MICA
Minerals Intelligence Capacity Analysis

FACTSHEET

Agent-based modelling (ABM) method

Agent-based modelling (ABM) is used to model the behavior of mineral raw materials players (or agents, e.g., countries or firms…) in order to know how they should individually or collectively react regarding any events (a price increasing, a mining firm closing, an export restriction policy by a producing country …) that may happen at different stages of the value-chain and at any scales of the market.

Scope (conceptual model & main characteristics)

► The aim of using an agent-based model (ABM) is to model the behavior of mineral raw materials players - agents - (i.e., countries and at a more detailed level firms at different stages of the value-chain) in order to know how they should individually react regarding any events that may happen at any scales of the market (micro, country, global): price increase or decrease, a mining company 'absorbed' by another mining company, etc. The interest is to detect to what extent micro-events will affect (if any) the global equilibrium (including possible disturbances) of the market and within which timeframe (immediately? In a near future? In a distant future). Indeed, ignorance of such events weree one of the sources of the 2008 economic crisis.

The particularity of the approach is then its ability (if the model is well carried out):

- to evaluate the effect of local , medium and global events on global market (if any),
- to reproduce non-linear variation of variables (price, production, consumption...), even at a very detailed spatiotemporal scale (week, month...) and evaluate its effect at any scales.

Contexts of use, application fields	-> contexts (e.g., environmental, economic, social assessment) -> which types of stakeholder questions are concerned?

► Contexts: analysis of evolutive interaction between environmental, economic, social and governance players involved in mineral resources field.

Type(s) of data or knowledge needed and their possible source(s)	-> which types of data are needed to run the method, from which sources could they come… -> could be qualitative data or quantitative data, and also tacit knowledge, hybrid, etc.

► All time-series data from 2000 to 2015 at three levels of the studied metal market: firms, countries and world. The possible sources are Eurostat, OECD, IMF (economic data), World Bank and Fraser Institute (governance data), EcoInvent (environmental data), BRGM (geological data), … as well as data produced by independent experts like Roskill… The more it is possible to find micro-scale data (e.g., quarterly, or even monthly data), the more the method will be efficient.

Model used (if any, geological mathematical, heuristic…)	-> e.g., geological model for mapping -> e.g., mathematical model such as mass balancing, matrix inversion, can be stepwise such as agent -based models, dynamic including time or quasidynamic specifying time series… -> can also be a scenario

► The model used is an agent-based model (ABM) which allows the modeler to represent and the stakeholder to drive the explicit and evolutive interaction between players in the market, along the value-chain and at a multi-scale level (firm, country, world). ABM can be coupled with MFA and LCA models – see factSheets '**LCA**' & '**MFA**'.

Once the model is validated in the business-as-usual scenario, a prospective scenario for the next 25 years can be carried out, for example to evaluate a restriction of exportation ratio from producers associated to an increase of the demand from consumers, e.g., for copper, or lithium or the REE market…

System and/or parameters considered	-> **the system can be described by its boundaries**. These can refer to a geographic location, like a country, or a city, the time period involved, products, materials, processes etc.

	involved, like flows and stocks of copper, or the cradle-to-grave chain of a cell phone, or the car fleet, or the construction sector, or the whole economy… -> **parameters** could possibly refer to geographic co-ordinates, scale, commodities considered, genesis of ore deposits and others…

► The boundary of the system is at both vertical and horizontal levels.

Vertically, the boundary is located at three levels:

- the countries in the whole world, possibly ranked at several levels (e.g., France, EU, …). Countries of interest are made explicit as-is, while other countries are grouped in an entity like 'rest of the world';
- the firms exploiting/consuming the studied metals along the value-chain possibly between the countries;
- the global level.

Horizontally, for each level abovementionned, the system covers the whole value-chain of a raw material transformation (easing at the same time the coupling with MFA).

Time / Space / Resolution /Accuracy / Plausibility…	-> to which spatio-temporal domain it applies, with which resolution and/or accuracy (e.g., near future, EU 28, 1 year, country/regional/local level…) -> for foresight methods can also be plausibility, legitimacy and credibility…

► The time scope of the prospective scenario is 25 years. The interesting minimal timestep for the ABM method is the week. However, according to available data, the timestep may be the month.

Indicators / Outputs / Units	-> this refers to what the method is actually meant for. Units are an important part but that is most of the time not sufficient to express the meaning. For example, **the indicators used in LCA express the cradle-to-grave environmental impacts of a product or service**. This can be expressed in kg CO_2-equivalent. But also in €. Or in millipoints. Or in m^2year land use. -> for foresight methods the outputs are products or processes

► Outputs: satisfaction level of end-product (car, phone, …) users over time, evaluated via:

- the ratio between the initial demand and production capacity, localization;
- the environmental impact of the scenario;
- the ratio of recycling part in the market supply.

The other main contribution of the method is to highlight the effects of micro-behaviours (e.g., a mining firm closing) to macro-behaviours (e.g., the global price of a metal) that could not have been detected by using classical macroeconomics approaches (general equilibrium models…)

Treatment of uncertainty, verification, validation	-> evaluation of the uncertainty related to this method, how it can be calculated/estimated

► To evaluate the ABM in a project,

- **Sensitivity analysis**: a scenario from a set of input values is introduced to evaluate the sensitivity of the model;
- For each scenario, many runs are necessary to evaluate the impacts of random values introduced in the model (representing aleas). The idea is to find a convergence of the model between runs despite the existence of these random situations;
- **Expert comments**: the results of each scenario are submitted to experts in the raw materials field for validation / correction in a iterative process with modelers.

Main publications / references	-> e.g. , ILCD handbook on LCA, standards (e.g. , ISO) -> can include reference to websites/pages

Andriamasinoro, F. & Ahne, H. (2013). Prospective analysis of the world lithium market: contribution to the evaluation of supply shortage periods. International Business & Economics Research Journal, 12 (3), 359-372.
http://fenintsoa.net/publications.html

Lefebvre, G. & Andriamasinoro, F. (2016). Mining economist opinions on using multi-agent methodology to simulate metal markets. International Journal of Trade and Global Markets, 9 (1), 83-102.
doi:10.1504/IJTGM.2016.074139

Riddle, M., Macal, C.M., Conzelmann, G., Combs, T.E., Bauer, D. & Fields, F. (2015). Global critical materials markets: An agent-based modeling approach. Resources Policy, 45, 307-321.
doi:10.1016/j.resourpol.2015.01.002

Sherwood J., Ditta A., Haney B., Haarsma L., Carbajales Dale M. (2017). Resource Criticality in Modern Economies: Agent-Based Model Demonstrates Vulnerabilities from Technological Interdependence. Biophysical economics and resource quality, 2(9), 1-22.
doi: 10.1007/s41247-017-0026-z

The Economist (2010). Agents of change: Conventional economic models failed to foresee the financial crisis. Could agent-based modelling do better? [Online] Retrieved from http://www.economist.com/node/16636121.

Related methods	-> List of comparable methods, their particularities… (or a link to one or several other fact sheet(s))

► Can be coupled with MFA: see factSheet '**MFA**'

► Can be coupled with LCA: see factSheet '**LCA**'

Some examples of operational tools (CAUTION, this list is not exhaustive)	-> e.g., software… Only give a listing and a reference (publication, website/page…) -> **should be provided only if ALL main actors are properly cited**

► Not applicable

Key relevant contacts	-> list of relevant **types** of organisations that could provide further expertise and help with the methods described above.

►The working Group on Collective Adaptive Systems (including agent-based models) of the LIM laboratory - university of La Réunion-France.

Web page: http://lim.univ-reunion.fr/staff/courdier/research/equipe/

►The working Group on Agent-based Computational Economics (ACE) - Iowa State University.

Web page: http://www2.econ.iastate.edu/tesfatsi/ace.htm

Glossary of acronyms /abbreviations used	-> Definition
ABM	Agent-based modelling
LCA	Life cycle analysis
MFA	Material flow analysis