

Cambridge University Press
978-1-108-84278-5 — Global Challenges for Innovation in Mining Industries
Alica Daly, David Humphreys, Julio Raffo, Giulia Valacchi
Frontmatter
[More Information](#)

GLOBAL CHALLENGES FOR INNOVATION IN MINING INDUSTRIES

People have been digging in the ground for useful minerals for thousands of years. Mineral materials are the foundation of modern industrial society. As the global population grows and standards of living in emerging and developing countries rises, the demand for mineral products is increasing. Mining ensures that we have an adequate supply of the raw materials to produce all the components of modern life, and at competitive prices. Innovation is central to meeting the diverse challenges faced by the mining industry. It is critical for developing techniques for finding new deposits of minerals, enabling us to recover increasing amounts of minerals from the ground in a cost-effective manner, and ensuring it this is done in a way that is environmentally responsible. This book provides the first in-depth global analysis of the innovation ecosystem in the mining sector. This book is Open Access.

ALICA DALY is an experienced IP professional, currently working as a Senior Policy Officer in the Division of Artificial Intelligence Policy of the World Intellectual Property Organization (WIPO). Prior to her time at WIPO, she spent ten years working at IP Australia. Her most recent position there was as its first Head of Patent Analytics. During this time, she was responsible for co-authoring a number of reports published by the Patent Analytics Hub.

DAVID HUMPHREYS is an Honorary Lecturer at the University of Dundee, Scotland, and former Chief Economist at Norilsk Nickel and Rio Tinto. David has written and lectured extensively on the economics of the mining industry, authoring over 200 articles and papers on subjects ranging from commodity markets, trends in the mining sector, resource availability, sustainable development, Russian mining and the impact of China on mining, to national minerals policy.

JULIO D. RAFFO is Head of the Innovation Economics Section at the Department for Economics and Data Analytics of the World Intellectual Property Organization (WIPO). His research interests include the economics and metrics of innovation and intellectual property, with a particular focus on their intersection with socio-economic development.

GIULIA VALACCHI is based in the Department for Economics and Data Analytics of the World Intellectual Property Organization (WIPO). Before joining WIPO, she worked for the Centre of International Environmental Studies as a Research Assistant in the Sinergia Project. Her research interests include innovation, technology diffusion, climate change and environmental economics.

INTELLECTUAL PROPERTY, INNOVATION AND ECONOMIC
DEVELOPMENT

Intellectual property is at the heart of modern economic life. In many countries, investment in intangible assets is growing faster than investment in tangible assets. Policy makers – whether in rich or poor economies – seek to promote an intellectual property framework that is conducive to innovation and economic growth.

The series *Intellectual Property, Innovation, and Economic Development* intends to inform such policy initiatives through rigorous scholarship. Each book in the series examines a major aspect of the interface between IP, innovation, and economic development. Economic analysis is complemented by contributions from other academic disciplines to present the latest scholarship and consider its real-world implications. The series builds on studies by the World Intellectual Property Organization, reflecting the research interests of the international policy-making community.

Series Editor

Carsten Fink,
Chief Economist, World Intellectual Property Organization

Books in the Series

The Informal Economy in Developing Nations – Hidden Engine of Innovation? Edited by Erika Kraemer-Mbula and Sacha Wunsch-Vincent

The International Mobility of Talent and Innovation – New Evidence and Policy Implications Edited by Carsten Fink and Ernest Miguelez

Harnessing Public Research for Innovation in the 21st Century Edited by Anthony Arundel, Suma, Athreye and Sacha Wunsch-Vincent

Global Challenges for Innovation in Mining Industries Edited by Alica Daly, David Humphreys, Julio D. Raffo and Giulia Valacchi

GLOBAL CHALLENGES
FOR INNOVATION IN
MINING INDUSTRIES

Edited by

ALICA DALY

World Intellectual Property Organization

DAVID HUMPHREYS

University of Dundee

JULIO D. RAFFO

World Intellectual Property Organization

GIULIA VALACCHI

World Intellectual Property Organization



CAMBRIDGE
UNIVERSITY PRESS

Cambridge University Press
978-1-108-84278-5 — Global Challenges for Innovation in Mining Industries
Alica Daly, David Humphreys, Julio Raffo, Giulia Valacchi
Frontmatter
[More Information](#)

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom
One Liberty Plaza, 20th Floor, New York, NY 10006, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre,
New Delhi – 110025, India
79 Anson Road, #06–04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781108842785
DOI: 10.1017/9781108904209

© World Intellectual Property Organisation 2021

This work is in copyright. It is subject to statutory exceptions and to the provisions of relevant licensing agreements; with the exception of the Creative Commons version the link for which is provided below, no reproduction of any part of this work may take place without the written permission of Cambridge University Press.

An online version of this work is published at doi.org/10.1017/9781108904209 under a Creative Commons Open Access license CC-BY-NC-ND 4.0 which permits re-use, distribution and reproduction in any medium for non-commercial purposes providing appropriate credit to the original work is given. You may not distribute derivative works without permission. To view a copy of this license, visit <https://creativecommons.org/licenses/by-nc-nd/4.0>

All versions of this work may contain content reproduced under license from third parties. Permission to reproduce this third-party content must be obtained from these third-parties directly.

When citing this work, please include a reference to the DOI 10.1017/9781108904209

First published 2021

A catalogue record for this publication is available from the British Library.

ISBN 978-1-108-84278-5 Hardback

Cambridge University Press has no responsibility for the persistence or accuracy of URLs for external or third-party internet websites referred to in this publication and does not guarantee that any content on such websites is, or will remain, accurate or appropriate.

CONTENTS

<i>List of Figures</i>	<i>page</i>	vii
<i>List of Tables</i>		xii
<i>List of Boxes</i>		xiv
<i>List of Contributors</i>		xv
<i>Acknowledgements</i>		xviii
<i>Foreword</i>		xix
1	Global Challenges for Innovation in the Mining Industries	1
	ALICA DALY, DAVID HUMPHREYS, JULIO D. RAFFO AND GIULIA VALACCHI	
2	Recent Trends of Innovation in the Mining Sector	25
	ALICA DALY, GIULIA VALACCHI, AND JULIO D. RAFFO	
3	Mining Foreign Direct Investments and Local Technological Spillovers	52
	BRUNO CASELLA AND LORENZO FORMENTI	
4	Innovation in Mining Global Value Chains: Implications for Emerging Economies	88
	MICHIKO IIZUKA, CARLO PIETROBELLI AND FERNANDO VARGAS	
5	The Role of Transport-Related Innovation in the Mining Sector	117
	FRANCESCO DIONORI AND MARYAM ZEHTABCHI	
6	Environmental Regulations in the Mining Sector and Their Effect on Technological Innovation	142
	MAXWELL ANDERSEN AND JOËLLE NOAILLY	

- 7 Global Trends of Innovation in the Mining Sector: the Role of Commodity Prices 172
 GIULIA VALACCHI, ALICA DALY, DAVID HUMPHREYS AND JULIO D. RAFFO
- 8 IP Use and Technology Transfer in the Brazilian Mining Sector 202
 DOMENICA BLUNDI, ANA CLAUDIA NONATO DA SILVA LOUREIRO, SERGIO MEDEIROS PAULINO DE CARVALHO, MARINA FILGUEIRAS JORGE, FELIPE VEIGA LOPES, GUSTAVO TRAVASSOS PEREIRA DA SILVA AND VITORIA ORIND
- 9 Innovation and IP Use in the Chilean Copper Mining Sector 231
 CLAUDIO BRAVO-ORTEGA AND JUAN JOSÉ PRICE
- 10 The MINER Act of 2006: Innovating for Safety and Health in US Mining 257
 ANDREW A. TOOLE, JAMES FORMAN AND ASRAT TESFAYESUS
- 11 Innovation in the Canadian Mining Sector 278
 BAHARAK COURTNEY DOAGOO, ELIAS COLLETTE, SEAN MARTINEAU, AMIRA KHADR, MARC NEVILLE AND MAZAHIR BHAGAT
- 12 Recent Trends of Innovation and IP Use in the Mining Sector in Australia 308
 ROHAN AMBURLE, ALMA LACKEN, EMMA FRANCIS, DEANNA TRAINHAM, GREG MALONEY AND CATRIONA BRUCE
- Index* 342

FIGURES

1.1	Simplified view of the life of a mine	<i>page 5</i>	
1.2	Productivity in the Australian and US mining industries		10
2.1	R&D expenditure in mining in Australia, 1993–2016		27
2.2	Worldwide mineral exploration expenditure (US \$ bn) by commodity, 1994–2017		29
2.3	Worldwide mining technologies, 1990–2015		29
2.4	Worldwide mining technologies as share of technologies, 1991–2015		31
2.5	Patent families potentially related to mining by source		32
2.6	Simplified view of the lifecycle of a mine		33
2.7	Mining technologies by subsectors, 1990–2015		34
2.8	Distribution of mining technologies in subsectors by period, 1990–2015		35
2.9	Patents families in automation class over time		36
2.10	Mining production and innovation by country, selected countries		37
2.11	Mining innovation by top country of origin		39
2.12	Mining patents share by country, selected countries		40
2.13	Mining relative specialization index (RSI), selected countries		41
2.14	RSI by mining sub-sector, selected countries		43
2.15	Number of mining patents families over the years by type of stakeholder		45
2.16	Mining Firms by technology, by earliest priority year		48
2.17	Patent families of mining firms by WIPO technology field		48
3.1	Ownership profile of (large) mining firms. Largest 100 mining companies based on operating revenues (distribution based on number of firms)		54
3.2	Recent trends in mining FDI		57
3.3	Largest investors in mining FDI		59
3.4	Development impact of mining FDI, multiple dimensions		61
3.5	An analytical framework		65
3.6	R&D expenditure of MNEs in UNCTAD top 100 ranking		68

- 3.7 The ownership profile of the top 100 applicants of mining patents Number of applications in the period 1990–2015, share to total 70
- 3.8 Internationalization of patent activity: evidence from WIPO patent statistics 72
- 3.9 Greenfield FDI by type of activity 75
- 3.10 Policy recommendations: linking analysis and practice for impact 77
- 4.1 Reserves of key minerals by countries' income level (2015, %) 92
- 4.2 Proportion of mineral production (%) 92
- 4.3 Number of mining patent families, by country of origin (2004, 2014) 93
- 4.4 Mining GVC firms and patents by type of firm and region (2004, 2014) 93
- 5.1 Transport in the international mining supply chain 120
- 5.2. Coal and lignite imports and exports 2014 122
- 5.3 Average commodity and transportation costs for US coal (2008–14) 123
- 5.4 Historical change in transport-related innovation (1900–2015) 127
- 5.5 Country of origin of mining transport patents (1990–2015) 130
- 5.6 Mining transport patents by transport mode (1970–2015) 131
- 5.7 Transport patents in automation 135
- 5.8 Transport automation innovation per country 136
- 5.9 Where does MTI source technology? 137
- 5.10 Which sectors make use of mining transport technologies? 138
- 6.1 Number of clean mining patents over time in total sample (left panel) and share of clean patents among all mining patents (right panel) 149
- 6.2 Decomposition of the OECD EPS index 151
- 6.3 Market and nonmarket EPS 153
- 6.4 Mining patenting and lagged EPS 159
- 6.5 Mineral price index (MPI) 159
- 7.1 Private R&D expenditure in mining and quarrying in EU countries and World Bank Metals and Minerals Price Index 175
- 7.2 Mineral exploration expenditure by commodity and nonferrous metals price index 176
- 7.3 De-trended Metals and Minerals Price Index and different cycles components 181
- 7.4 Number of patent families and R&D expenditure in the mining sector 183
- 7.5 Country exposure to mining sector rents 184
- 7.6 Mining and METS firms innovation relative specialization, by country and mining technology 185

LIST OF FIGURES

ix

- 7.7 Mining price, quantity and innovation co-evolution (1960–2015) 185
- 7.8 Mining price, quantity and innovation cycle decomposition (1960–2015) 186
- 7.9 Average marginal effect of long cycle component of price index on innovation with 95% confidence intervals 195
- 7.10 Average marginal effect of medium cycle component of price index on innovation with 95% confidence intervals 196
- 7.11 Average marginal effect of short cycle component of price index on innovation with 95% confidence intervals 196
- 8.1 Leading producing companies in Brazil (2015) 203
- 8.2 Innovative activities developed by extractive companies and degree of importance 208
- 8.3 Mining patents, by type of applicant (2000–15) 215
- 8.4 Mining patent applicants, by mining technology groups 215
- 8.5 Mining patents filed by METS, by country of origin (2000–15) 216
- 8.6 Leading METS applicants (2000–15) 217
- 8.7 Leading applicants among mining firms (2000–15) 218
- 8.8 Leading contractors (2000–15) 222
- 8.9 Leading suppliers, by country of provision of the contract (2000–15) 223
- 9.1 Types of firms surveyed by products supplied 242
- 9.2 Sales (frequency distribution, excluding the largest four firms) 244
- 9.3 Employees (frequency distribution, excluding the largest four firms) 244
- 9.4 Type of innovation 245
- 9.5 Do IP registration costs affect protection decisions in Chile? 248
- 9.6 Does your firm have trade secrets? 249
- 9.7 IP instruments of apparent interest to potential exporters 250
- 10.1 US mining employment (1900–2017) 259
- 10.2 Fatalities in US mining (1900–2017) 260
- 10.3 USPTO-granted patents in mineral mining (three-year moving average by filing year) 265
- 10.4 USPTO-granted patents in mineral mining separated into safety-related and non-safety-related groups (three-year moving average by filing year) 266
- 10.5 USPTO-granted patents in mineral mining for refuge chambers and TTE communications 268
- 10.6 Schematic diagram of a wall-to-wall barrier in a passageway of a mine 271
- 10.7 Through-the-earth (TTE) emergency tracking and communication system 272

- 10.8 Distributions of similarity scores for NIOSH granted patents in four mutually exclusive groups (mineral mining, safety-related mineral mining, TTE communications and refuge chambers) 273
- 11.1 Canadian patenting activity in the mining sector between 1990 and 2015 286
- 11.2 Top Canadian mining firms and METS and their associated mining sector category, 1990–2015 288
- 11.3 Priority country share for top Canadian mining firms and METS 289
- 11.4 Priority country share for all Canadian mining firms and METS 290
- 11.5 All mining patent families assigned to Canadian mining firms and METS 291
- 11.6 Canadian patenting activity by mining category between 1990 and 2015 293
- 11.7 Relative Specialization Index (RSI) 294
- 11.8 Patent families assigned to Canadian assignees in the exploration category 296
- 11.9 Collaborations and their distribution by mining sector category between 1990 and 2015 297
- 11.10 Collaboration map involving mining firms and METS 299
- 11.11 Canadian mining industry clusters 301
- 11.12 Geographical clusters of inventive activity in Canada 302
- 12.1 Patent families of Australian origin, by priority year, 1997–2015 311
- 12.2 Top Australian patent filers 313
- 12.3 Australian entities who file patents, by entity type 313
- 12.4 Patent filings by Australians, by mining technology 314
- 12.5 Patent filings by Australians, by mining technology, by priority year, 1997–2015 315
- 12.6 Jurisdictions in which Australian innovators seek patent protection 319
- 12.7 Australian patent filing collaboration by entity type 320
- 12.8 Top Australian collaborators in patent filings 321
- 12.9 Australian patent filings by CRCs 321
- 12.10 Mining sector expenditure in the R&D Tax Incentive, 2000–1 to 2015–16 324
- 12.11 Mining sector companies by entity size, 2000–01 to 2015–16 325
- 12.12 Comparison of mining sector industry subdivision trends under the R&D Tax Incentive by industry subdivision, 2000–1 to 2015–16 326
- 12.13. Mining sector R&D expenditure and patent filings for R&D Tax Incentive companies, 2000–01 to 2015–16 327

LIST OF FIGURES

xi

- 12.14 Mining sector performance under the R&D Tax Incentive by State and Territory, 2000–1 to 2015–16 328
- 12.15 Patent filings into Australia, by priority year, 1997–2015 330
- 12.16 RBA Index of Commodity Prices, 1997–2015 331
- 12.17 Mining sector profits as a share of nominal GDP, 1997–2015 331
- 12.18 Australian investment in mining as a percentage of GDP, 1997–2015 332
- 12.19 Patent filings into Australia by mining technology 332
- 12.20 Patent filings into Australia by applicant origin 333
- 12.21 Top applicants filing patents into Australia in the mining sector 335
- 12.22 International collaboration on patent filings into Australia in the mining sector 336
- 12.23 Collaboration on patent filings into Australia in the mining sector by technology 337
- 12.24 Collaboration on patent filings into Australia by technology by country 337

TABLES

2.1 Mining firms with and without patents	<i>page 47</i>
3.1 Mining MNEs in UNCTAD Top 100 ranking of the largest global MNEs	56
4.1 Natural resources matter for GDP and trade for emerging and Latin American countries	91
5.1 Average distance and Capesize vessel shipping price to Port of Qingdao, China	124
6.1 Patent classification of clean mining patents	148
6.2 Top countries as ranked according to their share of clean patents in total mining patents, 1990–2015	150
6.3 Control variables	157
6.4 Baseline results	160
6.5 Results – Impact of market vs. nonmarket EPS	163
6.6 Results – Impact of individual policy instruments	164
6A Summary statistics of key variables	170
6B Robustness best of baseline estimation, using further lags and moving-average definition	171
7.1 Characteristics of mining and METS firms	177
7.2 Effect on innovation and access to finance of price change	179
7.3 Time series estimation	187
7.4 Time series estimation, different mining categories	189
7.5 Time series estimation, different mining categories, decomposed price cycles	190
7.6 Time series estimation, mining vs METS firms	191
7.7 Panel estimation	192
7.8 Panel estimation, using country-specific price index	193
8.1 Brazilian ore production (2015)	205
8.2 Mining sector challenges and technological demands	209
8.3 Patents applications: 2000–15	214
8.4 Coapplications and foreign inventors, by mining technology	219
8.5 Research sample (technology import contracts) (2000–15)	220
8.6 Technology import contracts by type, by contractor and by supplier (2000–15)	221

LIST OF TABLES

xiii

8.7 Mining firm contractors (subsidiaries and parent companies)	223
9.1 Share of global production and reserves (% , 2015)	233
9.2 Percentage of firms that innovate (mining suppliers vis-à-vis the industry and the economy)	236
9.3 Mining-related patents filed in the Chilean Patent Office	238
9.4 Major 10 nonresident (NR) firms filing patents in Chile, by country of origin	240
9.5 Descriptive statistics (in US dollars)	243
9.6 IP applications filed in the Chilean Patent Office and abroad, by instrument (%)	247
9.7 Questions on IP practices and regulation (%)	247
9.8 Innovating firms' reasons for not protecting innovations (%)	248
10.1 MINER Act on health outcomes, 1995–2014	275
12.1 Mining patent filings by Australians, by technology and entity type	316
12.2 Mining support service patent filings by Australians, by technology and entity type	318

BOXES

- 3.1 Tracking R&D Internationalization in Mining FDI Using Patent
Statistics *page 73*
- 9.1 Codelco's Innovation Strategy (The Role of Codelco Tech) 238

CONTRIBUTORS

- ROHAN AMBURLE is acting Director of Data Front Door and Analytics team and a former patent analyst at IP Australia, Australia.
- MAXWELL ANDERSEN is an international economics researcher at the Graduate Institute of International and Development Studies' Center for International Environmental Studies in Geneva, Switzerland.
- MAZAHIR BHAGAT is a data scientist at the Canadian Intellectual Property Office (CIPO), Canada.
- DOMENICA BLUNDI is the coordinator of partnerships and management of RD&I at Vale S.A., Brazil.
- CATRIONA BRUCE is Head of the Patent Analytics Hub at IP Australia, Australia.
- BRUNO CASELLA is Senior Economist at the Trends and Data Section in the Division for Investment and Enterprise of the United Nations Conference on Trade and Development (UNCTAD), Switzerland.
- SERGIO M. PAULINO DE CARVALHO is an intellectual property senior specialist at the Brazilian National Institute of Industrial Property (INPI), Brazil.
- ELIAS COLLETTE is Director of Business Improvement Services and Chief of the Economic Research and Strategic Analysis unit at the Canadian Intellectual Property Office (CIPO), Canada.
- ALICA DALY is Senior Policy Officer on Artificial Intelligence and Data at the World Intellectual Property Organization (WIPO), Switzerland, and former Research Fellow in the Innovation Economics Section at the Department of Economics and Data Analytics of WIPO.
- FRANCESCO DIONORI is Chief of Transport Networks and Logistics Section of the United Nations Economic Commission for Europe (UNECE), Switzerland.
- BAHARAK COURTNEY DOAGOO is a fellow at the Centre for International Governance Innovation (CIGI) and a former

post-doctoral fellow in the International Law Research Program CIGI, Canada, and is a CIGI Fellow.

MARINA FILGUEIRAS JORGE is Chief of the Economic Affairs Advisory at the Brazilian National Institute of Industrial Property (INPI), Brazil.

JAMES FORMAN is a data scientist at Google, Inc. and a former patent examiner detailee at the Office of the Chief Economist at the United States Patent and Trademark Office (USPTO), United States.

LORENZO FORMENTI is an associate expert at the Division of International Trade and Commodities of the United Nations Conference on Trade and Development (UNCTAD), Switzerland.

EMMA FRANCIS is an IP data expert at the World Intellectual Property Organization (WIPO), Switzerland, and former patent analyst at IP Australia, Australia.

DAVID HUMPHREYS is an honorary lecturer at the University of Dundee, Scotland, and former Chief Economist at Norilsk Nickel and Rio Tinto.

MICHIKO IIZUKA is a professor at the National Graduate Research Institute on Policy Studies (GRIPS), Japan.

AMIRA KHADR is a policy analyst at Innovation, Science and Economic Development Canada and a former research economist at the Canadian Intellectual Property Office (CIPO), Canada.

ALMA LACKEN is an Assistant Director and former patent analytics project manager at IP Australia, Australia.

GREG MALONEY is an IP searcher and analyst at the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, and former patent analyst at IP Australia, Australia.

SEAN MARTINEAU is interim manager of IP Analytics and Data Dissemination at the Canadian Intellectual Property Office (CIPO), Canada.

MARC NEVILLE is a senior economist at the Canadian Intellectual Property Office (CIPO), Canada.

JOËLLE NOAILLY is a lecturer in International Economics and Head of Research of the Centre for International Environmental Studies (CIES) at the Graduate Institute of International and Development Studies in Geneva, Switzerland.

ANA CLAUDIA NONATO is a researcher at the Brazilian National Institute of Industrial Property (INPI), Brazil.

VITORIA ORIND is an economic affairs advisor at the Brazilian National Institute of Industrial Property (INPI), Brazil.

LIST OF CONTRIBUTORS

xvii

- CLAUDIO BRAVO ORTEGA is an associate professor, director of the Master of Innovation and head of the Innovation, Entrepreneurship and Sustainability Group, at Adolfo Ibañez University, Chile.
- CARLO PIETROBELLI is a professor of economics at University Roma Tre, Italy; a professorial fellow at UNU-MERIT, The Netherlands; and an adjunct professor at Georgetown University.
- JUAN JOSÉ PRICE is a researcher at the Macquarie University and the Copenhagen Business School, Denmark.
- JULIO D. RAFFO is Head of the Innovation Economics Section at the Department of Economics and Data Analytics of the World Intellectual Property Organization (WIPO), Switzerland.
- ASRAT TESFAYESUS is a transfer pricing senior consultant at Deloitte US and former economist at the Office of the Chief Economist at the United States Patent and Trademark Office (USPTO), United States.
- ANDREW A. TOOLE is Chief Economist at the United States Patent and Trademark Office (USPTO), United States; and a research associate at the Centre for European Economic Research (ZEW), Germany.
- DEANNA TRAINHAM is a spatial data analyst at the Australian Government Department of Industry, Science, Energy and Resources, and a former data analyst at IP Australia, Australia.
- GIULIA VALACCHI is an external consultant and former research fellow in the Innovation Economics Section at the Department of Economics and Data Analytics of the World Intellectual Property Organization (WIPO), Switzerland.
- FERNANDO VARGAS is Competitiveness, Technology, and Innovation Specialist of the Inter-American Development Bank (IADB).
- FELIPE VEIGA LOPES is Head of Statistics Division at the Brazilian National Institute of Industrial Property (INPI), Brazil.
- MARYAM ZEHTABCHI is an economic officer at the Innovation Economics Section at the Department of Economics and Data Analytics of the World Intellectual Property Organization (WIPO), Switzerland.

ACKNOWLEDGEMENTS

The preparation of this book benefited greatly from the support of several institutions. National intellectual property offices of Australia, Brazil, Canada, Chile and the United States provided national data, expertise and feedback. IP Australia generously allowed Alica Daly to participate as a co-editor of the book. WIPO's Committee on Development and Intellectual Property (CDIP) contributed funding for the Experts Meeting on Global Innovation Patterns in the Mining Industries (May 2017, Geneva) and the contributions of Brazil and Chile under the Project on Intellectual Property and Socio-Economic Development—Phase II (CDIP/14/7).

We are most grateful to many people who greatly contributed to this book. First, we thank all the volume's contributors for their inspiring chapters and the time, dedication and patience they all committed to this project. Second, we also thank Bassen Awad, Graham Davis, Nicolas Depetris-Chauvin, Samo Gonçalves, David Kaplan, Marcela Paiva Véliz, and Catalina Olivos-Besserer, who participated in the above-mentioned expert meeting and whose perspectives enriched the direction of the book. Third, we are grateful to Alvaro Gonzalez Lopez, Sergio Escudero, Steve Melnick, and Pilar Trivelli, who contributed valuable expertise to the project.

Finally, special thanks to Samiah Do Carmo Figueiredo, Caterina Valles Galmès and Cécile Roure, who provided valuable administrative support.

Alica Daly, David Humphreys, Julio Raffo and Giulia Valacchi

FOREWORD

CARSTEN FINK

Chief Economist
World Intellectual Property Organization

BENJAMIN MITRA-KAHN

Chief Economist & General Manager
IP Australia

Innovations in mining do not make the same headlines as innovations in, say, electronics and cars. That is partly because it does not immediately lead to fancy new consumer products but, more deeply, it reflects a lack of appreciation for the importance of mining innovation. The productivity of extracting minerals from the earth has vastly improved since steam engines were introduced to clear water out of mines more than 200 years ago. The extraction and refinement of minerals now spans many fields of research and technology, from under-sea mining robots to chemical refinement methods. Raw mineral materials are at the root of industrial supply chains and the ability to supply ever-larger quantities of such materials has been a key contributor to the growth of the world economy. What's more, mining innovations have contributed to improved public health, by enhancing the safety of mining workers and limiting their exposure to harmful substances. Mining innovations have also reduced the adverse environmental impact of extraction activities, to which societies have rightly paid increasing attention.

Looking into the future, the importance of mining innovation will be no less important. With growing populations and growing economies, the demand for mineral products is set to increase. New “upstream” technologies generate new demands for certain minerals – such as lithium for battery-powered vehicles. Yet digging minerals from the earth is getting harder. The quality of existing mineral reserves is declining, rendering their extraction more difficult and complex. At the same time, the need to protect the environment and prevent climate change has become an even greater imperative. Technological innovation holds the key to addressing these challenges. There is promising potential in a number of technology fields relevant to mining, ranging from

mechanical engineering to biotechnology. New digital technologies promise to take the automation of mining tasks to a new level.

Opportunities for technological progress are hard to predict. Only time will tell how successful future mining innovations will be in raising mining productivity. There is an important role for governments in shaping the innovation ecosystem in which opportunities for technological progress are realized. Companies operating in the mining sector are at the forefront of innovation. Their incentives to innovate depend on a wide range of policies, including the tax treatment of R&D investments, the protection of intellectual property rights, environmental regulations, and safety standards. In addition, companies draw on knowledge generated by academia and specialized research institutes, many of which are publicly funded.

Charting a government strategy in support of mining innovation requires solid evidence on the effectiveness of different policy approaches as well as their wider pros and cons. Unfortunately, just as mining innovation itself is under-appreciated, there is a dearth of economic research for policymakers to use as an empirical basis for decision-making. It is with this background in mind that IP Australia and WIPO joined forces in 2017 to contribute to a better understanding of the nature and drivers of mining innovation. Patent data offered an obvious entry point to study mining-related technologies, but it soon became clear that a broader approach was needed to study this field of innovation. In addition, other countries expressed interest in pursuing this line of research, leading to a set of studies that eventually gave rise to this edited book volume. Anyone interested in the multifaceted dimensions of mining innovation will find this book worthwhile reading. We hope that policymakers in particular will draw inspiration from the evidence presented in the various chapters to promote policies that contribute to vibrant mining innovation and, ultimately, to a more productive mining sector that supports economic growth as well as broader societal objectives.