNEP, 2013).

After having extracted only ~30 per cent of the gold at a *chancha* (Veiga *et al.*, 2009),¹⁰ per above, these smaller mining actors typically sell to informal gold buyers or to “gold shops”, who often offer them only ~70 per cent of gold’s international price. Shops earn profit by later reselling at a higher price (as field observations suggest mercury-intensive processing does not stop gold from reaching the world, just increasing intermediaries). Thus, in total, these miners receive only ~22.5 per cent of ore’s gold value.

Non-mercury processing plants use cyanide leaching, or flotation, depending upon their ore. Economically, plants which process more ore than their own operations supply typically offer others what is referred to locally as “plant rental.” Miners pay input costs, a fee for processing and a small percentage of the output value, in exchange for mineral extraction services conducted by plant technicians (although typically supervised by at least one representative of the mining group). Based upon our fieldwork, we understand upfront payments sum to US\$10,000–12,000 per 100 tons. While there is a non-mercury-processing model in this landscape, then, it is out of reach for typical small (small artisanal or *jancheras*) extractor groups, who typically have only limited access to capital.

3. Survey statistics

3.1. Sample

We conducted a face-to-face survey with 236 *jancheras* around Camilo Ponce Enriquez (figure 1) in October and November of 2022. Questions were read aloud and responses were recorded using a phone-based module in KoboToolbox.¹¹ Our survey focused on socio-demographic characteristics, processing practices, working methods, trust, and mercury use and exposure. Our choice experiment showed printed choice cards to each respondent, with verbal explanations for each ore-selling offer.

⁹Plants impose a limit, e.g., two hours, on how long the machines grind ore before it is panned, and the amalgam is burned.

¹⁰See supplementary material appendix E for more information about gold recovery estimates from whole ore amalgamation.

¹¹Our collection of survey data was financed by the UNDP/PNGQ and carried out by a joint ESPOL-Duke field team.

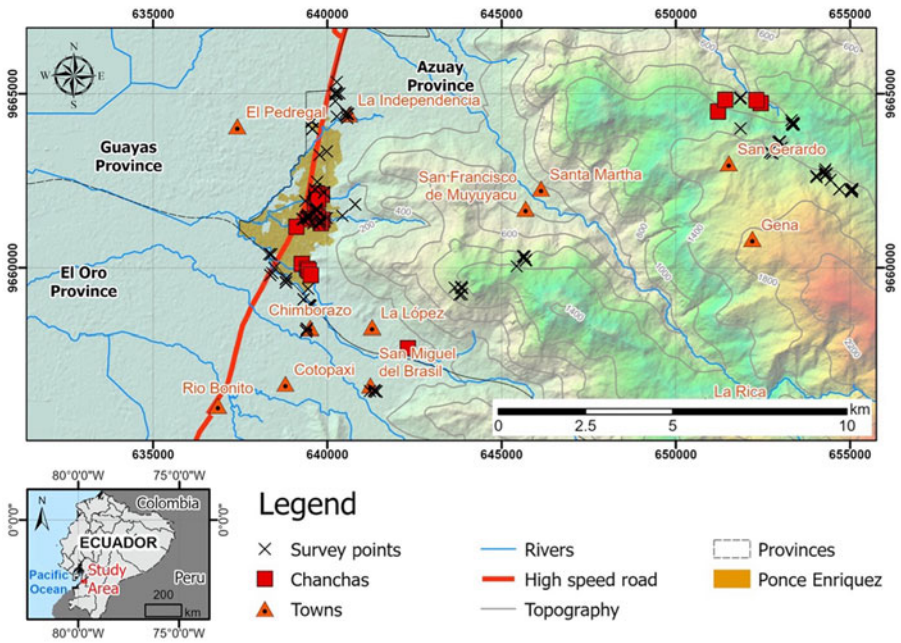


Figure 1. Map of Ecuador and survey points.

Given a lack of data on the location or number of *janchera* groups,¹² we used a two-pronged recruitment strategy. First, we introduced our survey team to groups in meetings (*convocatorias*) called by *janchera* leaders. Second, we visited *janchera* groups at sites identified via local connections. We framed the *jancheras*' participation within this ore-selling study as a voluntary exploration of their needs, without any promises of direct benefits from OSS or other programs.

We held 12 meetings with large *janchera* groups convened by local leaders. These included individuals from groups such as: *Unión y Progreso*, *Mujeres Emprendedoras en Alianza*, *Asociación de Mujeres Emprendedoras 4 de Junio*, *Reina del Cisne*, *Rumi Kuri*, *Fuerza Dorada*, *Virgen del Cisne*, *Mujeres Seleccionadoras de Material*, *Las Águilas*, *La Fortuna*, *La Unión*, and the *Asociaciones de Seleccionadoras de Muyuyacu*. Site visits were guided by community leaders and collaborators from *Escuela Superior Politécnica del Litoral* (ESPOL), who have long-term relationships with miners in this region. Our resulting sample (table 1) likely represents *jancheras* who could participate in ore-selling in the short run. We could not access *jancheras* on tightly controlled sites or those with strong ties to mercury-processing facilities, who likely have limited autonomy to switch processing methods.

¹²ESPOL has conducted studies. Vice-Ministry of Mines had a database for artisanal and small-scale mining concessions, but it was outdated (the Mining Cadaster ended in 2018) and it did not include *jancheras*.

Table 1. *Janchera* groups sampled and estimated population numbers

Group name	# Sampled	# in population	Percentage sampled
Asociación De Mujeres Emprendedoras 4 De Junio	15	60	25%
Asociación De Mujeres Recolectoras La Fortuna	10	50	20%
Atahualpa-Esmeralda	4	20	20%
Familia Unida	7	25	28%
Fuerza Dorada	11	15	73%
Las Águilas	8	30	27%
Mujeres Emprendedoras en Alianza	20	80	25%
Mujeres Seleccionadoras de Material	10	40	25%
Rumi Kuri	14	50	28%
Reina del Cisne	6	25	24%
Selección Muyuyacu	16	50	32%
Unión Y Progreso	40	60	67%
Virgen del Cisne	5	25	20%
Ex-mayor canteras	0	70	0%
La Unión	0	30	0%
Cantera La Lopez	0	60	0%
Total	236	998	24%

3.2. Descriptive statistics

3.2.1. Population and group dynamics

Survey descriptive statistics (table 2) refine our understanding of *jancheras*. We found 91 per cent women and, on average: 7.5 years of education; 2–3 dependents; and a monthly income below Ecuador's minimum wage (of US\$400/month at the time of the survey). In addition, 84 per cent work in groups, although few (9.6 per cent) pool their materials with others in their group.¹³ This implies that most process and sell individually. Most individuals report bringing less than a ton of material to process, which severely limits their ability to access non-mercury processing options. We found 94 per cent of those who report processing their material admit to amalgamating gold with mercury at least some of the time. These facts suggest that *jancheras* are quite appropriate intervention beneficiaries, given mercury use as well as the disadvantages that low-income women face in a male-dominated sector. They tend to work in groups, many of which have taken steps to associate and formalize the rules of their groups.

A key heterogeneity within the *janchera* population concerns the types of sites at which they work. About one-quarter work on sites where machines aid the material

¹³Comparing our *jancheras* sample to groups' sizes, we created survey weights to adjust statistics to reflect populations by correcting for group over-/under-sampling. The resulting statistics were very similar to the sample statistics we report.

Table 2. Key characteristics of the *janchera* population

Characteristic	Mean/Pct Total	IQR
Sex = female	91%	
Age	39	(30, 47)
Years of education completed	7.53	(6.00, 12.00)
Years in sector	14	(5, 22)
Number of dependents	2.65	(1.00, 4.00)
Total individual income (US\$/month)	347	(150, 500)
Income from jancheo (US\$/month)	268	(100, 350)
Part of group?	84%	
Group has statutes	54%	
Individuals decide where to process	90%	
Sells gold individually	94%	
Accumulates material w/ others	9.6%	
Has tax payer ID	2.6%	
Possibly can invoice	15%	
Site: only at botadero	68%	
Site: only at cantera	27%	
Processes ore (v. sell)	77%	
Processes with mercury	94%	
Keeps all selected material	73%	
Transport paid by plant	18%	

selection process (*canteras*),¹⁴ while about two-thirds work at traditional sites where mines dump waste rock believed to be low in valuable mineral content (*botaderos*) and ~5 per cent work at both types of sites (table 2). Mechanized sites (*canteras*) are new in this area, as a result of rising gold prices. To work within a *cantera*, a *janchera* must sometimes leave half of the materials they help select. Of the 27 per cent who reported leaving some of the material they select at the sites in exchange for access to such ore, most reported working at *canteras*.

3.2.2. Baseline processing: how many use mercury?

To address whether ore-selling might induce reductions in mercury use and raise *jancheras*' incomes, we considered three questions: whether any *jancheras* are interested in adopting ore-selling; if those with interest are able to adopt in light of key barriers; and whether adoption would generate impacts. For considering the likely mercury impacts of adoption, 3 groups differ in their status quo (table 3) or 'baseline'

¹⁴*Cantera* translates to "quarry". These sites operate with permissions as if they extract sand or other building materials, though are sorting waste rock to find gold. The *jancheras* use *zaranda* machines to sort ore by size. Using machines to expedite sorting processes appears to lower resulting ore quality but generate more material per week (supplementary material appendix table A1).

Table 3. Processing practices at baseline

Characteristic	N = 181
Uses chancha	163 (90%)
Creates Hg-Au amalgam: no	12 (6.6%)
Creates Hg-Au amalgam: sometimes	2 (1.1%)
Creates Hg-Au amalgam: yes	167 (92%)
Tests Au content of material	13 (7.2%)
Could only sell 1 ton or less	154 (86%)
Exposed to mercury vapor in last year	135 (75%)
Estimated ore grade (Au Gr./Ton) Mean (IQR)	20 (7, 24)
Material availability decreased in last 2 years	151 (83%)

ore-processing habits: mercury-intensive processors (169 of 181); non-mercury processors (up to 12 of 181);¹⁵ and ore-sellers, who do not process their ore themselves (23 per cent, as per table 2).

The first group contains most of the *jancheras* in our sample. The second group is small, within our sample (and likely even a smaller fraction of the full population, see supplementary material appendix C). These are the *jancheras* who appeared to have access to the “plant rental model” due to some relatively unusual characteristics (for instance, high education or a group with a well-connected leader). The third sub-group, larger than the second, sell their raw material to site owners or to intermediaries instead of processing.

4. Experiment methods

4.1. Discrete choice experiment

We used a discrete choice experiment to elicit *janchera* rankings of potential ore-selling offers. Miners saw seven choice tasks, each with two hypothetical ore-selling offers plus a “take neither” option to indicate that they would rather continue with their status quo, i.e., process and sell material as they currently are doing. Such “opt-out” options are commonly added within discrete-choice experiments to avoid “forced choices”, which also adds realism (Veldwijk *et al.*, 2014; Determann *et al.*, 2019).

We designed the choice tasks using a D_z -efficiency algorithm in Stata (Hole, 2017; Szinay *et al.*, 2021), with no priors,¹⁶ given the lack of prior information about ore-selling preferences. This algorithm reduced from 2,016 possible choice tasks to 28, with 56 unique offers (plus, in each card, a “take neither” option).¹⁷ D_z -designs are

¹⁵Of the non-mercury processing, we validated it for one group, accounting for 5 *jancheras* in our sample (supplementary material appendix C).

¹⁶The z subscript denotes “zero priors” (see, e.g., Szinay *et al.*, 2021; Choice Metrics, 2024).

¹⁷There are 64 possible combinations of attributes, if multiplying the number of levels per attribute ($4 * 4 * 2 * 2 * 2$), but 2,016 unique pairs of alternatives as $C(64, 2) = 2,016$. The algorithm initially generated 30 choice tasks using null priors. We further eliminated two cards in which each attribute in one option was “better” than in the other option, yielding 28 choice cards. We have since learned that a better design would

similar to making choice tasks ‘orthogonal’,¹⁸ i.e., showing different attribute levels at equal rates with zero correlation (Hensher *et al.*, 2015) but often are more efficient than ‘orthogonal’ designs, due to a more conservative scaling factor (Bliemer and Collins, 2016).¹⁹

While the blocks (seven choice tasks per block) were randomized by respondent, we did not randomize the order of the cards within blocks or the alternatives within a card. Per potential bias related to order within a card, we used a constant for the “left” offer to control for respondents preferring the first offer they see. We found its estimated coefficient was near zero and insignificant (we removed this from tables to avoid confusion but it is shown in supplementary material appendix table A4).

Offer attributes, and their levels, were based upon an actual offer by a plant in the PNGQ’s potential intervention, plus conversations with partners about how offers could adjust in the future (figure 2). The choice experiment was field tested within the research team and in a pilot with 44 miners in May 2022 to validate these attributes and levels: gold price (US\$35–65/gram); time between ore delivery and payment (24 hours, half in 24 hours and half in 1 week, full payment in 1 week, full in 2 weeks); who pays to transport the ore to the plant (plant vs. miners); whether an electronic invoice is required (yes vs. no); and whether a third-party metallurgical test is available (yes vs. no), in addition to the testing done at the processing plant to determine mineral content. Initially, we had an attribute with minimum tonnages (2–8 tons), but after initial field testing, we eliminated it – most *jancheras* process and sell ore individually and would take a very long time to amass ~8 tons.²⁰

Figure 3 is an example of a card that combines attributes, with two offers. The first includes a split payment (half immediately and half after 1 week), a gold price of US\$45/gram, plant-paid transport, no third-party analysis, and no required electronic invoice. The second has a higher gold price (US\$65/per gram), miner payment of transport, the option for independent metallurgical testing, later payment (after 2 weeks) and a required electronic invoice (*factura*). Implicitly, then, the “take none” option has a gold price between \$35 and \$45, payment immediately, miners paying for transport (for most), no analysis, and no “factura”. It would also represent an option in which miners would process themselves instead of selling (for the majority of the sample which does not sell).

Each actual choice card graphically depicts these offers’ attributes in order to more quickly communicate differences to respondents (see supplementary material

have been to encode sign and order priors in a Dp-design to avert needing to remove dominated priors (although our manual inspection and removal creates no biases).

¹⁸Historically, orthogonal designs were the most popular way to design choice cards. They have been largely supplanted by design methodologies that anticipate how the data will be analyzed within the design phase (Huber and Zwerina, 1996).

¹⁹D-efficient designs can introduce correlation between attribute levels as they use information on how discrete-choice data will be analyzed to generate designs to minimize the predicted standard errors of the parameters (Hoyos, 2010).

²⁰A solution may be pooling individuals’ materials – perhaps based on interventions to facilitate formation of stronger mining associations. We opted to not include this hurdle to avoid losing the opportunity to explore other preferences.

Attributes	Level 1	Level 2	Level 3	Level 4
Payment timing	Pay full price after 24 hours	Pay half now and half in one week	Pay full price in a week	Pay in two weeks
Price of gold	US\$35/g	US\$45/g	US\$55/g	US\$65/g
Transport of ore	Plant arranges and pays for transport	Miners arrange and pay for transport to plant		
Analysis	Only plant analyzes amount of gold	Plant and private lab analyze, if they disagree then gov lab analyzes		
Factura	Electronic factura required	No factura required		

Figure 2. Attributes and levels in the choice experiment.

Attributes	Offer 1	Offer 2	Take Neither
Payment timing	Pay half now and half in one week	Pay full in 2 weeks	
Price of gold	US\$45/g	US\$65/g	
Transport of ore	Plant arranges and pays for transport	Miners arrange and pay for transport to plant	
Analysis	Only plant analyzes amount of gold	Plant and private lab analyze, if disagree then gov lab analyzes	
Factura	No invoice requirement	Electronic invoice required	
Choice	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 3. Example of choice card.

appendix tables A7 and A8). To reduce hypothetical bias, we provide an introductory paragraph that links these choice tasks to options that might be implemented soon. To improve response quality, we employed “Real Talk” framing (Kaczan and Swallow, 2013) in explaining that, while these offers are hypothetical, still their responses could affect future ore-selling offers which could be available to them soon. This signal to respondents to answer honestly after acknowledging reasons why respondents might consider strategically accepting or rejecting hypothetical offers.

4.2. Analysis of discrete choices

Discrete choice experiments have informed the design of incentives to shift resource use, including in payments for environmental services and restrictions on access to common-pool resources (Beharry-Borg et al., 2013; Costedoat et al., 2016; Raes et al., 2017; Maldonado et al., 2019, Lliso et al., 2020). One study considers formalization of small-scale gold miners in Colombia (Velez et al., 2025). We apply this method to potential adoption of mercury-free, higher-capital alternatives in ASGM.

We model respondents’ preferences following random utility theory (McFadden, 1974; Domencich and McFadden, 1975), assuming individuals select the alternative that maximizes utility. Let U_{njt} be the utility of respondent n for alternative j in choice task t , with both observable (V_{njt}) and unobservable (ε_{njt}) components:

$$U_{njt} = V_{njt} + \varepsilon_{njt}. \tag{1}$$

The respondent chooses alternative i when

$$U_{nit} > U_{njt} \quad \forall j \neq i. \tag{2}$$

Observable utility V_{njt} includes offer attributes (x_{njt}), respondent characteristics (z_n), and constants for order or labeled alternatives (δ_j) – in our case, opting out. These are weighted by coefficients (β_{njt}):

$$V_{njt} = f(\beta_{njt}, x_{njt}, z_n, \delta_j). \tag{3}$$

A common econometric approach is the multinomial logit (MNL), estimated via maximum likelihood (Train, 2009). MNL is computationally efficient but assumes independence of irrelevant alternatives (IIA), which may not hold with an opt-out. Therefore, we also estimate two models that relax IIA: nested logit (NL), which assumes independence from irrelevant nests (IIN), and mixed logit (MMNL), which allows random preferences.²¹ We used NL as our default model, nesting the two unlabeled ore-selling alternatives separate from the opt-out alternative.

For MMNL, we estimate uncorrelated and then correlated random coefficients, using 10,000 Sobol draws. Gold price follows a log-normal distribution (ensuring positivity), while binary attributes follow normal distributions.

Each choice is a function of marginal utilities of the offer components:

$$\begin{aligned} U_{i1} &= \beta_1 \text{Invoice}_{i1} + \beta_2 \text{TimeDelay}_{i1} + \beta_3 \text{Analysis}_{i1} + \beta_4 \text{Trans}_{i1} + \beta_5 \text{GP}_{i1} + \varepsilon_i \\ U_{i2} &= \beta_1 \text{Invoice}_{i2} + \beta_2 \text{TimeDelay}_{i2} + \beta_3 \text{Analysis}_{i2} + \beta_4 \text{Trans}_{i2} + \beta_5 \text{GP}_{i2} + \varepsilon_i \\ U_{\text{opt-out}} &= \beta_{\text{opt-out}}. \end{aligned} \tag{4}$$

In Apollo (Hess and Palma, 2019), categorical variables are dummy-coded; continuous variables remain unchanged. For payment time, we use four dummy variables. “Invoice” equals 1 when an electronic invoice is required. “Analysis” equals 1 when

²¹See Train (2009, p. 77) for a full discussion of nested logit including the calculation of marginal and conditional utilities.

independent testing is available. “Transport” equals 1 when the plant pays. Gold price ranges from US\$35–65/gram.²²

Modeling utility implies an ordinal ranking, meaning only differences between alternatives matter (Train, 2009; Hensher *et al.*, 2015). Initial regressions reveal the direction and magnitude of preferences. We later compute marginal rates of substitution, such as willingness to accept (WTA), and choice probabilities.

Choice probabilities follow

$$P(i) = \frac{\exp(V_i)}{\sum_{j=1}^J \exp(V_j)}, \quad (5)$$

where $P(i)$ is the probability of choosing alternative i , V_i is the systematic utility, and J is the total number of alternatives. The numerator sums the exponentiated utility of the offer; the denominator includes all alternatives, including opt-out.

Finally, we calculate WTA for each attribute by dividing coefficients by the gold price coefficient. We use the Delta Method in Apollo to compute robust standard errors for these WTA estimates (Daly *et al.*, 2012; Hess and Palma, 2019).

5. Choice experiment regression results

5.1. Full sample responses to ore-selling offers

Our MNL, NL, and MMNL results support the clear hypotheses that *jancheras* prefer higher gold prices, plant-paid transport, and the availability of independent tests (table 4). Importantly, our full-sample estimates suggest that *jancheras* perceive invoicing as a substantial cost. Column 3 of table 4 suggests that preferences for testing, transport, and invoicing are heterogeneous – though, when random preferences are allowed to be correlated, we find that the standard deviations of the coefficients for invoicing and transport are no longer significant due to the correlation of preferences for these factors with those for other features (see cross-standard deviations for panel A.3 in supplementary material appendix table A9). In other words, we only detect heterogeneous preferences for invoicing and transport in the uncorrelated MMNL model.

Compared to being paid in one day, *jancheras* are relatively indifferent to a one-week payment delay in the MNL and NL models, but appear to dislike split payments (half after 24 hours, half one week later). The MMNL results suggest *jancheras* regard all payment delays as costly, with split payments and two-week delays especially undesirable. Our models indicate that *jancheras*, overall, preferred to opt-out of ore-selling (positive values significant and large, although insignificant when we correct for bias by adding NLs nested structure, and a significant value below 1 for λ indicates that the NL structure is appropriate).

The results in table 4 support some components of the OSS pilot, such as independent laboratory testing. Yet they also highlight a significant barrier: *jancheras* strongly

²²We noted that US\$65/gram was approximately the value of the international spot price during the study period, whereas US\$35/gram would be on the lower end of the observed range of gold prices within the local gold shops.

dislike any required electronic invoicing. This indicates challenges for formalization, which were especially acute for *jancheras* at the time of this study, since there were no regulatory frameworks for this population.

Model fit rises as we add complexity (from models 1–4). In column 4, standard deviations for transport and invoicing coefficients lose significance: variation is absorbed by significant correlation with price and testing, respectively (table 4, panel A.3). Some miners are sensitive to all prices (i.e., transport costs and gold price). Groups who place higher value on tests are less averse to invoicing, possibly reflecting that both are related to a *janchera*'s latent comfort with such formal transactions.

Applying equation (5) to table 4's coefficients, from all the models, we compute the choice probabilities that *jancheras* would accept the three ore-selling models shown in table 5. These three ore-selling offers represent (stylized) offers that our team witnessed in the processing landscape.²³ The comparison of panels B.2 and C.2 in table 5 suggests, in line with a WTP estimate in table 6, that many of our participants would be happy to give up > \$15 per gram in order to not need to have invoicing (yet, per heterogeneities within this population, notably over 40 per cent could accept invoicing). This is consistent with a field note that some ASGM groups chose to sell ore to plants at lower price to lower their paperwork requirements (i.e., without the purchasers following traceability standards).

Stepping back to consider OSS's pilot, table 5 shows that few ore-selling models resulted in choice probabilities over 50 per cent for the full sample. A large alternative specific constant for opting out, and large negative coefficient for invoicing, yield probabilities which suggest the average *janchera* is unlikely to choose to sell without a meaningful price gain. Even for a higher price, as in OSS's pilot, many *jancheras* are not interested in 'pilot' offers (with independent metallurgical tests but 2-week payment delays and required electronic invoice). Nevertheless, choice probabilities can exceed 50 per cent when gold price is high and time to payment is short (supplementary material appendix table A10), such as in Dynacor's program in Southern Peru (Veiga *et al.*, 2022). However, even in that program, most miners bring at least five tons of ore to the plant per visit (quantities greater than most *jancheras* believe they could bring).

Table 6 uses table 4's NL gold-price coefficient to estimate what compensation to *jancheras* is needed to balance other shifts in processing practices. We find that miners would need to receive US\$19 and US\$11 more per gram of gold to balance invoicing and delaying payments by two weeks, respectively. To offset offer benefits, our results indicate miners would accept US\$9 and US\$14 per gram less if ore were transported by a plant or independent testing existed, respectively.

Finally, we estimate total additional compensation *jancheras* would need to shift from their processing status quo to ore-selling. On average, *jancheras* would need to be

²³ Gold-price levels in our choice experiment proxy expected increases due to changes in both gold price and gold recovery in ore-selling (accounting for profit-sharing). Neither status quo gold value nor ore-selling gold value could be precisely estimated, given *jancheras*' lack of knowledge about their gold content (or recovery) and processing plants' non-sharing of payment tables. Conversations with gold shops, plants, program officials, and miners support that *jancheras* could receive US\$10–20 more per gram of gold in ore as a result of shifting from processing themselves (at *chanchas*) to selling to a responsible processing plant.

Table 4. Estimated models for full sample

	MNL	NL	MMNL	sMMNL-Corr
Panel A.1: utility scale coefficients				
Opt-out constant	0.674 (0.157)	0.243 (0.221)	0.818 (0.203)	0.634 (0.194)
Gold price	0.026 (0.004)	0.017 (0.005)	0.058 (0.007)	0.058 (0.008)
Independent analysis	0.386 (0.095)	0.226 (0.093)	0.359 (0.146)	0.259 (0.146)
Plant paid transport	0.247 (0.068)	0.150 (0.060)	0.425 (0.114)	0.407 (0.121)
Invoicing requirement	-0.526 (0.091)	-0.309 (0.109)	-1.274 (0.199)	-1.161 (0.189)
Payment time: split (24hr, 1wk)	-0.417 (0.117)	-0.276 (0.104)	-0.647 (0.172)	-0.650 (0.162)
Payment time: 1 week	-0.081 (0.091)	-0.061 (0.057)	-0.326 (0.131)	-0.339 (0.125)
Payment time: 2 weeks	-0.273 (0.098)	-0.186 (0.085)	-0.606 (0.144)	-0.581 (0.139)
Nesting λ	- -	0.555 (0.184)	- -	- -
Panel A.2: standard deviations of random coefficients				
Gold Price (SD)	-	-	0.101 (0.025)	0.107 (0.026)
Independent Analysis (SD)	-	-	1.759 (0.184)	1.524 (0.183)
Plant Paid Transport (SD)	-	-	0.896 (0.156)	0.072 (0.144)
Invoicing Requirement (SD)	-	-	1.402 (0.196)	0.355 (0.335)
Panel A.3: correlations among random coefficients (MMNL-Corr only)				
Analysis and price	-	-	-	Positive
Transport and price	-	-	-	Positive
Invoice and analysis	-	-	-	Positive
Invoice and transport	-	-	-	Negative
Panel B: model fit statistics				
Final log-likelihood	-1703.63	-1701.50	-1498.52	-1470.69
AIC	3425.27	3423.00	3023.05	2979.37
BIC	3473.88	3477.01	3093.27	3081.99
Observations	1638	1638	1638	1638

Notes: Robust standard errors in parentheses. MMNL models allow for random coefficients; SDs for fixed coefficients are not reported. MMNL price coefficient and SD was converted from log-normal using the Delta Method in Apollo in R.

Table 5. Choice probabilities for example offers

Panel A.1: example OSS offer vs. SQ		
Attribute	Ore-selling	Status quo (base level)
Gold price (US\$/g)	\$45	\$35
Independent analysis	Yes (1)	No (0)
Invoice required	Yes (1)	No (0)
Payment time	2 Weeks	24-hours (reference)
Plant Paid transport	No (0)	No (0)
Panel A.2: estimated choice probabilities		
Model	Ore-selling	Status quo
MNL	30.4%	69.6%
NL	41.5%	58.5%
MMNL	14.7%	85.3%
MMNL-Corr	17.7%	82.3%
Panel B.1: high gold price vs. SQ		
Attribute	Ore-selling	Status quo (base level)
Gold price (US\$/g)	\$65	\$35
Independent analysis	Yes (1)	No (0)
Invoice required	Yes (1)	No (0)
Payment time	2 Weeks	24-hours (reference)
Plant paid transport	No (0)	No (0)
Panel B.2: estimated choice probabilities		
Model	Ore-selling	Status quo
MNL	42.4%	57.6%
NL	50.0%	50.0%
MMNL	35.5%	64.5%
MMNL-Corr	40.7%	59.3%
Panel C.1: higher GP & no invoice vs. SQ		
Attribute	Ore-selling	Status quo (base level)
Gold price (US\$/g)	\$50	\$35
Independent analysis	Yes (1)	No (0)
Invoice required	No (0)	No (0)
Payment time	2 Weeks	24-hours (reference)
Plant paid transport	No (0)	No (0)
Panel C.2: estimated choice probabilities		
Model	Ore-selling	Status quo
MNL	45.7%	54.3%
NL	51.3%	48.7%
MMNL	45.1%	54.9%
MMNL-Corr	47.9%	52.1%

Table 6. Willingness to shift practices

Characteristic	N = 235 [†]
Would join material w/ group	142 (67%)
Would change processing practices w/ group	
Yes	117 (50%)
Maybe	57 (24%)
No	60 (26%)
Would change processing practices w/ guaranteed higher income	217 (92%)
Would sell to processing plant	171 (73%)
Would pay for analysis	136 (84%)
Would be willing to get taxpayer ID (RUC)*	49 (28%)
Believes mercury affects health	204 (87%)
Believes mercury affects environment	216 (92%)
Believes plants contaminate less than chanchas	31 (13%)
Rejected all choice cards	38 (16%)
Selected at least one DCE offer requiring an invoice	153 (65%)

[†] n (% of non-missing). * This question was only asked to 181 respondents who process.

compensated US\$31 to adopt offers with independent tests, pay after two weeks, requiring miner-paid transport, and requiring invoice (supplementary material appendix table A6). Thus, on average, for a majority of our sample, *jancheras* prefer status quo (US\$-denominated WTA above zero for opt-out expresses costs of moving from self-processing under their specific baseline).

5.2. Results for sub-populations

While we estimated that *jancheras* would have a 41.5 per cent likelihood of adopting an ore-selling model like OSS's pilot on average (table 6, A.2), results indicated heterogeneity, e.g., with standard deviations for attributes in the MMNL (table 7). We add here by modeling of latent classes (supplementary material appendix table A5), which suggests some groups would not opt out.

Interacting the opt-out term with respondents' covariates in the NL model, we find that the wealthiest *jancheras* and those who worked full-time are more interested in ore-selling (table 7).²⁴ Those who work within traditional mining sites (*botaderos*), plus the *jancheras* in groups with stronger associativity (having statutes), are less interested – suggesting traditional *janchera* groups are more resistant to change. One interpretation is that the *jancheras* with unfavorable or the most favorable status quo are more

²⁴The NL regression in supplementary material appendix table A2 shows the results of adding main effects of these covariates to the regression. For completeness, we interacted all attributes by covariates to get the choice probabilities in table 7. Raw tables are available upon request.

Table 7. Willingness to accept for offer components

WTP component	Estimate (US\$)	Std. error	T-ratio
Independent analysis	\$13.62	\$3.54	3.85
Plant paid transport	\$9.04	\$2.37	3.81
Invoice requirement	−\$18.63	\$3.69	−5.06
Pay time: 1 week later	−\$3.70	\$3.21	−1.15
Pay time: 2 weeks later	−\$11.22	\$3.60	−3.12
Pay time: half upfront, half 1 week	−\$16.67	\$4.78	−3.49
Opt-out	\$14.67	\$9.71	1.51

Notes: Willingness to accept (WTA) values are in US\$/gram. Estimates derived from nested logit model using the Delta Method for robust standard errors.

Table 8. Choice probabilities by subgroup

Subset	Probability of opting-in
Botadero	25.0%
Group has statutes	35.0%
Works ≤ 3 days as janchera	42.0%
Non-botadero	51.0%
Group does not have statutes	56.0%
Works > 3 days as janchera	61.0%
75th percentile income	67.0%

Offer: Factura required, 2-week time delay, US\$65/gram, miner pays transport.

interested in ore-selling. The former may have most to gain while the latter may find changes easier.

The regression results are complemented by further survey statistics (table 8). While over half our choice-card offers were rejected, some *jancheras* expressed a desire to change (table 8). About 28 per cent are willing to get a taxpayer ID (RUC), with 67 per cent willing to aggregate ore with others, and 73 per cent willing to sell to processing plants, plus 92 per cent who would sell to a plant if doing so would definitely raise income.

Jancheras exhibit high awareness that mercury affects health (87 per cent) and the environment (92 per cent). Juxtaposed with *jancheras*' ongoing mercury use, this result suggests that more information through mercury-education campaigns alone will not stop mercury use (Veiga and Fadina, 2020). This could be partially explained by the fact that *jancheras* who process with mercury plants may not be exposed: *chancha* technicians burn amalgams and gold-shop workers reheat sponge gold. *Jancheras* appear to care most whether options provide economic benefits. They may not view processing plants as 'societal-individual win-wins' given that few believe (table 8, only 13 per cent) that mercury-free processing plants are better for the environment.

6. Discussion

6.1. Barriers to ore-selling

In carrying out this choice experiment and, more generally, by interacting with this population, we found three main barriers to ore-selling: minimum tonnage requirements (related to the fact that, even within groups, *jancheras* collect and process mineral themselves, exhibiting weak ‘associativity’); invoicing requirements (related to informality); and mineral availability (relating to sectoral changes). After our initial field work, we decided to eliminate an attribute from the choice experiment related to the plant requiring some minimum tonnage, given that we found that few *jancheras* would be able to meet an 8-ton requirement at baseline. Our survey confirmed this barrier. We found that 75 per cent brought 0.54 tons or less per visit.²⁵ While this is currently a large obstacle, *jancheras* might be able to meet such a requirement if a supplementary intervention facilitated ways to pool material within the groups. As above (table 8), many would be willing to pool their material under the right conditions.

Our survey also showed that, at baseline, few *jancheras* could invoice. We did not ask if they generated electronic invoices during recent sales. We did ask if they had a taxpayer ID (6 per cent) and how likely it was they could invoice (15 per cent said ‘possibly’ or ‘easily’). We then observed that some *jancheras*, who at the time of our survey could not invoice and reported not being willing to get a taxpayer ID, still chose experimental offers with invoicing. This could reflect that, with large and clear financial benefits and/or assistance to lower the costs, many *jancheras* would be willing to attempt invoicing.

Over 80 per cent of *jancheras* said access to material has fallen. We heard stories that many who had lost access to material shifted to other sectors. Access loss appears to follow from firms’ profits per unit of ore rising, with gold prices and improved extraction, creating incentives for firms to avoid discarding ore with minerals (e.g., to wash ‘waste’ materials to reveal gold). Along these lines, some mining areas also started to condition site access upon *jancheras* selling all selected ores back to site owners. Further, new actors (mechanized *canteras*) have started buying the ‘waste’ minerals previously given to *jancheras* for free.

Field observations also suggested other components of ore-selling offers could be barriers. One might imagine that a shift from processing ore to ore-selling would decrease processing time, while keeping mineral-transport costs constant, as at baseline only 18 per cent say *chanchas* paid for mineral transport to a facility (table 2). However, the transport costs at baseline were likely low: while most *jancheras* were indeed responsible for transporting material, they typically travel only short distances within the same canton. In contrast, if an ore-selling offer were available only in Portovelo-Zaruma, then *jancheras* would need to transport their ore further to take up that offer.

One might also argue that ore-selling could reduce time spent on processing. We found the opposite might be the case. Processing at *chanchas* is fast – under a day and

²⁵We report the 75th percentile as this distribution is heavily skewed. Mean is misleading (although still far below 8 tons) given five over 10 tons, eleven within 2–10 tons, and twelves within 1–2 tons. The rest process 0.27 tons per visit to plant on average.

sometimes capped at just two hours by the facility (as another way to ensure a processing facility is left with more of the gold). Sales of gold thereafter are immediate – both of which contrast with likely timing within ore-selling. Meanwhile, one plant associated with the OSS noted that miners would have to wait 10–15 days for payment, after a delivery, due to administrative (liquidity) constraints. Depending upon the details of ore-selling, then, time spent on mineral transport and processing could increase rather than decrease.

Finally, even benefiting from independent testing options in ore-selling offers would entail behavioral change by miners since, in the baseline, only 7.2 per cent use metallurgical testing laboratories to estimate ores' metallic contents. Though independent testing was seen as a benefit on average in our experiment, in the post-DCE survey, 31 per cent of *jancheras* said they trusted plants' metallurgical analyses (correlating with those *jancheras* who expressed higher trust in plants in general (supplementary material appendix table A11)). The large, significant standard deviation for independent testing in the MMNL models (table 4) is quite consistent with this, reflecting that not all *jancheras* viewed an independent-testing option as a benefit.

7. Conclusion

To consider ore-selling by vulnerable miners, we studied poor predominantly female *jancheras* who were considered as potential beneficiaries of OSS but who faced substantial barriers to participation. Reflecting fieldwork, the attributes of our choice experiment's hypothetical offer (5, panel A) mimic a recent ore-selling offer from a plant linked with the OSS program which required miners to: offer electronic invoices for sales; bring at least 8 ton of ore; and wait 10–15 days for payments. It included independent metallurgical testing (for US\$20–25, more worthwhile for higher ore quantities and grades). For these attributes, our results predict low uptake. Without support, minimum tonnage and the invoicing requirements likely make *jancheras*' adoption of this type of ore-selling infeasible.

Others also find that interventions do not help informal and subsistence miners, despite pro-poorest rhetoric (Hilson *et al.*, 2018; Veiga and Fadina, 2020; Prescott *et al.*, 2022). Strategies often target larger firms, while one-size-fits-all efforts in formalization can have costs and delays beyond the reach of most smaller miners (Hilson and Maconachie, 2017; Hilson, 2020; Sippl, 2020; Veiga and Fadina, 2020; Coy *et al.*, 2021; USAID, 2021; Hilson *et al.*, 2022).²⁶ Others argue that, to move actors out of subsistence mining, policies supporting formalization should aid in aggregation (Hruschka, 2011; Hilson *et al.*, 2022). States seek tax revenues from ASGM yet, without support for miners, plans often fail (Siegel and Veiga, 2010).

Returning to ore-selling, given data limits, we do not assess impact for the OSS intervention, which invested in processing plants and testing labs and then required plants buy ore from miners (focusing on artisanal and small-scale miners, given barriers). We do know that the program's initial transactions were for 100 tons at a time (Ministerio de Energía y Minas, 2022). Thus, the sellers had to be larger and, as a result, likely had

²⁶ Exceptions include ENAMI for copper in Chile (Atienza *et al.*, 2023) and Guyana's ASGM (Hilson and Laing, 2017).

access to mercury-free processing ‘plant rental’ – like our sample’s 2nd or 3rd groups, who would not reduce mercury use by ore-selling.

Ore-selling impacts remain important yet also not studied with empirical rigor. Recent work cites some ore-selling as a success, including Dynacor in Southern Peru (Veiga *et al.*, 2022). To our knowledge (including from asking Dynacor), no independent quantitative studies show ore-selling has raised income or reduced mercury use in ASGM. Even if Dynacor’s Veta Dorada plant has been a success, e.g., if the prospects of higher incomes via ore selling have induced formalizations in that context, then understanding how those occurred and what applies to other contexts requires study.

Returning to *jancheras*, Ecuador issued an inter-ministerial accord for a regulatory framework (Interministerial Accord, 2022). However, it capped ore at 225 kg per month,²⁷ yielding sales far below minimum wage. It also mandated ore sale to processing plants. In our July 2023 focus group, the consensus of the 50 *jancheras* present was that government was actually trying to eliminate their activity by imposing new requirements without support to comply with new rules. When presenting our study in Quito, we heard many believed the *jancheo* activity would vanish soon due to market forces (price and extraction efficiency) that we noted reduce *jancheras*’ mineral access.

Unlike in Colombia, where waste-rock collection (*chatarreo*) is one type of subsistence mining recognized by the mining regulatory framework (Decree 1073 of 2015) (Quintero Chinchilla, 2017), *jancheo* in Ecuador is not considered to be a mining activity, but rather related to waste management (Interministerial Accord, 2022). Consequently, the *jancheras* are not allowed to process the ore or sell the gold on formal markets. In Peru, *pallaqueras* (Peruvian *jancheras*) faced a similar regulatory situation: since their work was not recognized as mining activity, they were excluded in 2012 from the Integral Mining Formalization Process led by the Ministry of Mines and Energy (Law 27651 of 2012). However, from 2013, with external support, *pallaqueras* have worked on strengthening associativity and consolidated political representation as the National Network of Women in ASM (Winkelfried, 2022). Working together, they improved their interactions with the Peruvian mining authorities. By 2018, they had managed to get a pilot authorized to participate in commercial transactions with ore processors and traders (D.S.018–2018 EM) (Winkelfried, 2020).

Support of this kind seems necessary within future interventions targeting such populations. Without recognition from mining authorities, basic conditions are not in place to begin discussions of contractual and organizational arrangements to enable these women to participate in ore-selling. It remains to be seen if such complementary action will improve the environmental and economic realities of *jancheras* in Ecuador but we are aware that work to engage these groups is still underway. Ideally, both actions and outcomes are documented so ASGM interventions learn from each other.

²⁷ Over 96 per cent of the “full-time” *jancheras* in our sample ‘pick’ more ore than that. Assuming an ore-grade of 20 grams per ton and a gold price of US\$60, *jancheras* would take home US\$270 per month with this limit. The median ore grade of 13 and a standard gold shop gold price of US\$45 would yield about US\$132 from 225 kgs (0.225 tons), under half of the minimum wage.

Supplementary material. The supplementary material for this article can be found at <https://doi.org/10.1017/S1355770X2510017X>.

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