Exploration funding and the mineral investment climate

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ABSTRACT

This study analyzes how sensitive exploration funding is to investment climate changes. The paper conducts a separate analysis of different types of exploration funding: (i) total and grassroots exploration; (ii) directed towards specific minerals exploration targets (gold, base metals, and diamonds); and (iii) divided by funding origin country. The sensitivity of exploration budgets to investment climate depends on targeted minerals or metals. Adequate investment conditions bring in more of total and grassroots exploration for gold and base metals. Total exploration for diamonds is not affected by the investment conditions, while grassroots exploration for diamonds is negatively correlated with the investment climate. The study of top three exploration funding countries demonstrates that the Canadian mining companies are sensitive to investment environment in host countries, while exploration budgeting of the Australian and UK companies is not linked to investment climate. The Canadian and Australian companies allocate more of exploration funds to countries in geographical proximity, while the UK companies invest more in distant countries. Paper findings will be useful for host countries and mining companies making exploration budgeting decisions.

Keywords: minerals exploration funding, investment climate, grassroots exploration, exploration targets

INTRODUCTION

For mineral producing countries, exploration investments are important for future global competitiveness. In a recent paper (Khindanova, 2011), the author examined impacts of geological potential and investment climate on obtaining exploration funding. The paper showed that, beside of the geological potential, investment climate is an important factor for exploration. Harsher investment conditions might cause mining companies to move elsewhere. Jara, Lagos, and Tilton (2008) suggest that mineral exploration expenditures are more responsive to changes in investment conditions, comparing to mineral output or investment in new production capacity. Or, the exploration investments will "move" first. Jara, Lagos, and Tilton (2008) also find that grassroots exploration expenditures for specific metals, not a country's total exploration, immediately respond to investment climate transformations. This work analyzes how sensitive exploration funding is to investment environment changes. It considers grassroots exploration budgets and specific minerals exploration targets (gold, base metals, and diamonds), while the previous study, Khindanova (2011), analyzed total exploration investments. The current paper also investigates whether there are variations in the exploration target and location decisions among funding countries.

Chender (2009) points to one of current challenges facing exploration – "the need to better justify spending". It requires more scrupulous target decisions. The paper's results on sensitivity of exploration target funding to investment conditions will be useful for host countries and for mining companies making exploration target selections.

The paper is based on the previous works on minerals exploration and resource seeking Foreign Direct Investment by Johnson (1990), Eggert (1992 and 2008), Otto (1992a and 1992b), Dunning (1998), Bullington (1999), Campos and Kinoshita (2003), the Fraser Institute (2006), Buckley et al. (2007), UNCTAD (2007), Jara, Lagos, and Tilton (2008), and Khindanova (2011). Similarly to these works, this study includes two major factors of exploration investments: geological potential and investment environment. Some companies might prefer to invest locally or in neighboring countries despite attractive global geological potential and investment climate. The paper considers the third factor – geographical proximity of exploration locations to funding countries. The population variable is added to take into account countries' sizes. The analysis uses land areas as an indicator of geological potential and the Index of Economic Freedom of the Heritage Foundation and the Wall Street Journal as a measure of investment climate.

The paper is organized in the following way: the data description is provided in the second section; sensitivity of exploration to investment climate changes is estimated in the third section; main findings are summarized in the fourth section.

DESCRIPTION OF DATA

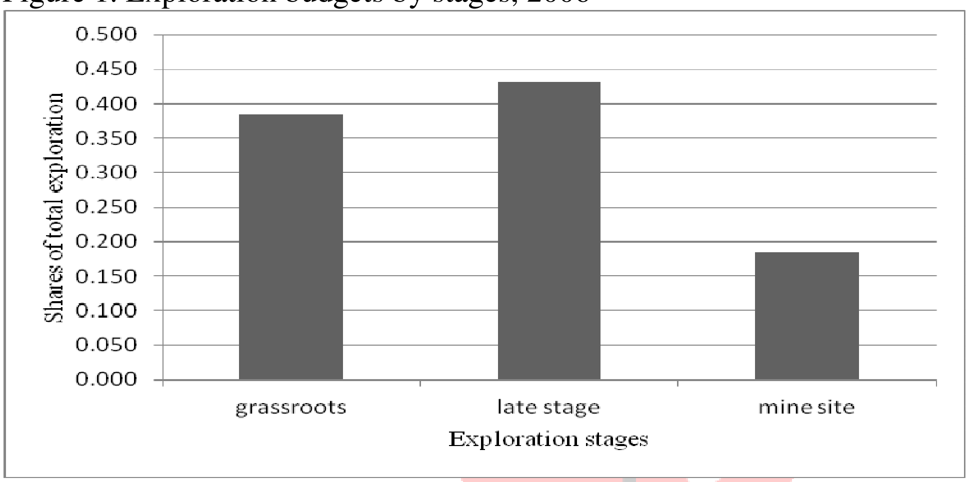
This section provides a description of the data on exploration investments, indicators of the geological potential and investment climate, population, and distances.

Exploration budgets data are from the Corporate Exploration Strategies 2006 Study by the Metals Economics Group[1] (MEG, 2006). The analysis uses the numbers for three major exploration targets (gold, base metals, and diamonds) in 103 countries. Total exploration

[1] The Metals Economics Group is considered to be "the most reliable source of exploration data for the mineral sector" (Jara, Lagos, and Tilton, 2008). The MEG data were also used in Khindanova (2011).

investments of considered countries amount to about 98% of the reported worldwide exploration funding in 2006. The paper uses MEG's definition of the *grassroots* stage - the beginning exploration stage, perimeter drilling, and the quantification of initial mineral deposit (MEG, 2006). The *late stage* exploration further quantifies and defines an identified ore body and conducts the feasibility study, up to a production decision. The *mine site* exploration means exploration at or immediately around operating sites or projects pledged to develop. Figure 1 shows distribution of exploration budgets of the included mining companies by different explorations stages in 2006: grassroots – 38.41%, late stage – 43.18%, mine site – 18.41%. The late stage exploration budgets exceed the grassroots and mine site budgets. This paper focuses on the grassroots exploration funds. The top ten destinations with largest grassroots investments were Canada, Australia, United States, Russia, Mexico, Brazil, Peru, Brazil, Chile, and China. These 10 countries accounted for 72.19% of the worldwide grassroots exploration.

Figure 1. Exploration budgets by stages, 2006

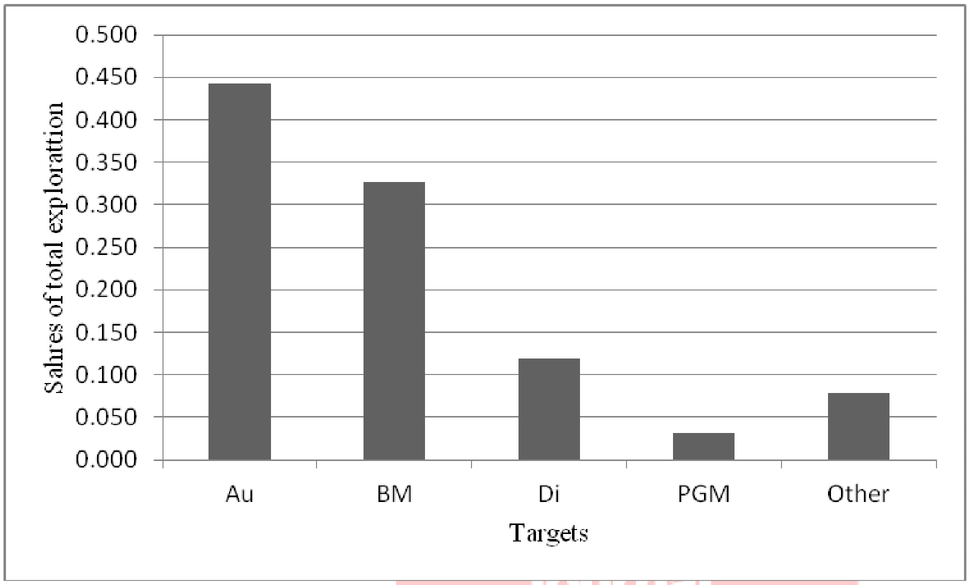


Data source: MEG, 2006

Figure 2 illustrates allocations for specific minerals exploration targets in 2006. Shares of total exploration are calculated with respect to the total exploration investments in 103 countries covered in the analysis. The figure uses the following target abbreviations: Au – gold, BM – base metals, Di - diamond, PGM – platinum group metals, Other – Other metals. The gold exploration allocations (44.35%) are the largest across the exploration targets allocations, while the base metals allocations (32.68%) are the second largest, followed by the diamonds exploration allocations (11.97%). Top ten countries with largest gold exploration investments were Canada, Australia, United States, Russia, Mexico, China, Peru, Brazil, and Argentina. Top ten countries with largest base metals exploration budgets were Canada, Australia, Mongolia, United States, Peru, Brazil, Chile, Mexico, and Russia. Top ten countries with largest diamonds exploration funds were Canada, South Africa, Angola, Botswana, Russia, Democratic Republic of Congo, Sierra Leone, Brazil and Australia.

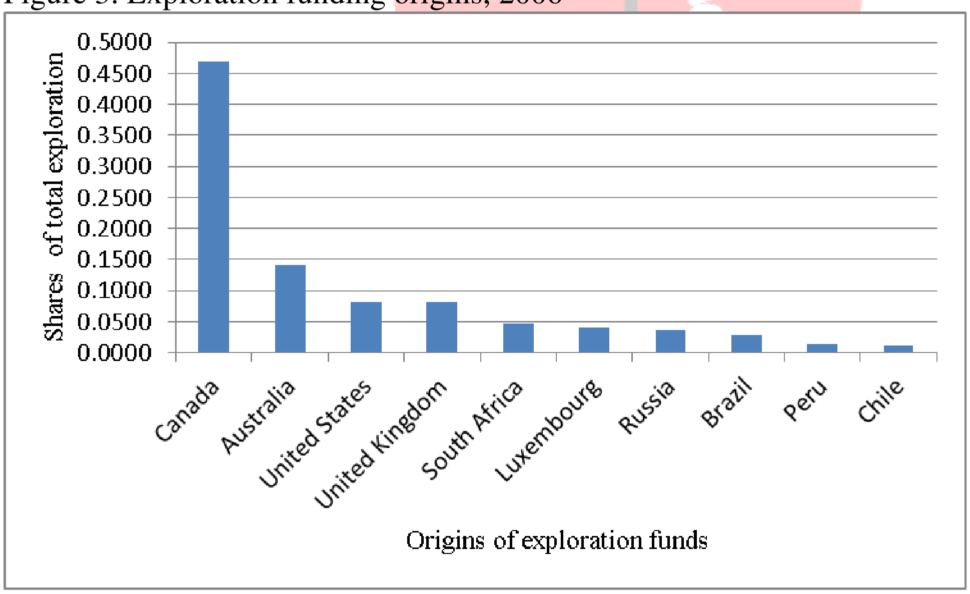
Exploration funds for analyzed 103 countries were provided by 34 countries. Six countries allocated funds for investments abroad only, 12 countries planned investments only at home, remaining 18 countries budgeted investments at home and abroad. Figure 3 displays top 10 countries ranked by exploration funding origin, determined by companies' headquarters locations. These 10 countries accounted for 95.34% of the total exploration budgets in 2006.

Figure 2. Exploration Budgets by Targets, 2006



Data source: MEG, 2006

Figure 3. Exploration funding origins, 2006



Data source: MEG, 2006

Canada stood out with a 47.03% contribution of worldwide exploration budgets. The Canadian mining companies invest more in exploration abroad (62%) than at home (38%). In contrast, Australia, the second-ranked country by exploration funding, planned larger proportion of funds (55%) for investments at home and 45% - for investments abroad. Interestingly, the UK mining companies planned only 0.07% of funds for home exploration, and 99.93% - for overseas.

In the analysis, I employ land areas as an indicator of the mineral potential. Land areas were used as measures of geological and natural resource potential in (Johnson, 1990), (Sachs and Warner, 1995), (Stijns, 2005), (Birdsall et al, 2001), (Khindanova, 2011). The countries' land areas were downloaded from the “World Development Indicators 2005” database (World Bank, 2005). For several countries, the land areas numbers are from the “The World Factbook 2005” database compiled by the Central Intelligence Agency (CIA, 2005). I use the Index of Economic Freedom as a measure of the investment environment. The index is constructed by Heritage Foundation and the Wall Street Journal. It fluctuates between 0 and 100. The larger value of the index implies better economic freedom conditions (Heritage Foundation and the Wall Street Journal, 2009). The paper uses the 2005 values of the index of economic freedom. To account for economies’ sizes, I add the population factor. The population numbers are from the “World Development Indicators 2005” database. For several countries, the population data are from “The World Factbook 2005” database (CIA, 2005).

I incorporate an additional variable into an analysis of investments decisions by the funding countries – the geographic proximity of the funding country to the recipient country, measured by distances between capital cities of two countries, in kilometers. The distance data are from HappyZebra.com, a website for travel information and tools.

ESTIMATION OF SENSITIVITY OF MINERAL EXPLORATION FUNDING TO INVESTMENT CLIMATE

This section analyzes the sensitivity of exploration funding to changes in investment climate. I consider total and grassroots exploration; specific minerals exploration targets (gold, base metals, and diamonds); and funding origin country, determined by companies’ headquarters locations. The models for countries receiving exploration investments have the exploration funding as the dependent variable, and geological potential, investment climate, and population as explanatory variables. The models for funding countries add distance between the funding and receiving countries as the fourth explanatory variable. I use logarithms of exploration budgets, population, and distances to condense their substantial differences across countries, following works on foreign direct investments by Bullington, 1999; Cheng and Kwan, 2000; Wei, 2000; Buckley et al, 2007.

Log-linear model of exploration investments for receiving countries[2]:

$$lexploration_i = c + b_1 geology_i + b_2 investment_i + b_3 lpopulation_i + \varepsilon_i , \qquad (1)$$

here $lexploration_i = ln(exploration_i)$, $exploration_i$ is total and grassroots exploration investments directed to country i; $geology_i$ is the mineral potential measure for country i; $investment_i$ is the investment environment measure for country i, $lpopulation_i = ln(population_i)$, $population_i$ is the population of country i, $\varepsilon_i \sim N[0, \sigma^2]$, i denotes a receiving country, $i = 1, \ldots, 103$. I estimate model (1) using log-transformed land areas (*lland*) and the index of economic freedom (*econfreedom*):

$$lexploration_i = c + b_1 lland_i + b_2 econfreedom_i + b_3 lpopulation_i + \varepsilon_i \quad . \qquad (2)$$

Results of the model (2) regressions for total and grassroots exploration funds are reported in Table 1. The adjusted R^2 values are 0.477 and 0.493 for total and grassroots exploration,

[2] Model (1) was also used in Khindanova (2011).

respectively. The statistically significant coefficients in Table 1 are shown in the bold font. In both regressions, the coefficient of geological potential (land areas) is significant and positive, implying that geological potential is an important factor for both total and grassroots exploration investments and that better geological potential attracts more of exploration investments. The coefficient of investment conditions is positive and significant for total exploration budgets at the 2.92% significance level and insignificant for grassroots exploration. The results confirm a conclusion in (Khindanova, 2011) that total exploration investments are sensitive to countries' investment climate. This paper determines the overall grassroots exploration funding is not sensitive to investment environment. The country size (measured by country's population) does not play a significant role for total explorations but is a factor for grassroots exploration.

Table 1. Model 2 estimation results for total and grassroots exploration funds*

Explanatory variables	Dependent variable – exploration budgets	
	Total	Grassroots
Constant	**-11.724** (-7.748)	**-12.545** (-8.219)
lland	**1.009** (7.959)	**1.071** (9.080)
econfreedom	**.031** (2.213)	0.021 (1.404)
lpopulation	-0.184 (-1.384)	**-0.310** (-2.676)
Number of observations	103	98
Adjusted R^2	0.477	0.493

* The numbers in parentheses are t-statistics of the model (2) coefficients estimates. The t-statistics were calculated with the White heteroskedastisity consistent standard errors.

Jara, Lagos, and Tilton (2008) suggest that grassroots exploration expenditures for specific metals, not total exploration, react to investment climate changes right away. The paper examines whether sensitivity of total and grassroots exploration to investment climate depends on targeted metals and minerals. I run regressions of model (2) for total and grassroots exploration budgets targeting gold, base metals, and diamonds[3]. Results of those regressions are provided in Tables 2 and 3, respectively. The gold, base metals, and diamonds exploration investments account for about 89% of the 2006 total exploration budgets. Gold exploration was

Table 2. Model 2 estimation results for total exploration targeting specific minerals*

Explanatory variables	Dependent variable – total exploration target budgets		
	Gold	Base metals	Diamonds
Constant	**-9.670** (-5.666)	**-14.151** (-8.054)	**-8.538** (-2.447)
lland	**0.720** (4.842)	**1.046** (6.797)	**0.958** (3.190)

[3] There were not enough data to model explorations targeting platinum group metals.

econfreedom	**0.042** (2.683)	**0.045** (2.888)	-0.028 (-1.038)
lpopulation	-0.050 (-0.273)	-0.219 (-1.346)	**-0.514** (-1.657)
Adjusted R^2	0.295	0.474	.174
Number of observations	93	74	31

* The numbers in parentheses are t-statistics of the model (2) coefficients estimates. The t-statistics were calculated with the White heteroskedastisity consistent standard errors.

conducted in 93 countries, exploration of base metals – in 74 countries, and diamonds exploration – in 31 countries. The adjusted R^2 values in Table 2 for gold, base metals, and diamonds are 0.295, 0.474, and 0.174, respectively. In all three exploration target regressions, the coefficient of geological potential (land areas) is significant. Similarly to total exploration, target explorations increase with a better geological potential. The investment climate is statistically significant for gold and base metals exploration, and is insignificant for the total diamonds exploration. The diamonds exploration is driven mainly by the geological potential. The country size (population) does not play a role for the gold and base metals exploration but is significant for the diamonds exploration at the 10.91% significance level. The positive sign of the geological potential coefficient and the negative sign of the population coefficient indicate that a substantial proportion of diamonds exploration goes to countries with higher per capita geological potential.

The grassroots exploration for gold, base metals, and diamonds was carried out in 86, 68, and 28 countries, respectively. The adjusted R^2 values in Table 3 for the targets are 0.334 (grassroots gold exploration), 0.488 (grassroots base metals exploration), and 0.172 (grassroots diamonds exploration). As for total exploration, in all three targets grassroots exploration regressions, coefficient of geological potential is statistically significant. Investment climate is positively associated with the gold and base metals grassroots exploration, and negatively correlated with the diamonds grassroots exploration at the 10.41% significance level. The negative sign of the index of economic freedom coefficient in the grassroots diamonds exploration regression indicates that companies conduct significant proportion of grassroots diamonds exploration in countries with inadequate investment climate. The t-statistics of population in Table 3 suggest that the country size does not influence the gold and diamonds grassroots exploration funds but affects the base metals grassroots exploration budgeting. These findings imply that enhancements in geological potential will result in increased grassroots exploration of all three analyzed targets: gold, base metals, and diamonds. Improvements in investment climate will bring in more of gold and base metals grassroots exploration.

Table 3. Model 2 estimation results for grassroots exploration targeting specific minerals*

Explanatory variables	Dependent variable – grassroots exploration target budgets		
	Gold	Base metals	Diamonds
Constant	**-10.580** (-6.406)	**-13.987** (-7.895)	**-7.324** (-2.078)
lland	**0.790** (5.796)	**1.051** (7.388)	**0.864** (3.013)
econfreedom	**0.031**	**0.035**	**-0.037**

	(2.176)	(2.306)	(-1.689)
lpopulation	-0.166 (-0.988)	**-0.372** (-2.690)	-0.418 (-1.405)
Adjusted R^2	0.334	0.488	.172
Number of observations	86	68	28

* The numbers in parentheses are t-statistics of the model (2) coefficients estimates. The t-statistics were calculated with the White heteroskedastisity consistent standard errors.

The paper studies if the worldwide exploration target and location decisions vary among top funding countries. I consider three explanatory variables of model (2) and an additional variable – distance between funding and receiving countries:

$$lexploration_{ij} = c + b_1 lland_i + b_2 econfreedom_i + b_3 lpopulation_i + b_4 ldistance_{ij} + \varepsilon_{ij} \quad . \qquad (3)$$

where $lexploration_{ij} = ln(exploration_{ij})$, $exploration_{ij}$ is exploration investments in country *i* funded by country *j*; *geology* is the geological potential measure; *investment* is the investment environment measure, $lpopulation_i = ln(population_i)$, $ldistance_{ij} = ln(distance_{ij})$ is the log-transformed distance between countries *i* and *j*[4], $\varepsilon_{ij} \sim N[0, \sigma^2]$, *i* denotes a receiving country, *j* represents a funding country. In the analysis of funding countries, I examine exploration investments abroad[5]. The results of model (3) regressions for three top overseas funding countries (Canada, Australia, and United Kingdom)[6] are provided in Table 4. These three countries accounted for 69.21% of the total exploration budgets in 2006. Canadian mining companies allocated budgets for exploration in 74 foreign countries, Australian companies – in 57 countries, the U.K. companies – in 59 countries. The geological potential and distance coefficients are significant in the Canadian, Australian, and UK regressions. The negative signs of the distance coefficient in the Canadian and Australian regressions suggest that the Canadian and Australian mining companies prefer to conduct exploration in geographical proximity. The investment climate (index of economic freedom) is significant only for the Canadian mining companies. The country size (population) coefficient is insignificant in three regressions. Thus, the three top funding countries invest more in countries with better geological potential. The Canadian and Australian companies invest more in countries which are closer geographically. The UK mining companies do not mind explorations in distant countries. The investment climate matters for the Canadian companies but does not play a role for the Australian and UK companies. The three countries are not concerned with host countries sizes.

Table 4. Model (3) estimation results for total exploration budgets of top three funding countries*

Explanatory variables	Dependent variable – total exploration budgets		
	Canada	Australia	UK
Constant	-3. 440 (-1.234)	3.886 (0.756)	**-11.630** (-5.848)
lland	**0.722**	**0.480**	**0.423**

[4] Distances between countries are measured by distances between capital cities of the countries.
[5] Thus, receiving country *i* is different from funding country *j*.
[6] The funding origins were determined by companies' headquarters locations.

	(5.162)	(2.496)	(2.734)
econfreedom	**0.036** (2.485)	-0.007 (-0.337)	0.021 (1.257)
lpopulation	-0.047 (-0.267)	0.042 (0.211)	0.048 (0.364)
ldistance	**-0.651** (-2.475)	**-0.939** (-2.318)	**0.700** (3.315)
Adjusted R^2	0.352	0.206	.372
Number of observations	74	57	59

* The numbers in parentheses are t-statistics of the model (2) coefficients estimates. The t-statistics were calculated with the White heteroskedastisity consistent standard errors.

An analysis of host countries' exploration investments showed that total exploration investments are sensitive to countries' investment climate, while grassroots exploration investments are not. The paper investigates whether the funding countries grassroots and total exploration decisions differ. Results of model (3) regressions for grassroots explorations by Canada, Australia, and the UK are presented in Table 5. The geological potential is significant for the three countries' grassroots exploration budgets. The investment climate matters only for the Canadian mining companies at the 11.13% significance level. The country size does not influence grassroots exploration funding by the countries. The proximity to destination countries plays a role for grassroots exploration decisions by Canada and the UK. The Canadian companies allocate more grassroots exploration budgets for neighboring countries but the UK companies invest more in faraway countries. The Australian companies' grassroots exploration decisions are not affected by distance.

Table 5. Model (3) estimation results for grassroots exploration budgets of top three funding countries*

Explanatory variables	Dependent variable – grassroots exploration budgets		
	Canada	Australia	UK
Constant	**-4.087** (-1.757)	1.331 (0.256)	**-11.319** (-5.902)
lland	**0.734** (5.105)	**0.494** (2.559)	**0.572** (4.075)
econfreedom	**0.024** (1.614)	-0.016 (-0.806)	0.015 (1.061)
lpopulation	-0.081 (-0.538)	-0.038 (-0.223)	-0.066 (-0.586)
ldistance	**-0.614** (-2.740)	-0.693 (-1.385)	**0.438** (2.119)
Adjusted R^2	0.357	0.149	.405
Number of observations	70	50	50

* The numbers in parentheses are t-statistics of the model (2) coefficients estimates. The t-statistics were calculated with the White heteroskedastisity consistent standard errors.

CONCLUSIONS

This study analyzes sensitivity of exploration funding to investment climate changes. The paper conducts a separate analysis of different types of exploration funding: (i) total and grassroots exploration; (ii) directed towards specific minerals exploration targets (gold, base metals, and diamonds); and (iii) divided by funding origin country. The analysis is based on a cross-country log-linear model of exploration budgets with investment climate, mineral potential, population, and distance as explanatory variables. The paper results show that better geological potential attracts more of the total and grassroots exploration investments. The investment climate is significant for total exploration and insignificant for grassroots exploration. An exploration target analysis shows that the sensitivity of exploration budgets to investment climate depends on targeted minerals or metals. Better investment conditions lead to higher total and grassroots exploration for gold and base metals. Total exploration for diamonds is not affected by the investment conditions, while grassroots exploration for diamonds is negatively correlated with the investment climate. The study of top three exploration funding countries demonstrates that the Canadian mining companies are sensitive to investment environment in host countries, while exploration budgeting of the Australian and UK companies is not linked to investment climate. The Canadian and Australian companies allocate more of exploration funds to countries in geographical proximity, while the UK companies invest more in distant countries. The paper findings will be useful for host countries and mining companies making exploration budgeting decisions.

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