

# How Space Mining Missions Will Disrupt Minerals Markets and Contracts

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# Motivation

- Technical feasibility of extracting resources (e.g., platinum) from asteroids and importing to earth is improving.
- What about economic feasibility?
  - What kinds of contracts between buyer and seller produce the right incentives for efficient exploration and production?
  - What kinds of changes might occur to the terrestrial market structure when new supply from space is imported?

# Outline

- Economic features of contracts
- Market context within which contracts are made
- How contracts and markets may adapt to Space Mining Missions

# Typical feasibility study

- 1) What is a good guess at current commodity price?
  - 2) What is a good guess at the cost of production per unit with current or expected technology?
- Is (1) bigger than (2)? If yes, do it!
  - What is wrong with this approach?
  - Firm with market power that can sign long term bilateral contracts are more complicated!
    - New sources of risk will change contracting incentives.
    - New supply will change industry composition and “fair” contract prices.

# Why do we have procurement contracts for metals commodities?

- Risk sharing
  - Agree on a price ahead of time to reduce uncertainty and facilitate investment
- Relationship-specific investment
  - Making product tailored to an individual buyer may require specific capital investments that can't be easily repurposed if the venture fails

# Contracting: risk sharing

- Buyer and seller may want to lock-in a price before laying out capital for a venture, particularly if prices are volatile.
  - Forecasting commodity prices is hard even for terrestrial commodities.
  - If parties are risk-averse, agreeing to a fixed price or price schedule ahead of time provides value.
- Generally thought to be a less important driver of contracting when market participants know the probability distribution of returns.
  - Easier to invest some money in another asset whose returns are uncorrelated with the mining venture (hedge) than to write/enforce a detailed contract.
- Perhaps not true for space resources (initially)...

# Contracting: risk sharing

- With new sources of supply, the probability distribution of outcomes is not yet known.
  - What alternative investments can provide a hedge for space mining accidents?
- Risk-sharing takes on renewed importance in contracting.
- It becomes very important to categorize and quantify new sources of risk:
  - Accidents/disruptions in launch, extraction & processing activity, and re-entry
  - Surprises in the quantity and quality of recoverable resource

# Contracting: risk sharing

- Most commonly studied contract set-up involves use of either a fixed price or cost-plus pricing mechanism
- Previous research finds that more complex transactions or contracting for early stage products tends to be with cost-plus contracts
- Generally due to the uncertainties of early stage development, cost-plus contracts are utilized in these cases.



# Contracting: risk sharing

- High powered incentives arise from fixed price contracts because if the space miner can produce the commodity in less expensive fashion, they receive the full benefits from those cost reductions
  - The price received does not fall if costs fall
- Low powered incentives arise when cost-plus or similar type contracts are used
  - In cost-plus contracts, the space miner is paid their cost plus something
  - If they produce the commodity cheaper, the amount they receive falls

# Contracting: relationship-specific investment

- If the buyer has unique needs, the seller (mining firm) may need to make unique investments to meet those needs.
  - If the buyer reneges, the seller's investment is (partially) sunk.
- Example:
  - A space miner targets an asteroid with a particular composition of metals that meet the needs of an important buyer.
    - The choice to set up operation on *this* asteroid is specific to the relationship with that buyer.
  - If their relationship breaks down, the space miner can sell the metals to another buyer, and/or move to another asteroid.
    - But this is costly.
  - If the buyer is opportunistic, they may take advantage of the space miner's
- One purpose of long-term contracts is to avoid such opportunism.

# Market context

- Many minerals markets are oligopolistic.
  - Fixed costs to enter large market implies:
    - Number of firms small enough that each firm may influence the price
    - Number of firms large enough that there is still competition, no single firm can fully determine the price.
  - Strategic market equilibrium:
    - Each firm has an incentive to in which prices are below what a monopolist would charge and above the minimum cost to produce.
- Introduction of space resources:
  - Larger fixed cost
    - launch costs, space extraction and processing infrastructure, delivery to earth
  - Smaller marginal costs
    - Abundant supply in space, each additional unit produced may be cheaper than terrestrial sources

# Market context and contracts

- Technical/engineering analyses of recoverable space reserves and physical costs of extraction and delivery can help form an expected magnitude of the change in market equilibrium.
- The noise around that expected equilibrium is driven by new sources of risk that individual contracts will be designed to mitigate.
  - Particularly around production and delivery risks, accidents, and resource quality/quantity.

# Market context and competitors

- Should I space mining company begin production, it is expected that terrestrial mining companies would alter their production and investments
- Generally these responses are modelled using a game theoretic approach
- These models can help reveal likely market outcomes from the importation of resources to earth

# Conclusion

- Commodity markets have devised many different contract forms in order to facilitate investment and extraction
- Space mining contracts are likely to facilitate risk sharing
- Most common contract set-up involves use of fixed-price vs cost-plus pricing mechanism with cost-plus pricing common in early stage development