

What changes when mineral markets face tighter rules?

A more reliable certificate, a mine that produces less and a better livelihood are different outcomes. This research follows the connections between them: where minerals can still be sold, how buyers and miners share the costs, and what makes investment and public action possible.

1 Does cleaner certification mean less mining?

In this static comparison, extraction from the potentially exposed group falls by less than 0.51% in every mineral. In the original model, material from that group remaining on the certification register falls by roughly 56-58%.

2 Who bears the cost of tighter rules?

In the two active sell-or-retain examples, extraction is unchanged while the intermediary's profit falls by about 0.89%. In the rebuilt buyer-competition example, there is no production either before or after. The same headline of "no change" can therefore describe very different situations.

3 What makes change last, and who pays?

Among the displayed available pairs, the combined package reduces the exposed group's extraction by roughly 13% at period 100. Detection alone has much smaller effects. The larger reduction includes the assumed fall in outside spending; it is not a result of certification alone.

How we found these results

Start with observed evidence: Production and price records set the scale of each mineral market, using 2024 as the reference year. Trade records describe reported routes. Mine visits and fiscal reports help document institutions.

Describe how people respond: A model connects production, sales, payments and investment. Where observations do not tell us how people respond, the research states assumptions and explores alternatives. A country name identifies the setting; some responses still need to be measured.

Change one policy or a named package: Researchers solve a baseline, change specified rules, then compare outcomes within that same model. They check quantities and financial accounts separately. Unresolved calculations stay visible as unavailable results.

The figures are comparisons inside models anchored to observed data. They show what follows from stated assumptions, rather than measured effects of an existing regulation. The five mineral markets are gold, cobalt, tantalum, tin and tungsten.

Does cleaner certification mean less mining?

What we compare. The model raises the assumed chance of finding a false origin claim after the initial checks from 25% to 50%, keeping other buyers' spending fixed. The main comparison uses the same production-cost assumption across models.

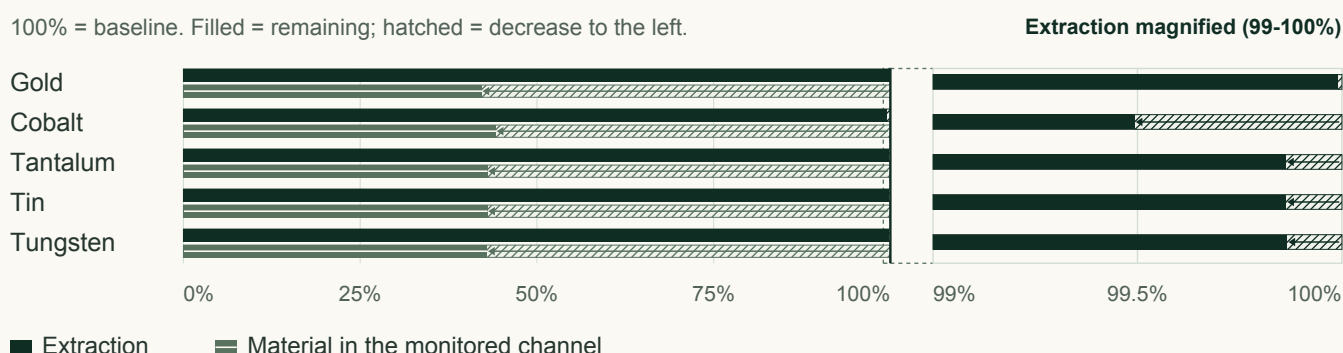
Main finding. In this static comparison, extraction from the potentially exposed group falls by less than 0.51% in every mineral. In the original model, material from that group remaining on the certification register falls by roughly 56-58%.

Why this happens. Imagine a checkpoint becoming better at rejecting ineligible deliveries. Its register becomes cleaner. But material rejected there can still find another buyer. A large change at the checkpoint can therefore accompany a small change at the mine.

The register changes much more than extraction

Original model: each outcome compared with its own baseline (%)

100% = baseline. Filled = remaining; hatched = decrease to the left.



Mineral	Extraction Original	Extraction Muir	Extraction VCG	Monitored material Original
Gold	-0.01%	-0.01%	-0.01%	-57.76%
Cobalt	-0.51%	-0.38%	-0.38%	-55.75%
Tantalum	-0.14%	-0.10%	-0.10%	-56.96%
Tin	-0.14%	-0.10%	-0.10%	-56.96%
Tungsten	-0.13%	-0.10%	-0.10%	-56.98%

Bars show the level remaining; the table gives signed changes. A fall in registered material does not mean the same percentage fall in extraction.

How to read it. The potentially exposed group means producers assigned an origin-compliance concern in the model. Its size is partly assumed. Its extraction is not total mining, measured illegal production or environmental damage. Each percentage uses its own model's baseline and the outcome named in the figure.

The rebuilt static examples route 25% through a separate retail channel. Their smaller response partly reflects that assumption.

Source: Paper 1 and the journal synthesis: matched static comparison, supply exponent 1, stronger discovery and unchanged outside spending.

Who bears the cost of tighter rules?

What we compare. A buyer faces a new charge, while the village's selling rules, access to household goods and dependence on mining for basic needs stay fixed. The figure compares the same hypothetical village with and without this charge, using each model's own starting point.

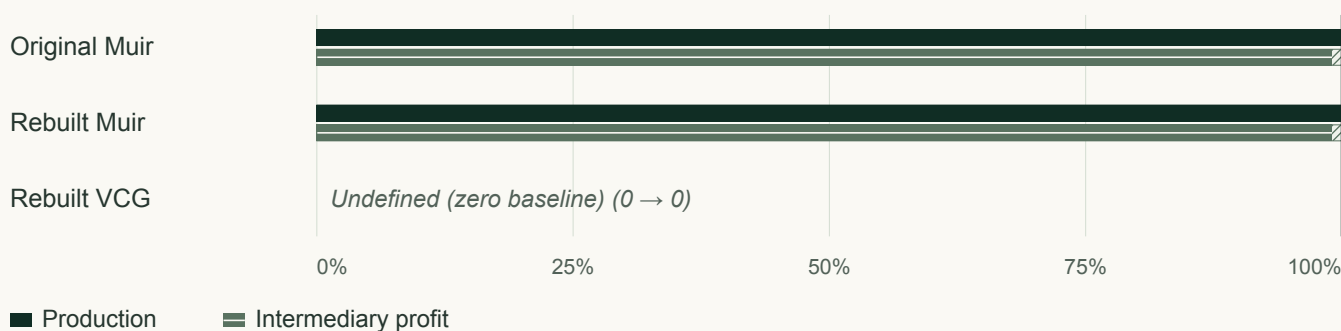
Main finding. In the two active sell-or-retain examples, extraction is unchanged while the intermediary's profit falls by about 0.89%. In the rebuilt buyer-competition example, there is no production either before or after. The same headline of "no change" can therefore describe very different situations.

Why this happens. A buyer who also provides food or credit can adjust several terms of a relationship. If households have few alternatives, they may keep mining after the terms worsen. An intermediary can also change sales channels or hold material instead of immediately reducing purchases.

Follow both production and the intermediary's profit

Level remaining, relative to the same model's baseline (%)

100% = baseline. Filled = remaining; hatched = decrease to the left.



Model	Production	Intermediary profit
Original Muir	0.00%	-0.89%
Rebuilt Muir	0.00%	-0.89%
Rebuilt VCG	Undefined	Undefined

Table: signed changes from each outcome's baseline. The selected hypothetical examples use different trading rules, preventing a direct ranking of countries or institutions.

The displayed charge rises from 0 to 0.1 illustrative monetary unit per mineral unit; it is not a 10% tax. The selected full configuration combines selling arrangements, an intermediary supplying household goods and dependence on mining for basic needs. The original example uses zero retention value.

How to read it. These are constructed examples, not surveyed villages or country estimates. In one rebuilt VCG example, production is zero before and after the change: zero contraction there means continued inactivity, not a working mine protected from the restriction.

Source: Paper 2: paired institutional experiments and saved allocation accounts in the original extension and nonlinear reconstruction.

What makes change last, and who pays?

What we compare. The dynamic models follow investment and government decisions over successive periods. They compare stronger detection alone with a package that also gradually lowers other buyers' spending by about 25%, with research support and public intervention available.

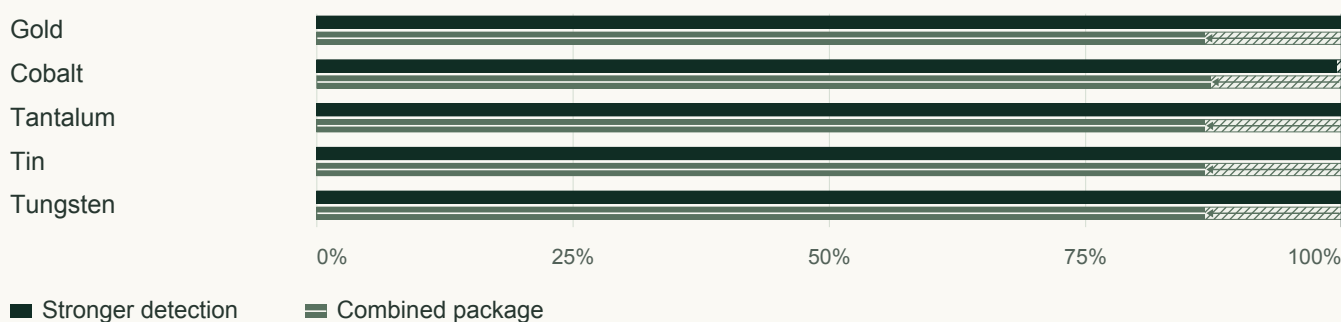
Main finding. Among the displayed available pairs, the combined package reduces the exposed group's extraction by roughly 13% at period 100. Detection alone has much smaller effects. The larger reduction includes the assumed fall in outside spending; it is not a result of certification alone.

Why this happens. Investment depends on who earns the return from an improvement. Public action depends on whether future collected taxes justify costs today. Even a programme with later receipts may need cash upfront, while refundable deposits remain money owed back.

The combined package changes the production incentive

Rebuilt sell-or-retain model (Muir), period 100: exposed extraction (%)

100% = baseline. Filled = remaining; hatched = decrease to the left.



Mineral	Original Detection	Original Package	Muir Detection	Muir Package	VCG Detection	VCG Package
Gold	-0.01%	-13.38%	-0.01%	-13.35%	-0.01%	-13.35%
Cobalt	-0.53%	-12.57%	-0.40%	-12.73%	-0.40%	-12.73%
Tantalum	Unavailable	Unavailable	≈0.00%	-13.28%	≈0.00%	-13.27%
Tin	≈0.00%	-13.41%	≈0.00%	-13.28%	≈0.00%	-13.27%
Tungsten	≈0.00%	-13.32%	≈0.00%	-13.27%	≈0.00%	Unavailable

Table: Period-100 changes relative to each economy's own baseline. The combined package includes lower outside spending. Unavailable pairs are not zero effects. ≈0 means rounded, not exactly zero.

How to read it. These are model periods, not years or forecasts. Ownership and technology differ across models. Weaker tax collection prevents intervention in some original examples but delays it in some rebuilt examples; it does not universally stop action.

Source: Paper 3 and the journal synthesis: supported-research, segmented-market comparisons at period 100, using each economy's own baseline.

The trading rules behind the results

The models share evidence but organize transactions differently. Their names identify these rules; knowing them helps explain why similar production totals can hide different payments or incentives. In the rebuilt models, decisions need not change proportionally: a new package, different buyer or decision to retain stock can cause a jump. "Nonlinear" describes this structure; it does not mean a more accurate country estimate.

The original model, extended to more minerals. Keeps the original production, certification and investment framework, then adds mineral markets and country scales. This provides continuity with the earlier gold and cobalt research.

An intermediary chooses sales and retention - Muir. The seller chooses what to deliver and what to retain, taking resale into account. The model follows how these choices affect receipts and actual physical output.

Buyers compete for packages - VCG. Packages go to the allocation with the highest modeled value, including the seller's option to retain stock. A buyer's payment reflects the value other participants forgo because that buyer participates.

What the reconstruction makes explicit

Account	Rebuilt framework
Buyer payments	Recalculates Muir receipts with resale and retention; VCG payments remove the whole buyer in the payment comparison.
Retention and resale	Makes retaining material part of the seller's choice; Muir also follows resale.
Processing	Tracks physical conversion separately from sales revenue; money received is not output.
Ownership	Specifies who owns improvements and earns access payments; public adopters do not generate private ownership returns.
Payment timing	Adds explicit installation payments, dated refunds and funded service and custody obligations.

Stronger detection. Makes a false origin claim more likely to be discovered. It changes the reward from entering the certified channel.

Other buyers' spending. Changes the money available outside that channel. The combined package assumes a reduction; the research does not establish how to achieve it.

Household alternatives. Changes access to other income, subsistence needs and goods supplied by an intermediary, which can affect households' ability to leave mining.

Research support. Changes the reward for developing and adopting improvements. Grants can encourage investment but also create a financing obligation.

Actual tax collection. Changes how much of a nominal tax liability reaches the government. A stated tax rate alone does not show what is available to finance intervention.

What the evidence supports

Production sources include USGS, BGS and the World Gold Council; price records retain their stated product stage. UN Comtrade describes reported trade routes. IPIS mine visits, EITI reports and the Rwanda mining study add institutional context. These sources answer different questions and are not one uniform sample.

Gold, cobalt, tantalum, tin and tungsten are modeled separately. Coltan is an ore or concentrate; the tantalum market uses its contained tantalum. Rough diamonds provide a certification comparison, while copper and nickel provide industrial context.

The production archive contains 6,277 historical records; its separate 2024 BGS panel has 309 country-resource combinations. Trade records cover 2005-2024, with a narrower six-country panel for detailed routes. Separate 2025 updates do not replace the 2024 calibration.

The papers and downloadable data identify the source, assumptions and saved result behind each comparison. Earlier gold and cobalt benchmarks are archived separately from the global extension.

What still needs measurement

- Matched evidence on miners' payments, production costs, buyers, household alternatives and actual enforcement is needed to estimate policy responses.
- Reported routes do not reveal every buyer or re-export. Visited mine sites do not form a representative national sample. Some trade categories combine several minerals.
- Scenario ranges are not confidence intervals. Failed or unavailable model comparisons remain identified and are never filled with zero.
- The results do not measure changes in conflict, environmental damage or household welfare, and do not establish programme affordability.

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Original model

- [1. Certification, purchasing and production](#)
- [2. How restrictions reach miners and intermediaries](#)
- [3. Innovation, public action and financing](#)

[Journal companion synthesis](#)

[Verified supporting results \(JSON\)](#)

[Selected supporting records \(ZIP\)](#)

Rebuilt models

- [1. Certification, purchasing and production](#)
- [2. How restrictions reach miners and intermediaries](#)
- [3. Innovation, public action and financing](#)

These briefs use completed research and saved results. No new estimation was performed for this presentation.