# Mining Global Value Chains: New Opportunities and Old Obstacles for Developing Countries

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# Motivation

- Mining is a large share of GDP in many LAC countries
  - ✓ GDP: 12% Chile – 12.35% Peru – 4% Brazil
  - ✓ Exports: 60% Chile - 52% Peru – 21% Brazil
- The same for many Natural Resources (NR)

**BIG QUESTION FOR DEVELOPMENT**

1. Are Natural Resources a **curse** or a **blessing** for a country?
2. Can NR become an engine of growth and development?
3. Did something change from the past?

*Conventional view: NR-based industries were **not very interesting** as they would **not** produce technological modernization, innovation and productivity growth.*

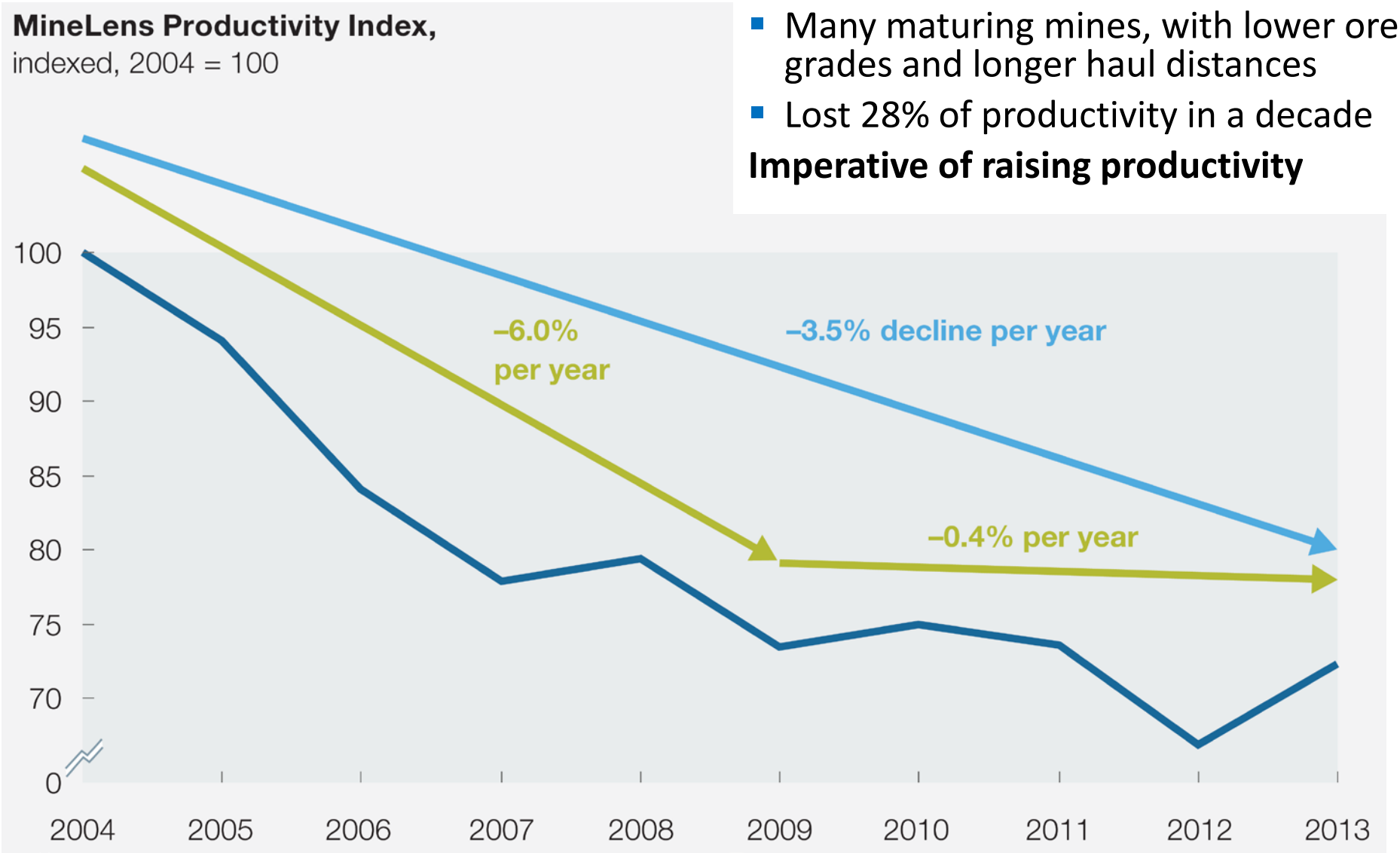
# Outline of the speech

- Global trends in the mining sector
  - ✓ Falling productivity
  - ✓ Technological changes: Patents and Digital technology use
- Questions motivating our research: the potential for local suppliers in developing countries
- Some results from analyses in Brazil, Chile, Peru, Argentina

# Global **decline in mining productivity** over the past decade (McKinsey, 2015)

- Global mining industry under pressure
- Falling commodity prices
- Many maturing mines, with lower ore grades and longer haul distances
- Lost 28% of productivity in a decade

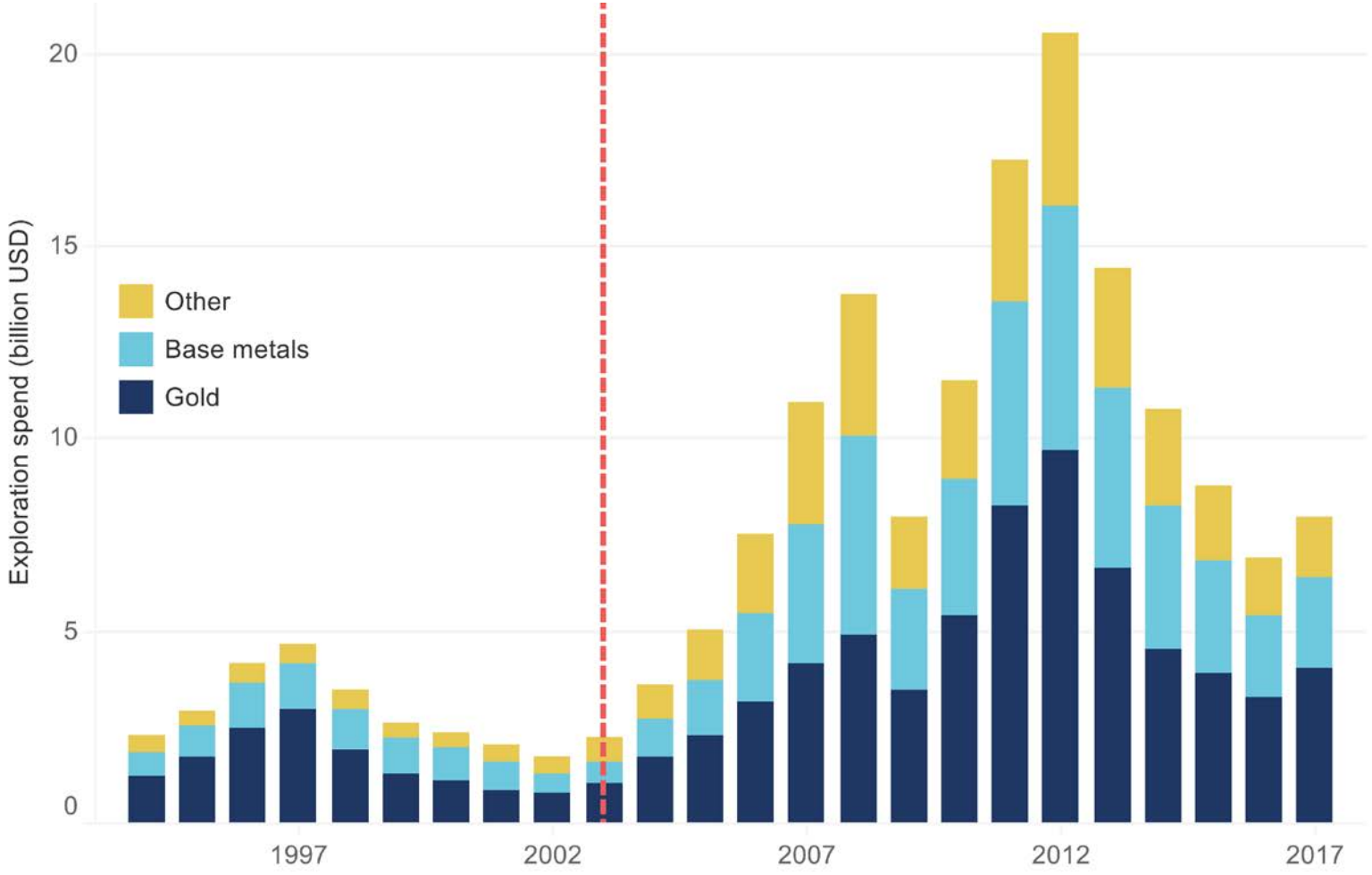
**Imperative of raising productivity**



# Can **Innovation** be the answer?
# Is the mining sector **innovative**? (Daly et al., 2019)

- The sector contains a larger number of **innovative firms**
- **Increase in R&D expenditures** in mining
- **Intellectual property (patents)** have an increasing importance
- **Mining Equipment, Technology and Services providers** (**METS**) also patent and innovate frequently – among patenting companies, METS are 10 times more likely to patent than mining firms (3.8%/0.4%)
- A lot of Research is carried out in the **exploration** phase
- A lot of **organizational innovation** – often in mining suppliers

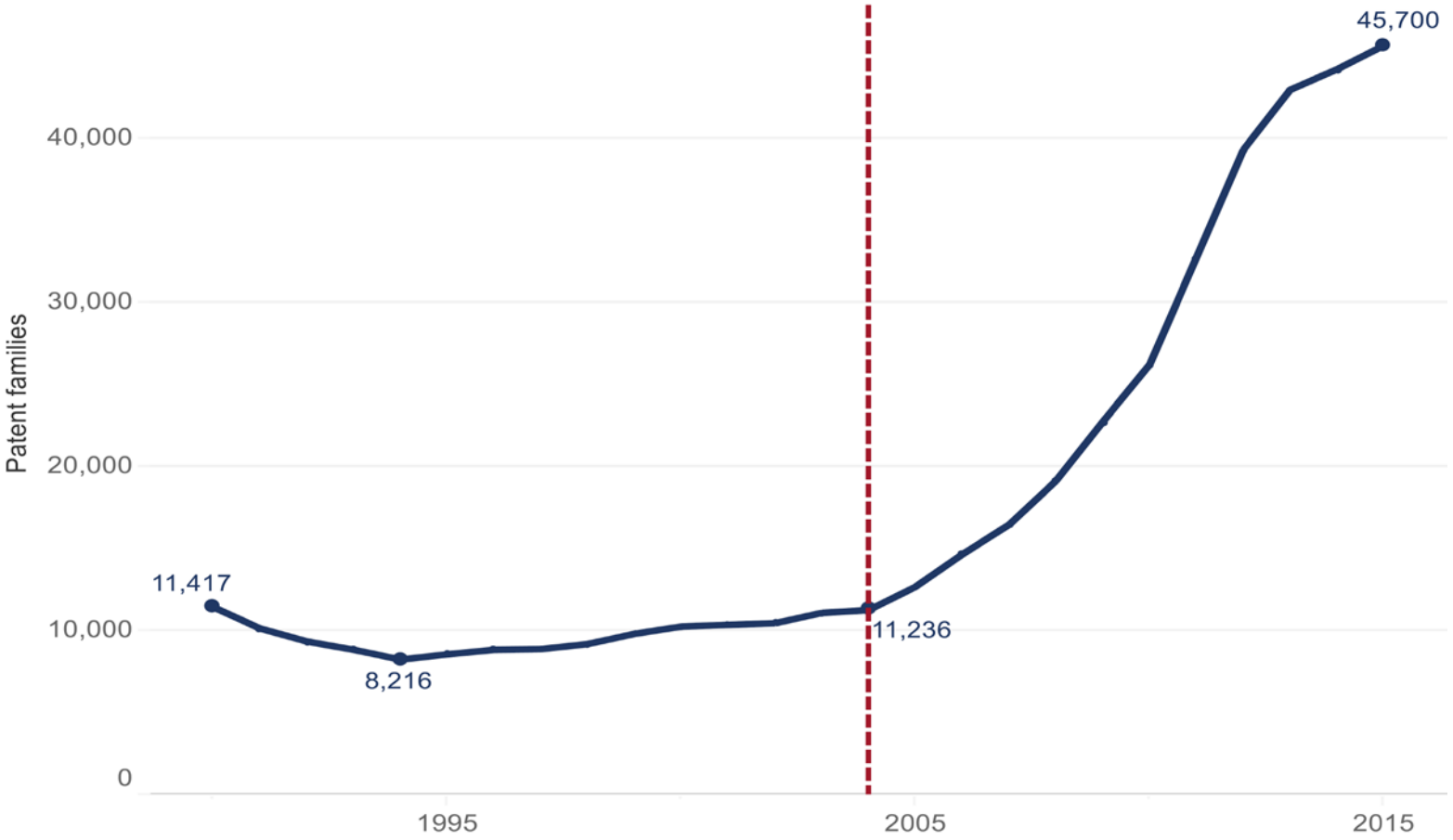
# Worldwide mineral exploration expenditure has increased since 2003




*Source: WIPO, Daly et al., 2019.* **HOWEVER** also non-innovation expenditures are included, innovation takes place also in other segments of the value chain, mining companies often outsource exploitation to specialized companies..

# Mining Patent have grown remarkably

(by earliest priority year)

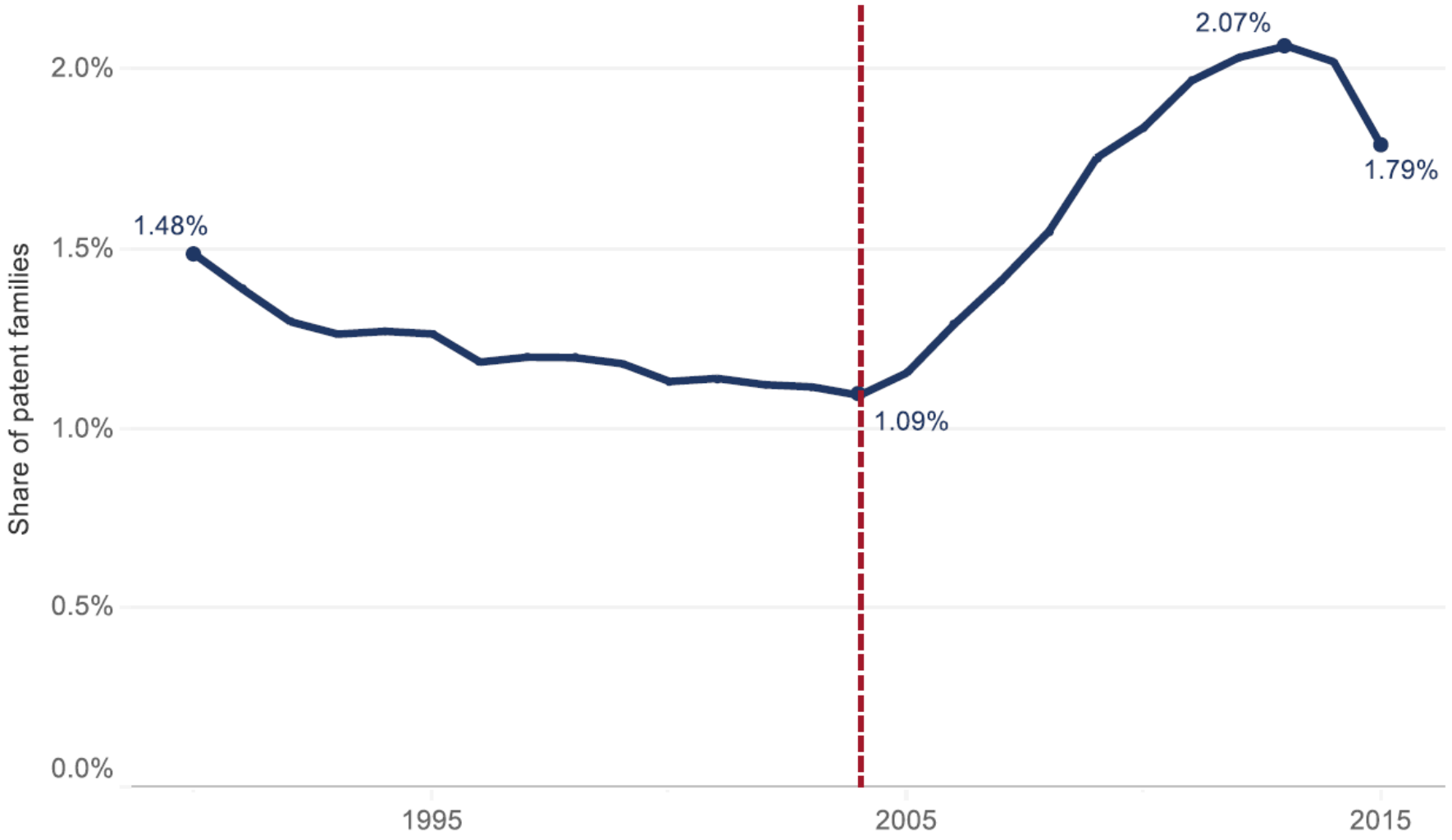



*Source: WIPO, Daly et al., 2019.* They identify **mining patents** on the basis of a **search for keywords in abstracts and titles**, and on the basis of mining **firms** patenting (ORBIS and national patent offices).

A patent **family** is a set of interrelated patent applications filed in one or more countries/jurisdictions to protect the same invention.

# …. Also relative to other sectors, since 2004

(by earliest priority year)




Source: WIPO, Daly et al., 2019. A patent **family** is a set of interrelated patent applications filed in one or more countries/jurisdictions to protect the same invention.

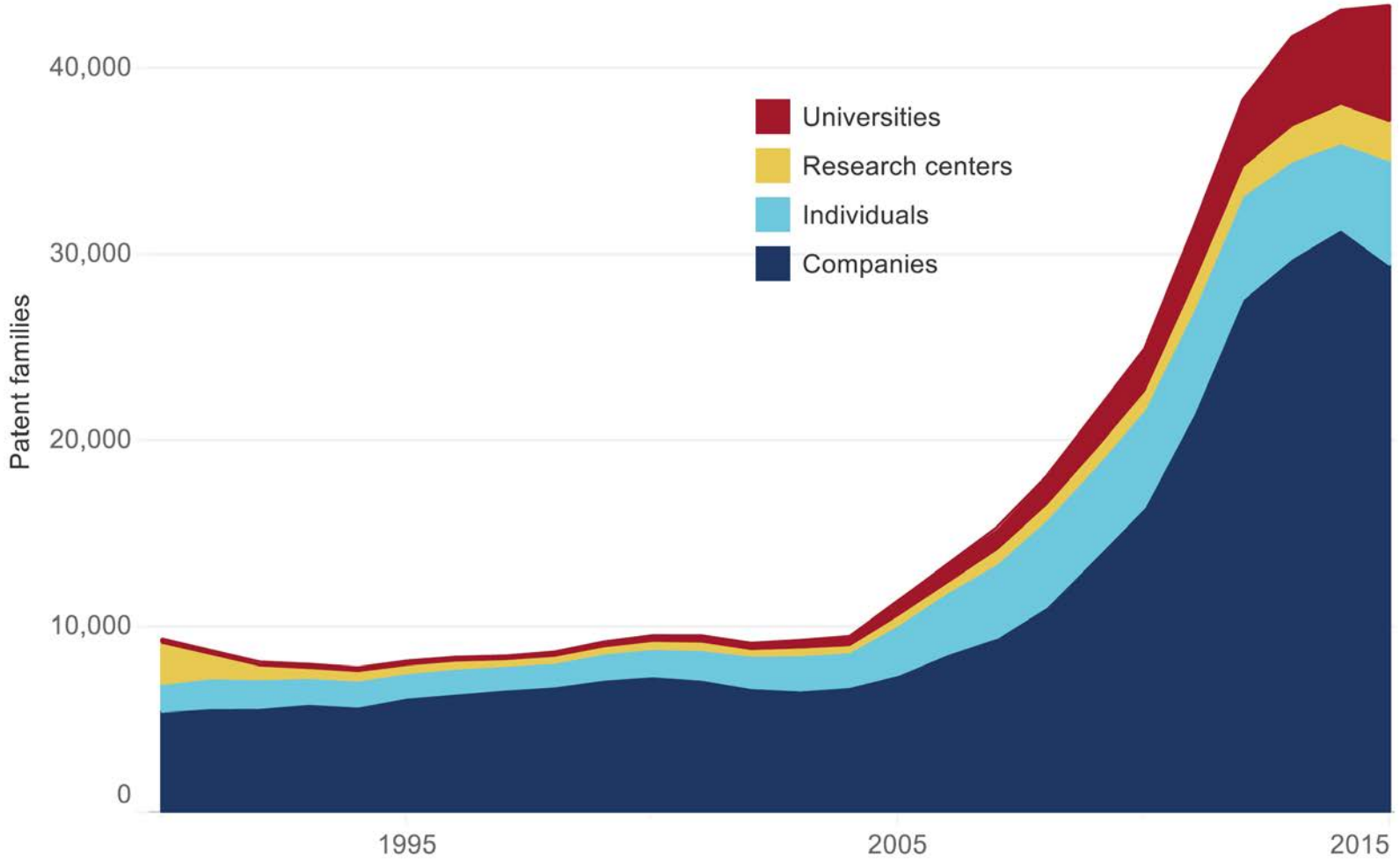

**Where** does all this innovation come from?

**NOT** from mining producing countries

only China and US >10% of both production and innovation

Japan generates >10% of innovation but produces <0.1%

# The **mining innovation ecosystem** is becoming more complex

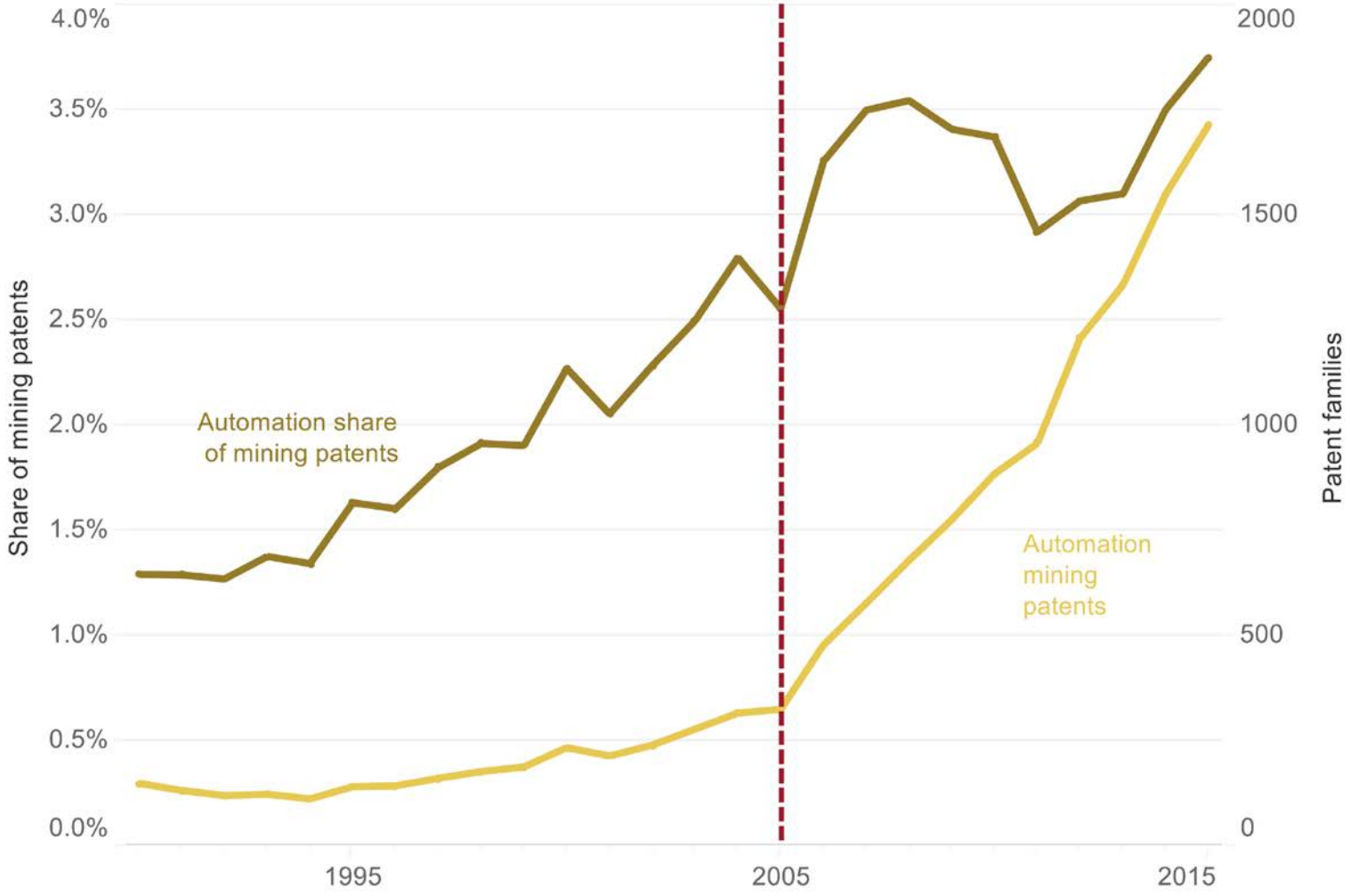



Number of mining patents over the years **by type of stakeholder** Source: WIPO, Daly et al., 2019.

# **Uncertainty** and **variability** in mining and the potential of **digital technologies**

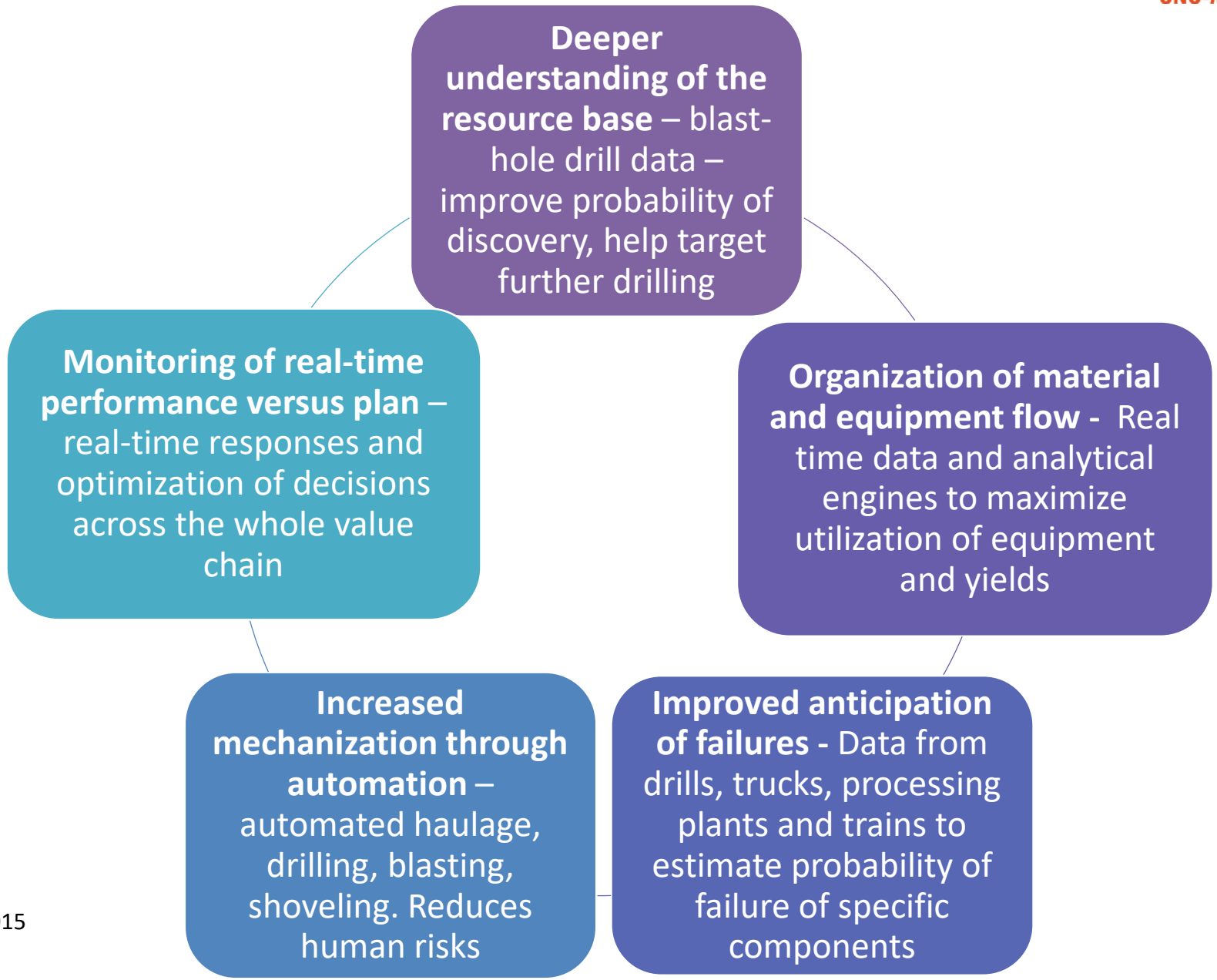
- Mining is **highly variable**, with **uncertainty** on the resource mined, on mine exploitation in extreme environments, on unpredictable obstacles.
- **Advances in IT and AI** such as Data, computational power and connectivity, Analytics and intelligence, Human-machine interaction (e.g. smart glasses and special clothing with sensors for workers), Digital-to-physical conversion (i.e. robots and teleremote and assisted-control equipment)
- **Digital technologies** can offer mitigation to **variability** and **uncertainty**, and thereby improve productivity, through:
    1. Deeper understanding of the resource base
    2. Organization of material and equipment flow
    3. Improved anticipation of failures
    4. Increased mechanization through automation
    5. Monitoring of real-time performance versus plan

# **Automation innovation in mining** has increased both in volume and share since 2005




*Source: WIPO, Daly et al., 2019*

# The potential of digital technologies




McKinsey, 2015

# Some innovation occurs locally: MNCs file mining patent applications also in host countries, sometimes with local inventors

- **MNCs are the major source of mining innovation globally.** Of the top 100 corporate applicants of mining and mining equipment technology and services (METS) patents between 1990 and 2015, 60 are large multinationals.
- MNE-owned patents are extensively **used and enforced by foreign affiliates in host countries**: 18% of 278,000 applications filed by top MNCs in countries other than headquarter's.
- Of these, over a third of foreign applications (37 per cent) list inventors whose nationality coincide with the country of filing. This hints that **sometimes MNCs foster some forms of local innovation in host countries** (*creative internationalization*)

Source: Formenti and Casella, 2019 https://blogs.lse.ac.uk/gild/2019/09/18/mining-for-tech-advances-the-impact-of-mineral-resource-fdi-in-the-era-of-global-value-chains/

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# Latin America is clearly behind in mining innovation

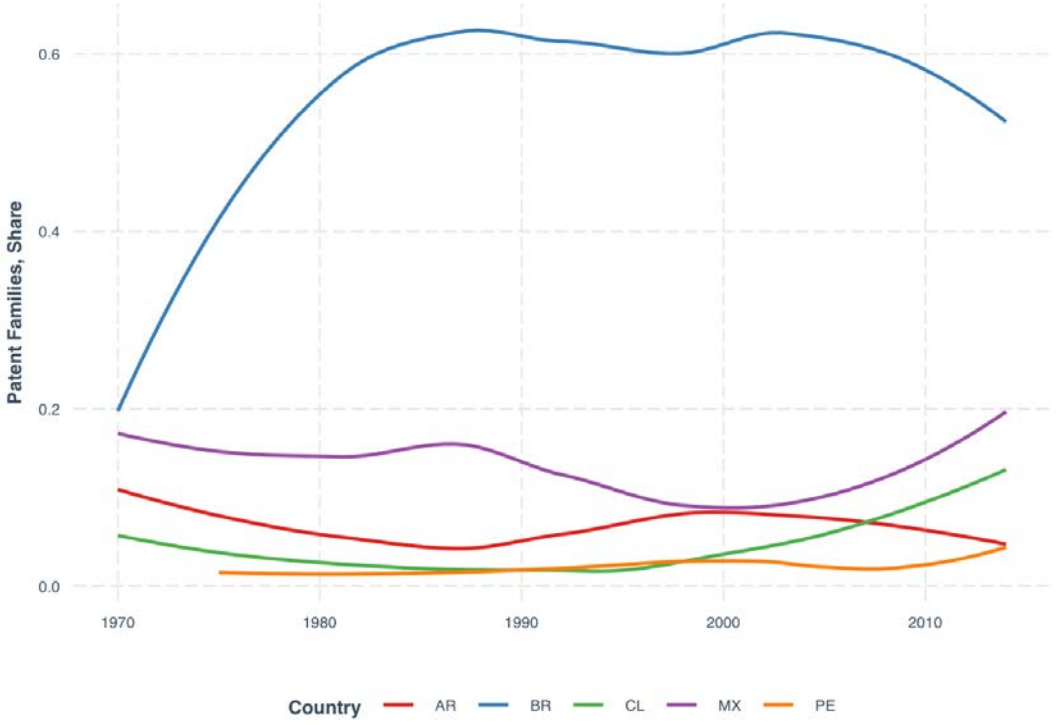
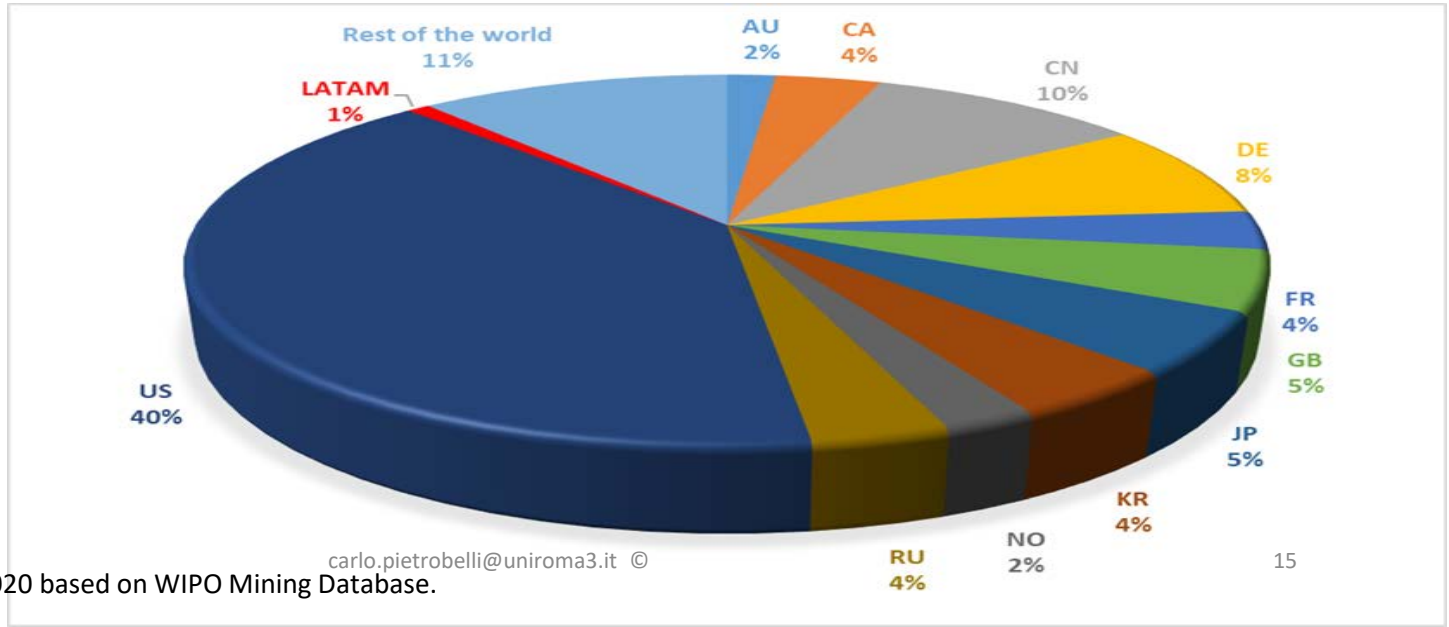



Figure 1. Mining technologies: top 5 Latin America countries of origin, in shares (smoothed lines)

Figure 2 - Share of mining patents in terms of inventor country of origin worldwide, 1970-2015




Source: Nenci and Quatraro, 2020 based on WIPO Mining Database.

# Recent research

- **Qualitative case studies in Brazil, Chile and Peru**: in-depth and semi-structured interviews to:
  - ✓Local suppliers
  - ✓Mining companies
- Unit of analysis: **innovative local suppliers** that developed innovative solutions to mining problems in different stages of the GVC
  - ❑ Waters pumps; hammers and drills;
  - ❑ biotechnological products and services;
  - ❑ engines; remote control services;
- Sample:
  - ✓Brazil (5) – Chile (9) – Peru (8)

## Summary of results

**LSE BLOG**
https://blogs.lse.ac.uk/gild/2019/05/10/mining-global-value-chains-new-opportunities-and-old-obstacles-for-developing-countries/

**World Bank WDR 2020 p.73**
https://www.worldbank.org/en/publication/wdr2020

# Research questions

- **What new opportunities for developing countries** are being created for structural change and diversification in the mining industry?
- **Are local firms and new ventures successfully exploiting these opportunities?** How does this relate to their level and type of technological and other **capabilities**?
- How do the **inter-firm linkages** that characterize GVCs **foster (hinder)** emergence and consolidation of these local firms and new ventures?

Hypothesis: A **new context** is emerging, which is opening up **new opportunities** for innovation and **fruitful linkages** in mining industries.

# New Stylized Facts relevant for the mining sector in Latin America

(Pietrobelli, Olivari, Marin, Molina, Figueiredo, Piana, Navarro, Stubrin, Katz, Special Issue in *Resources Policy*, 2018)

1. **World demand for commodities** (and food) has been growing at exponential rates (China and East Asia)
2. NR-based activities have become more **knowledge**-intensive, and have been affected by **major changes in world knowledge frontier in many scientific and technological fields** (e.g. molecular biology, genetics, health sciences, computing, digital technologies, metallurgy)
3. **Challenges demand innovative solutions to local firms**. (i.e. falling ore grades, rising production costs, labour and environmental disputes)
4. Mining companies have started to **outsource** key activities of their operations.
5. **New high value added activities and services** are increasingly emerging in some LA countries.

# What theory to discuss growth with NR?

**Received economic theory is not very helpful:**

- Production functions for NR-based commodities are not 'generic' and universal
- They have a highly 'location-specific' nature
- The environment and ecology determine the resource 'loading capacity' of each location.
- Production factors remarkably differ.
- Firms very different from one another, even if producing the same commodity.

# What theory to discuss growth with NR?

**Three concurring factors and their coevolution**

**Industrial Organization**

- increasingly shaped by features like production fragmentation and dispersion with GVCs

**Public Sector regulatory agencies**

- responsible for monitoring environmental impact and NR management

**Local communities**

- engaged in the exploitation of the resource demand respect for their 'environmental rights'. Highly vocal, "social license", veto power

**Networks** of **interdependent** and **co-evolving agents**

# Relevant strands of literature

- Role of **science in natural resource industries**
- **Firm-level capabilities**
- Role of industrial organization in the form of **global value chains**
- Role of **local communities** and of **regulatory agencies**

# How opportunities for local suppliers emerge

The role of **demand forces**

- ✓ Importance of ***location specificities***: demand for tailor-made solutions so companies are forced to innovate.
- ✓ ***With vertical disintegration, some linkages*** between suppliers and buying firms within value chains matter for learning and innovation.

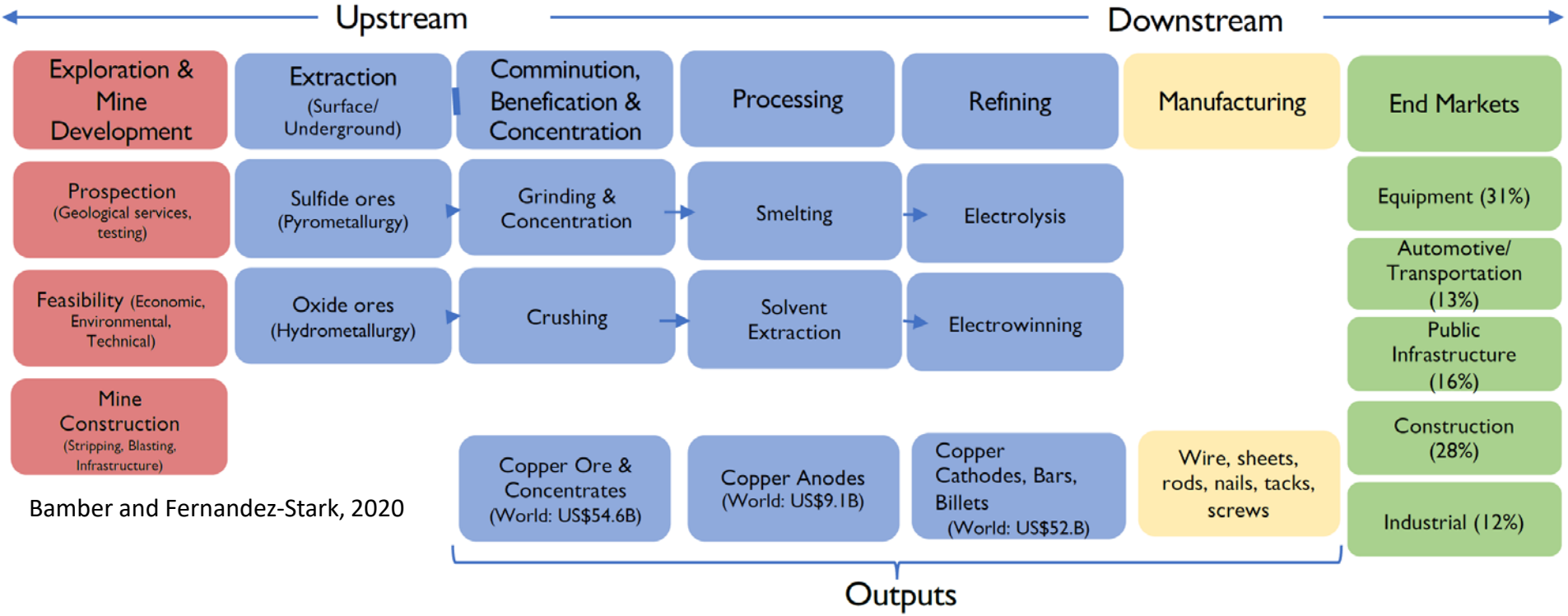
The role of **supply forces:**

- ✓ Recent **advances in scientific knowledge** have opened new technological opportunities for innovation in NRs in general, and in mining in particular, such as **ICT**, **biotechnology** and **new materials**.

**Firms capabilities**

- ✓ Local suppliers can take advantage to enter the knowledge intensive layers of the value chain with **strong technological and other capabilities.**

# Copper Global Value Chain (GVC)




Bamber and Fernandez-Stark, 2020

- **Few stages** that can be disaggregated
- Little geographical fragmentation
- High levels of **capital intensity**
- Long-term investments
- Sector **upstream** is relatively concentrated, but large variety of **downstream** industries

**The mining GVC is also made of various sophisticated METS**

**Core engineering design & project management (EPCM)**

Engineering Services, Process & Mechanical Design; Asset and Resources Management; Mining Engineering & Contracting; Mine Planning; Mineral Analytical & Processing Services; Project & Contract Management; Closure, Reclamation & Remediation; Mapping Services; Mine Site Design & Construction

**Contract operations**

Engineering Contractors; Contract Mining & Mining Services; Alluvial Mining & Mineral Sands Operations; Drilling Services

**Other services**

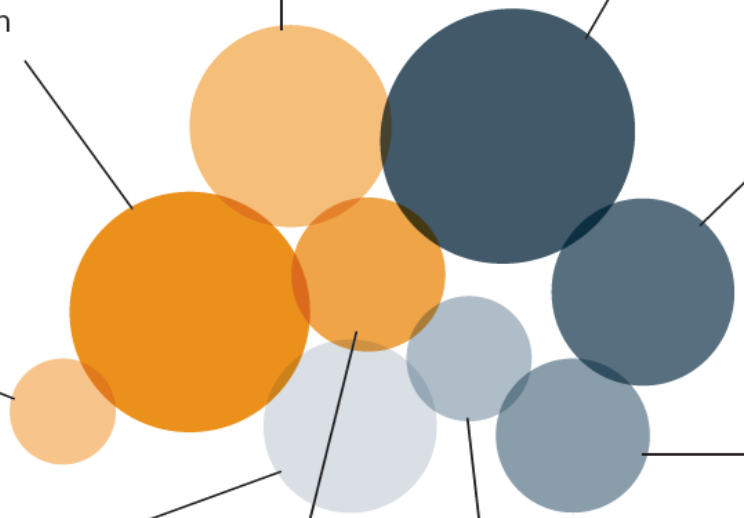
Equipment and Component Supply and Servicing

**General equipment & components**

Supply of Parts, Equipment Modifications & Improvements, Related Components & Consumables

**General Support Services**

Education & Training, Safety & Health Systems & Services, Recruitment & HR Solutions, R&D, Finance Services



**Core mining & processing equipment**

Bulk Material & Mineral Handling & Processing, Open Cut, Hard Rock & Underground Mining; Specialised Vehicles, Drilling, Blasting & Rock-breaking, Earth Moving, Surface Mobile, Water Management, Electric Power, Coal Beneficiation

**Information technology equipment & related services**

Information Management Systems; Software; Communication Systems; Automation, Simulation & Remote Communications; Ground Control Equipment & Supplies; Satellite Communication

**Consulting services**

Mining Consulting, Consulting Geologists & Engineers, Metallurgical Geotechnologies & Environmental Services

**Specialised technology**

Analytical Laboratories & Supplies; Exploration & Supplies; Mining Instrumentation; Strata Reinforcement Technology

**Source: Scott-Kemmis, 2013, p.26. Size of shapes indicates segment size**

# Distribution of Copper producing countries **by Value Chain Role**

## *Integrated Producers & Refiners*

Chile, Zambia, China, Australia, Mexico, Russia, United States, Canada, Poland

Most large, mature producers of copper refine a considerable share of their mined output. Generate between 33%-45% of copper export revenues from refined copper.

| Exploration & Mine Development | Extraction (Underground/ Surface) | Comminution, Beneficiation & Concentration | Processing | Refining |
|---|---|---|---|---|

## *Miners Only*

Peru
Indonesia
Mongolia

These countries account for less than 2% of global refinery capacity and over 75% of their export revenues are generated from unrefined copper.

## *Processors Only*

Japan
India
Germany
South Korea

These countries produce less than 0.5% of global mine output), import unprocessed or smelted copper and generate over 90% of their copper export revenues from refined copper.

Bamber and Fernandez-Stark, 2020, based on COMTRADE data

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# Some findings from our case studies

## *Demand forces*

- **Current challenges** faced by the industry are **confirmed**:

  Decreasing ore grades; Increasing incidence of local specificities; Decreasing productivity and increasing costs; Increasing social and environmental problems (investment projects blocked due to social and environmental conflicts)

- But these **challenges are <u>not</u> being adequately translated** into concrete demands for (technological) solutions (and new procurement.

- The organization of the industry (very **hierarchical**) does not seem to promote quality linkages between lead firms and suppliers

# Some Findings

## *Supply forces*

**Recent advances in technologies (often science-based)** that are applicable to the value chain:

- **ICT:** New development of a remote control system for trucks that operate at very high temperatures; remote monitoring and wireless communication that allows predicting wear points in key equipment and anticipate replacements to avoid stopping operations.
- **New materials:** Development of pumps for one of the biggest open-pit mine in the world, adapted to operate at 4,500 meters above the sea level, by upgrading materials and applying advanced engineering.
- **Robotics:** Tool for controlling irrigation at key parts of the process, helping to detect failures through irrigation maps and alarm systems.

# Some Findings

## *Firms' capabilities*

- Innovative solutions mainly offered by **existing firms. Small creation of new firms**, including spin-offs from universities and from existing firms.
- Firms use **different strategies to enter the markets**:
  - ✓ **Incumbents** improve existing solutions (product and services) to old problems, benefit from location specificities.
  - ✓ **New firms** develop new products or processes that are addressing both traditional and new challenges.
- Most of these firms **invested in developing advanced S&T capabilities**.

# Some Findings

## *GVC governance*

- The organization of the GVC (very **hierarchical**) **does not promote quality linkages** between lead firms and suppliers: Little impact on suppliers' learning and innovation.
- **Formal and informal interactions help** suppliers **identify chain leaders' demands**, but **do not help in developing a solution**.
  - ⇓ Lead firm informs of what it seeks
  - ⇓ Suppliers eventually develop solutions (in isolation, no room for testing)
  - ⇓ Selected supplier eventually benefits of closed interactions.
  - ⇓ Incumbents preferred over new entrants.
- **Many open challenges remain:**
  - Lacking spaces for **experimentation and testing**.
  - **New suppliers' access** to the GVC
  - Lacking **capacity of market creation** to exploit the technological innovations developed.

# Conclusions

- Some new **windows of opportunity for local suppliers** emerge, often related to new technologies
- Still a small and emerging reality of successful suppliers from Latin American countries
- **Hierarchy** in the relationships within the GVC does not help suppliers' upgrading
- **Lead firms rarely commit and engage** in collaborations. They shift risk to their suppliers and have them compete
- **Local suppliers** (especially of services) **invest, take the risk,** explore, adapt solutions and technologies to be successful.
- Different and varied **capabilities** are needed
- Institutions and regulations

# Thank you

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https://www.merit.unu.edu/about-us/profile/?staff_id=1560

# Back-up material

# Ongoing work

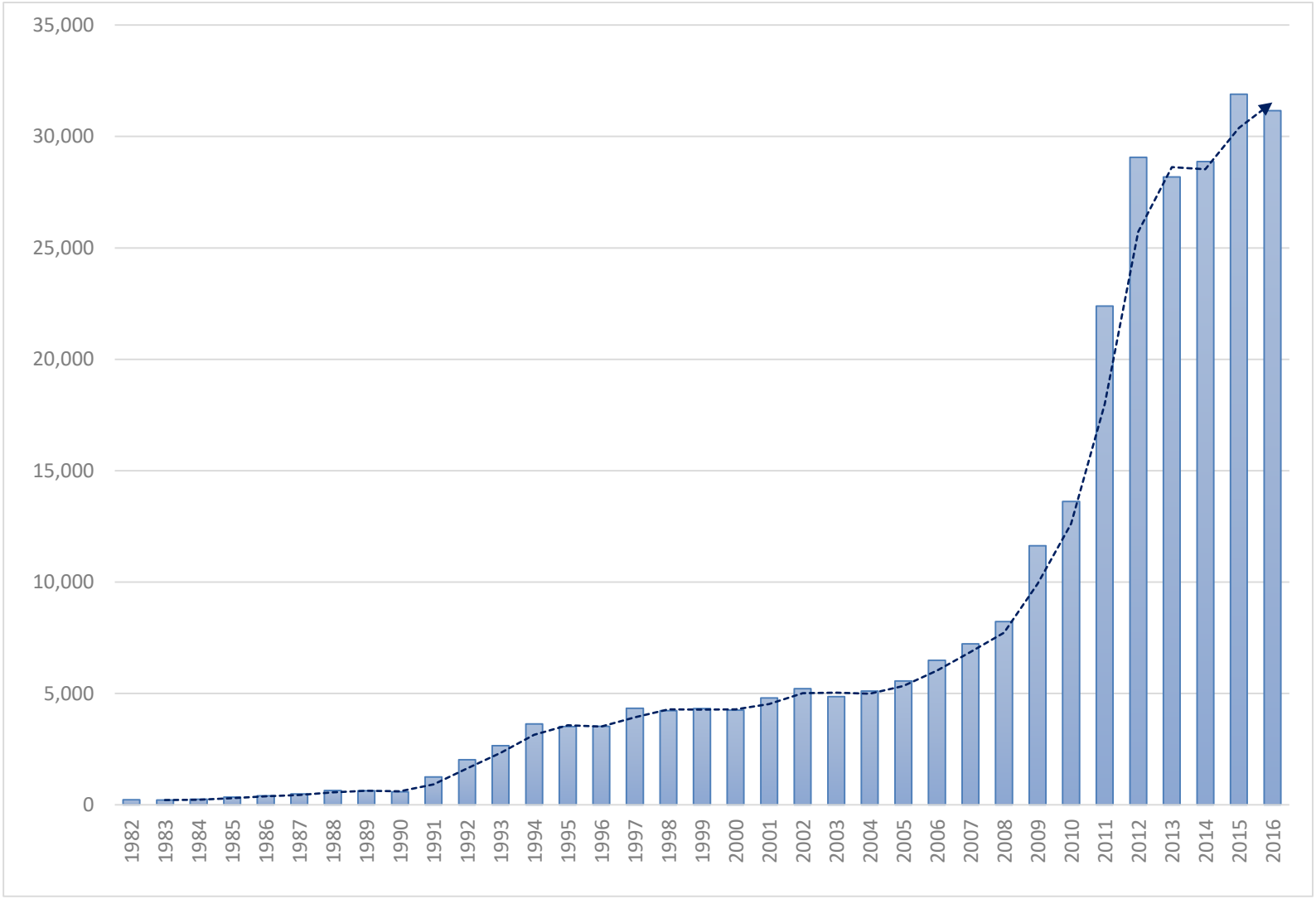
- Mapping of GVCs in mining with trade in VA data, and the related knowledge flows (via patents and bibliometrics)
- Case studies in Argentina, Brazil and Peru
  - ✓ Opportunities for local suppliers in manufacturing and services
  - ✓ Mapping of capabilities' requirements
  - ✓ Mediating role of GVC governance
  - ✓ Role of regulation and institutions
- Review of policies in mining countries (i.e. Australia, Chile, South Africa)

# Role of Regulatory Agencies: an example of good practice

- In such context NR regulatory agencies monitoring environmental impact and human health risk play a major role:
  - ✓ E.g. Set up norms and protocols, grant mining concessions, monitor company operations on waste disposals, human life risk and accidents, atmospheric conditions, air pollution, water contamination etc..
- For such purpose these agencies **need**:
  - ✓ a staff of **highly trained professionals** and a **proprietary data base**.
  - ✓ To put in place and develop an ongoing **learning process**.
- Example of Chile's SERNAGEOMIN – *Servicio Nacional de Geologia y Mineria* -
  - ✓ Created in 1981, grew stronger to respond to crises.
  - ✓ Contributed to a reduction in frequency of accidents.

# Diagram 5. Sernageomin budget in current Chilean pesos

Dramatic expansion after the 2008 Mina San Jose Crisis

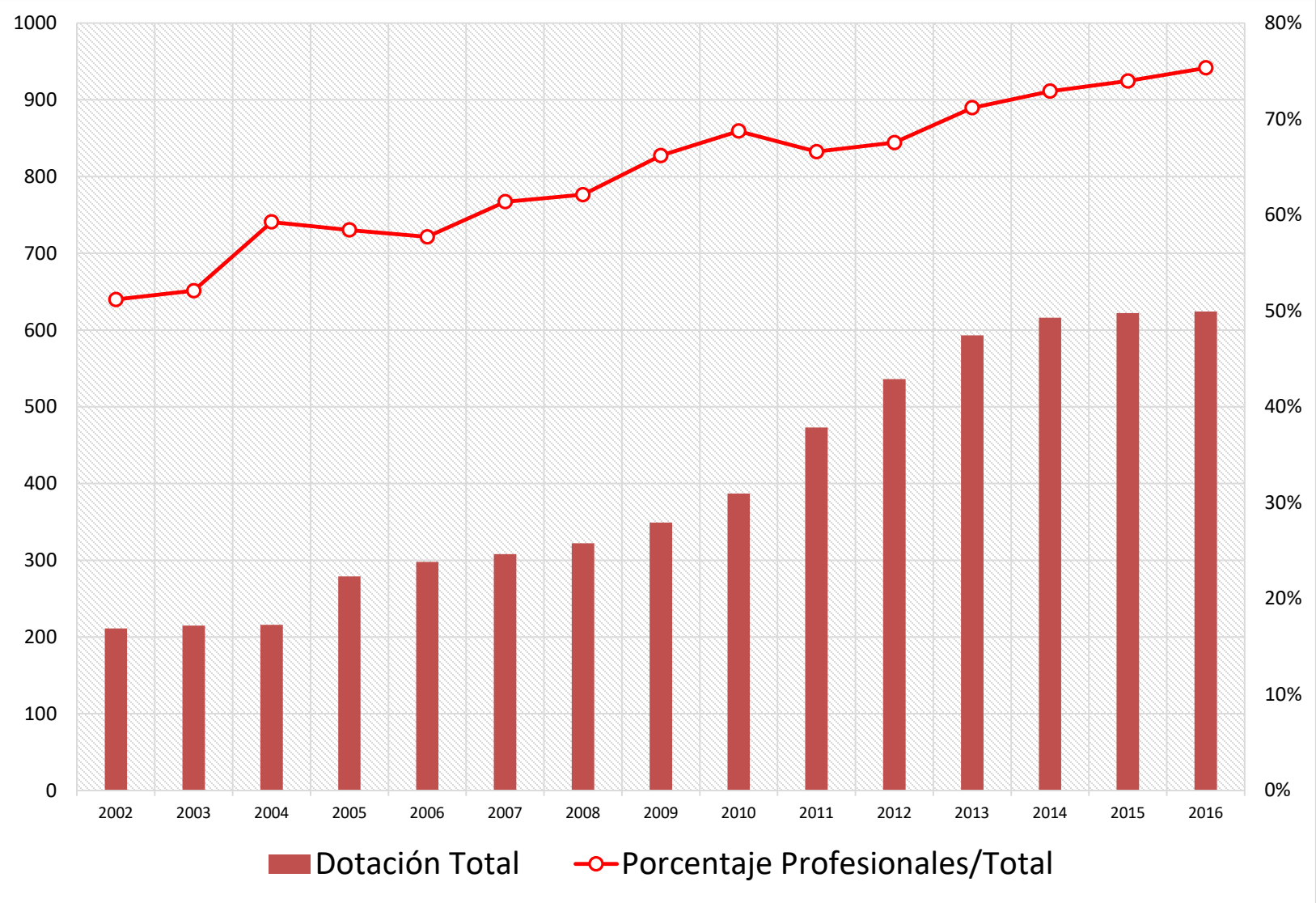





Source: Katz and Pietrobelli, 2018, Caceres et al., 2017

# Diagram 6. Sernageomin professional staff (2012-16)

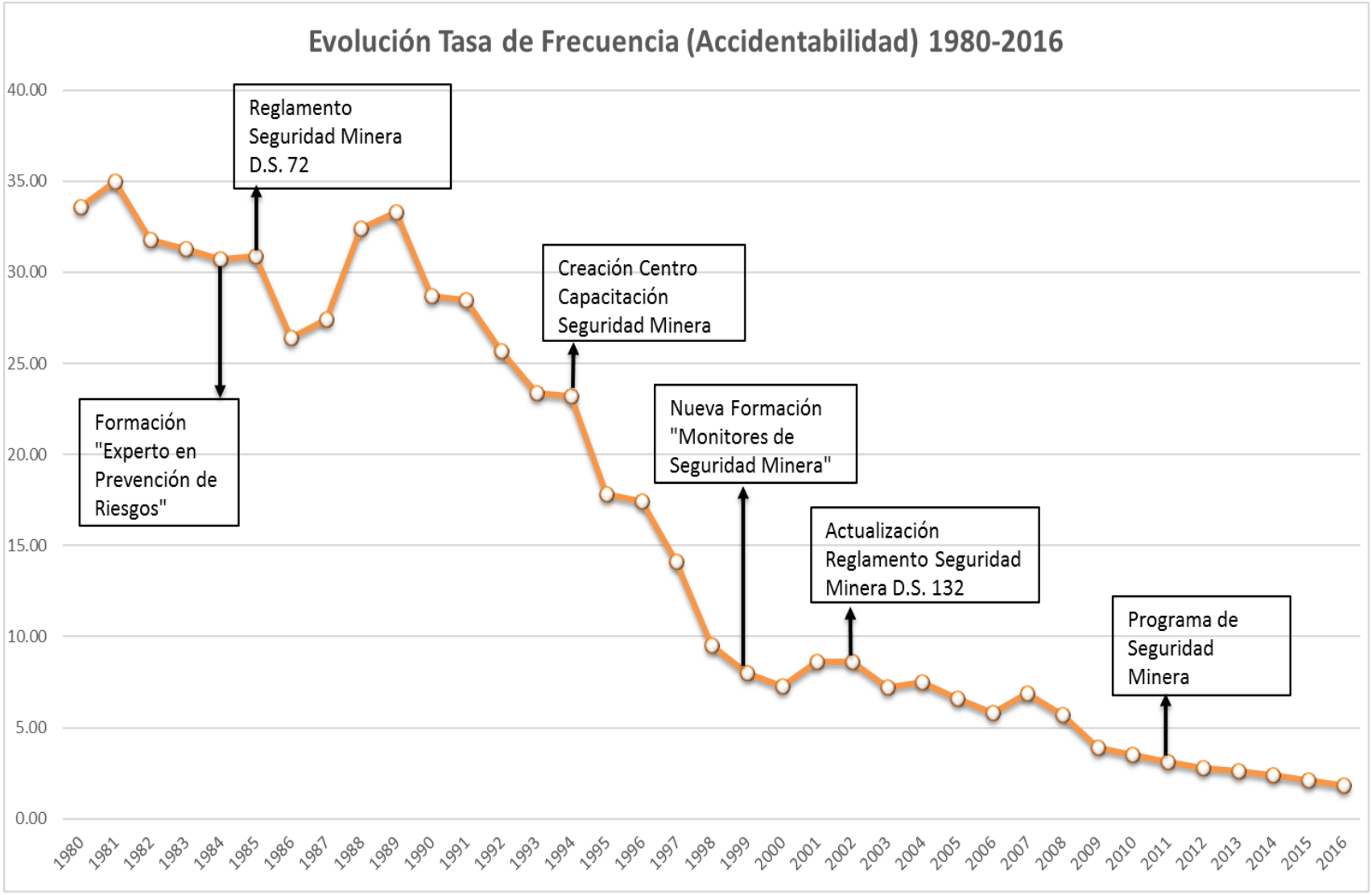
Dramatic expansion after the 2008 Mina San Jose Crisis






Source: Katz and Pietrobelli, 2018, Caceres et al., 2017

# Diagram 4. Fall in Annual accidents associated to mining activities in Chile (1980-2016)




Source: Katz and Pietrobelli, 2018, Caceres et al., 2017

# World-class suppliers to the Global Mining Industry in Chile

# Copper Mining Industry in Chile

Background:

- Decreasing mineral grade
- Increasing depth of operations (u. 1000-2000 mt)
- Higher standards for occupational safety
- Water scarcity
- High demand and cost of energy
- Highly demanding social and environmental conditions

- Drop in productivity
- Production costs increase

# Market and coordination failures underlying a joint private-public initiative

**Dominant features inside mining industry in Chile**

- Conservative capital-intensive culture.
- Low incentives for decision makers to innovate
- Bounded capacities to manage innovation and projects oriented to adopt technologies

**Information Asymmetries**

- Between Industry (challenges) and Suppliers (solutions)
- Eroding financing access and conditions
- Lack of testing fields for local innovative solutions.

**Coordination gaps**

- Misalignment between local R&D Centers and Industry requirements
- Systemic under–investment in innovation.

# Some Results

- BHP Billiton and CODELCO contracted about **70 local suppliers with innovative projects and medium-high technology content**, aimed at solving challenges identified by companies in various foci of the production process.
- Fundación Chile created a **platform of interactions** between companies and suppliers, to identify gaps and follow up projects and suppliers.
- **New players** into the ecosystem, with R&D capabilities (international Universities and Centers of Excellence in the country); support to emerging companies (Accelerators, specialized venture capital fund)
- **Yet** suppliers face serious difficulties in scaling-up and exporting
- Since **2016**, within the framework of the "**High Law" Strategic Mining Program**, the **Program is relaunched**, with a greater number of mining companies involved, focusing on scaling up and internationalization of suppliers