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How "international" is international research collaboration?

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Abstract

In the context of the increasing global connectivity in science, this article investigates the internal heterogeneity of international research collaborations (IRCs). We focus on the prevalence of shared heritage collaborations and the rise of multiple institutional affiliations as a collaboration mechanism. An analytical typology of IRCs based on the characteristics of collaborating researchers' location and heritage is developed and empirically tested on the dataset of Russia's publications in 2015. We found that shared heritage IRC and IRC via multiple affiliations are the cornerstones of internationalization. Significant structural differences are revealed between conventional IRC and these nonconventional IRCs across fields of science, locations, visibility of international partners, and the sources of funding. These results contribute towards a better understanding of IRC as a complex, heterogeneous phenomenon, which encompasses a variety of arrangements for knowledge creation across borders. A more nuanced understanding of IRC is needed for smarter university strategy, metric development, and policymaking.

1 | INTRODUCTION

Researchers across the globe are more interconnected than ever before (Adams, 2013; Chinchilla-Rodríguez et al., 2018; Glänzel, 2001; Leydesdorff et al., 2013; Leydesdorff & Wagner, 2008, 2009; Luukkonen et al., 1992; Scellato et al., 2015; Wagner et al., 2019). With the massification of the scientific knowledge production enterprise (Rossi, 2010), the scale, scope, and dynamics of international research collaboration (IRC) are changing. A recent study found that it is international, not domestic collaborations that drive research output growth of European universities (Kwiek, 2021). For universities and countries that aim to internationalize, IRCs represent the resource and the driver of growth (Knobel et al., 2013; Postiglione, 2013). Yet, the new complexities of global connectivity and their effects on IRCs received less attention in the literature compared to other related phenomena, for example, team science (Bozeman & Youtie, 2017; D'Ippolito & Rüling, 2019; Youtie et al., 2017).

IRC research has long been plagued by inconsistent and sometimes contradictory findings. Previous critiques pointed primarily to issues with operationalizing IRC in bibliometric data or fallacies arising from untested assumptions regarding causality mechanisms (Chen et al., 2019; Glänzel, 2001; Katz & Martin, 1997; Laudel, 2002; Wagner et al., 2019). In this article, we argue that the growing internal heterogeneity of IRC networks imposes further conceptual and methodological issues on IRC analyses, likely aggravating the inconsistencies reported in previous studies. This article argues that at

least a part of the problem stems from the widespread assumptions regarding what constitutes a "conventional" form of IRC: excellence-driven international cooperation processes between countries and organizations, analyzed via co-publications of researchers, in their majority, as representatives of those countries (Chinchilla-Rodríguez et al., 2019; Hollanders, 2019; Leydesdorff et al., 2013; Leydesdorff & Wagner, 2008; OECD, 2017). As an approach to enable more nuanced analysis of IRC, we develop an analytical understanding of *nonconventional IRCs* and offer an empirical exploration of their prevalence and mechanisms, illustrating in particular their differences in juxtaposition with *conventional IRCs*.

In particular, two nonconventional forms of IRC are examined: shared heritage collaboration and IRCs via multiple affiliations. These IRCs encompass a variety of knowledge co-creation arrangements whose aims often transcend purely scientific goals (Hofman & Kramer, 2015; Tang, 2013; Welch & Zhen, 2008). These kinds of IRCs illustrate concerns that different IRCs pursue different goals, emerge for different reasons and lead to different outputs (Schubert & Sooryamoorthy, 2010). However, bibliometric IRC research has not sufficiently discussed these processes and their implications (Chen et al., 2019). We ask: how prevalent are *nonconventional IRCs* compared with *conventional IRCs*? Which characteristics of intellectual, social, and institutional organization of research influence the prevalence of *nonconventional IRCs* compared with *conventional IRCs*?

We focus on two kinds of *nonconventional IRC* in this article: shared heritage IRC and IRC via multiple affiliations. Shared heritage IRCs are built when collaborating researchers reside in different countries, but share heritage: their community of origin, the social and cultural context of their socialization into the scientific profession (Karaulova et al., 2019). Thus, heritage is a part of researchers' scientific and technical human capital (Corley et al., 2019). IRCs via multiple affiliations emerge when multiple affiliations of the author(s) is the only attribute that assigns an international status to a collaboration. The research on multiple affiliations is emerging, with ongoing debates regarding which processes in the research system are represented by their increase (Bachelet et al., 2019; Hottenrott et al., 2021; Lander, 2015).

This article draws in the empirical analysis of 39,448 publications of authors affiliated with organizations in Russia in 2015. Russia represents a fascinating case to explore the prevalence of nonconventional IRCs, because despite decades of brain drain, certain Russian research fields have remained internationally competitive, especially in physics. Taking advantage of the method to reliably distinguish Russian-named authors in international co-publications, we can analyze the structure of Russia's international collaboration with high degree of precision. The analysis identified internationally coauthored publications (ICPs) with a diaspora author, including those ICPs in which co-publications are assigned international status only because of an author's second affiliation. The influence of factors related to the fields of science, locations, visibility of international partners and funding sources are examined. This article opens up new ways to generate enhanced understandings of IRC as a complex and heterogeneous social phenomenon, calling for more nuance in IRC analyses.

2 | UNPACKING INTERNATIONAL RESEARCH COLLABORATION

2.1 | What is international research collaboration?

Research collaboration is a fundamental activity in science. When scientists collaborate, they pool their skills, knowledge, know-hows, and resources to work towards a common goal (Bozeman & Boardman, 2014). The combined effort enables them to tackle more complex or interdisciplinary issues, conduct larger-scale experiments, or simply do research more efficiently. Collaboration is defined as "international" when scientists work across national borders. Collaborated research is thus the outcome of a social process with aggregated effects on meso (organizational) and macro (national) levels. It is analyzed in bibliometric datasets via coauthored publications. Previous studies identified three areas where IRCs show distinctive characteristics: generative mechanisms, outputs, and their meso- and macro-level effects.

2.1.1 | Generative mechanisms

A key motivation of IRCs is shared scientific interest. In addition, their emergence is shaped by various social and institutional forces, as well as the existing power dynamics in the global research system. IRCs tend to be more costly to establish and sustain, because researchers encounter technical, communication, resource, cultural, administrative, and language barriers (Cetina, 1999; Gaulé & Piacentini, 2013; Stahl et al., 2010). Researchers typically require clear incentives for IRC, such as access to unique data, materials, expertise, or research infrastructure (Bozeman & Corley, 2004; Corley et al., 2006; Karaulova et al., 2020; Melkers & Kiopa, 2010; van Rijnsoever et al., 2008). IRCs are often considered "elite" collaborations

involving resource- and reputation-endowed researchers (Luukkonen et al., 1992). Researchers from peripheral countries seek collaborations with highly visible scientists to improve their own visibility (Gazni et al., 2012; Glänzel, 2001; Hwang, 2008; Leydesdorff & Wagner, 2008; Li et al., 2013; Wagner & Leydesdorff, 2005).

Path dependence is another generative mechanism of IRC: researchers sometimes continue collaboration after one of them moves to a different country, thanks to the benefits of ongoing productive relationships (Celis & Kim, 2018; Eduan, 2019). Such benefits outweigh the costs imposed by the distance. IRC is more likely to emerge between researchers from institutions with lasting ties, reflecting the importance of institutional opportunities and incentives for collaboration (D'Ippolito & Rüling, 2019). Geographic and historical proximity also influence IRC dynamics (Fu & Li, 2016; Heringa et al., 2016; Luukkonen et al., 1993).

2.1.2 | Outputs

Although ICPs are fewer in number than domestically coauthored publications, they are more likely to be published in journals with higher impact factor and are more likely to be highly cited (Bozeman & Corley, 2004; Confraria et al., 2017; Narin et al., 1991). Authors participating in IRCs tend to be more productive (Zhang et al., 2018; Zhou & Tian, 2014), which is partially attributed to the higher visibility of IRC research outputs and the above-average reputation of collaborating researchers (Parker et al., 2010; Wagner et al., 2019). Bozeman and Corley (2004) suggested that scientists would be likely to collaborate internationally on topics that they find particularly important and worth investing resources in. Such efforts would be more likely to result in higher quality outputs. Others discussed the influence of knowledge and resource recombination on the likelihood of IRCs to produce more novel or radical research (Hird & Pfotenhauer, 2017; Muriithi et al., 2018; Youtie et al., 2017). Cultural diversity of collaborators also likely plays a role, enhancing creativity and novelty of research outputs (Heinze et al., 2009; Lee et al., 2015).

2.1.3 | Meso- and macro-effects of IRC

Organizations and countries benefit from the flows of knowledge, people, and technology in IRC networks (Agrawal et al., 2011; Saxenian, 2007). Internationally coauthored publications play a significant role in determining universities' positions in league tables, incentivizing universities to promote IRCs (Souto-Otero & Enders, 2017). IRCs also generate non-research effects, directly or indirectly, such as development and international security (Flink & Schreiterer, 2010; Lepori et al., 2015). Occasionally, non-research effects are the priority goal of IRCs (Meyer, 2008; Séguin et al., 2006).

Despite the broad consensus on distinctive IRC characteristics, inconsistencies in reported results have accumulated over the past three decades of bibliometric research. Contradictory findings related to citation performance, visibility, novelty, and researcher productivity in IRCs have been noted (Chen et al., 2019; Duque et al., 2005; Glänzel, 2001; Guerrero Bote et al., 2013; Harirchi et al., 2007; Hayati & Didegah, 2010; Leimu & Koricheva, 2005; Wagner et al., 2019).

These inconsistencies can be attributed to several factors, including the discrepancy between the social reality of IRC and its measurement via a simple co-publication metric (Katz & Martin, 1997; Laudel, 2002); variations in empirical contexts, over time and across disciplines (Eduan, 2019; Guerrero Bote et al., 2013); differences in methodological choices in the bibliometric analyses. Additionally, internal heterogeneity must also play a role: if different kinds of IRC are underpinned by different knowledge creation arrangements and are driven by different mechanisms, then it is reasonable to expect that these IRCs will produce different outputs and perhaps even lead to differential scientific and societal outcomes compared to what is assumed or reported. Thus, analyses that use a simplistic blanket IRC metric are inadequate for capturing the full range of IRC mechanisms and effects. Nevertheless, a systematic examination of internal heterogeneity of IRC is still lacking. In the next section, we elaborate on some of the potentially significant differences by distinguishing between *conventional IRC* and *nonconventional* types of IRC.

2.2 | Shared heritage IRC and IRC via multiple affiliations

Shared heritage IRCs are built when collaborating researchers reside in different countries, but share heritage: their community of origin, the social and cultural context of their socialization into the scientific profession (Karaulova et al., 2019). Recently Corley et al. (2019) argued that identity and background constitute a part of researchers' scientific and technical human capital, because identity directly influences available opportunities, their decisions and, ultimately, research productivity, performance, and career development. Shared heritage could stem from shared ethnicity, but not necessarily, and it is therefore a more inclusive term. We use the term "heritage" to highlight the

influence of cognitive and cultural proximity of authors in IRCs. Scientists with shared heritage often speak the same language, have similar tacit knowledge, norms and working practices, and are embedded in overlapping networks.

Shared heritage collaborations are fairly common, because researchers tend to gravitate to others like themselves (Celis & Kim, 2018; Freeman & Huang, 2015; Tanyildiz, 2015; Zhang et al., 2018). Shared heritage can offset some of the barriers typical for IRC by enhancing mutual understanding and trust. In the study by Welch and Zhen (2008), interviewees with Chinese heritage appreciated "*the relative ease and familiarity of dealing with other Chinese*." Diaspora researchers who reside outside their country of origin can act as matchmakers, mediators, and interpreters in IRCs, helping navigate cultural and language barriers, or as gatekeepers, managing knowledge networks (Jin et al., 2007; Tang & Shapira, 2011). The connecting role of diaspora scientists may be particularly important for peripheral countries who wish to pursue internationalization but are not preferred IRC partners for the core group (Leydesdorff & Wagner, 2008). Shared heritage IRCs are often multidimensional and include activities beyond research, such as teaching, training, and technology transfer (Agrawal et al., 2011; Hofman & Kramer, 2015; Kerr, 2008; Marmolejo-Leyva et al., 2015; Saxenian, 2007). Policy initiatives support and promote these collaborations (Meyer, 2008).

Our second point of interest is the growing number of IRCs mobilizing multiple affiliations as the collaboration mechanism (Bachelet et al., 2019; Hottenrott & Lawson, 2017; Huang & Chang, 2018; Kanavakis et al., 2006). Prevalence of multiple affiliations varies across disciplines and countries: for example, Hottenrott and Lawson (2017) found more researchers with multiple affiliations based in the UK and US compared to Germany or Japan.

Researchers with multiple affiliations can signal strong institutional ties or reflect mobility (Cattaneo et al., 2019). Here, multiple affiliation can be both an expression of, and an antecedent to research collaboration (Sanfilippo et al., 2018). Alternatively, some multiple affiliations are driven by strategic decisions to maximize research metrics (Bachelet et al., 2019). Kosyakov and Guskov (2019) found that in the case of Russia, a significant share of multiple affiliations are not underpinned by any meaningful IRC and are only the result of capitalization on scientific credit. Hottenrott et al. (2021) reported that multiple affiliations increase after countries enact research performance-based excellence initiatives.

Analyses of these two *nonconventional* forms of IRC have typically not been conducted in juxtaposition with *conventional IRC*. Conventional IRC analyses typically make several key assumptions that affect their results interpretation. Frequently, collaborating researchers are seen as proxies for collaborating countries or institutions (Abramo et al., 2011; Gazni et al., 2012; Hoekman et al., 2010; Leydesdorff et al., 2013). The differences in collaboration strategies and mechanisms of different kinds of researchers residing in these countries and institutions has rarely been contextualized or operationalized. This could lead to some misleading assumptions and conclusions. For example, OECD (2011) defines researchers from developing countries "local researchers." They collaborate with researchers from developed countries, who are called simply "researchers," indicating both assumptions about heritage and asymmetric nature of collaboration.

These assumptions do not always hold true. For example, Tang (2013) found that in the early years of China's internationalization over 99% of researchers who coauthored nanotechnology publications with authors in China had Chinese family names, indicating their Chinese heritage. Next, we expose the breadth of internal heterogeneity of IRC and explicate the cases where assumptions of conventional IRC do not hold when tested for nonconventional IRCs.

2.3 | A typology of international research collaborations

In order to unpack the heterogeneity in IRC, we develop an analytical typology of shared heritage IRC. A classification of researchers is proposed in the first step (Table 1). Since diaspora researchers can play different roles in collaborations, the typology reflects these combinations. A researcher can be located in the country of origin (i.e., "home") or not (i.e., "abroad") (rows in Table 1). Researchers may also have "local" heritage of the country of origin or a foreign heritage (columns in Table 1). Intersecting these dimensions, four types of researchers emerge. *Domestic researchers* are "local" heritage researchers who reside in their country of origin ("home"). *Diaspora researchers* are "local" heritage researchers who reside outside of their country of origin ("abroad"). "Foreign" heritage researchers who reside in the local country ("home") are *immigrant researchers*. All others are *international researchers* because they do not have the heritage of the "local" country, nor do they reside in the "home" country.

The second layer of the typology is differentiation between IRC types based on the combinations of the researchers involved in them (Table 2). *National* collaborations include researchers within the country. These collaborations can be domestic, that is, involving domestic researchers only, or diverse if they also involve immigrant

TABLE 1 Types of researchers by heritage and location.

		Heritage of the country of origin	
		Local	**Foreign**
Current Location	Home	Domestic researchers	Immigrant researchers
	Abroad	Diaspora researchers	International researchers

TABLE 2 Types of collaboration based on location and heritage of researchers.

Type of collaboration		**Type of researchers included**			
Type	**Sub-type**	**Domestic**	**Diaspora**	**Immigrant**	**International**
National	Domestic	Yes	No	No	No
National	Diverse	Yes	No	Yes	No
Conventional IRC	Conventional IRC	Yes	No	No	Yes
Nonconventional IRC	Transnational IRC	Yes	Yes	No	No
Nonconventional IRC	Diaspora mediated IRC	Yes	Yes	No	Yes
Nonconventional IRC	Immigrant mediated IRC	Yes	No	Yes	Yes
Nonconventional IRC	Extra heritage IRC	No	No	Yes	Yes
Nonconventional IRC	Other	All other combinations not listed above			

researchers. Diverse collaborations are not international, but they could constitute a significant minority in national collaboration networks (Rubin & O'Connor, 2018), especially in countries with inflows of foreign-born researchers.

Among international collaborations, IRC between domestic researchers and international researchers are labeled *conventional IRC* in the typology as per discussions above. We collectively label other forms as *nonconventional IRC* and further distinguish between them based on author combinations. Shared heritage collaboration, in this view, consists at least of two kinds of author combinations. IRCs only between researchers with shared heritage, that is, domestic researchers and diaspora researchers, are *transnational IRCs*. Immigrant researchers can be involved in similar types of transnational collaborations, with the reverse focus on their country of origin. Immigrant or diaspora *mediated IRCs* have mixed heritage teams of domestic, international and diaspora researchers. Immigrant researchers will likely have other collaborations with various international authors, which we call *extra heritage IRC*. Additionally, IRCs involving immigrant and foreign researchers can create various configurations of residence and heritage resulting in fascinating combinations, but they remain outside of this article's scope.

Of the various types of collaboration in our typology, some might be more prevalent than others in certain contexts. For instance, in research systems with high inward migration such as the United Kingdom and United States, *immigrant mediated IRC* and *extra heritage IRC* will be highly represented, while in other research systems with high outward migration such as Russia and China, *transnational IRC* and *diaspora mediated IRC* might be more prevalent and important.

Multiple affiliations can be found across the collaboration types. They are one of the mechanisms used to build an IRC. In this article, we examine instances where multiple affiliation is the only attribute that assigns an international status to the publication. For example, this includes publications that would otherwise be "National" (domestic only), but are indexed as an ICP, because one or more authors have a second affiliation abroad.

2.4 | Characteristics of nonconventional IRCs

With the typology in place, we now explore the internal heterogeneity of IRC. In this section, we formulate a range of expectations regarding the prevalence and some of the distinguishing characteristics of the two forms of *nonconventional IRC* compared to *conventional IRC*.

Our first expectation is that the share *nonconventional IRC* should be increasing alongside with the global volumization of scientific knowledge. Scientific mobility is increasing faster than ever before (Chinchilla-Rodríguez et al., 2018; Robinson-Garcia et al., 2019; Scellato et al., 2015) and mobile researchers are likely to maintain IRCs with countries where they worked previously (Edler et al., 2011; Hoekman et al., 2010; Sugimoto et al., 2017; Trippl, 2013; Yang & Welch, 2010). Furthermore, certain

policies incentivize specifically scientific diaspora engagement (Meyer, 2008; Tejada et al., 2013). Even though the share of *nonconventional IRC* will likely vary across countries, we propose that:

> **H1.** *Nonconventional IRCs* constitute a significant share of a country's IRC volume.

Next we discuss the influence of scientific fields, focusing on two factors: the extent to which the field is internationalized and the national capacity of a collaborating country.

In certain types of "big science," access to large-scale experimental facilities is organized around stable long-term IRCs (Karaulova et al., 2020). In other fields, the nature of scientific problems and resources needed to address them do not necessarily require an IRC. A country may attract international interest if its local resources are essential for research, for example, patient data of tropical diseases. Thus, if research fields with cross-national or cross-sectoral resources, scientists will be more likely to use MAs to secure access. Since these fields are concentrated mainly within physics/astronomy and life sciences, we propose that:

> **H2a.** *IRCs* via *multiple affiliation* will be more associated with the domains of physics and life/medical sciences than *conventional IRCs*.

In terms of national strength in research, countries tend to specialize (Abramo et al., 2022). If national research system is internationally competitive in a certain field, researchers from this country will be able to secure jobs abroad, leading to the formation of scientific diasporas. Diaspora researchers have interest to enter IRCs with their home country, because of lower barriers to initiating IRCs due to shared language, cultural norms, and lingering ties. Therefore:

> **H2b.** *Transnational and mediated IRCs* are more associated with research fields with strong knowledge base in the home country than *conventional IRCs*.

Funding is a key enabler for resource-intensive IRCs. Researchers' collaboration-seeking behavior can be significantly influenced by organizational incentives and steering (Gök et al., 2016). *Nonconventional IRCs* are supported by dedicated policies, especially in developing countries that want to link up to global knowledge flows, for example, S&T initiatives in countries of origin (Tang & Shapira, 2011) or dedicated scientific diaspora programmes (Harvey, 2009; Sabharwal & Varma, 2015; Séguin et al., 2006; Tejada et al., 2013). Therefore, we propose that:

> **H3.** *Transnational and mediated IRCs* are more likely to be supported by funding, especially by domestic funding sources, than *conventional IRCs*.

As mentioned above, multiple affiliations can be used by universities as the instrument to climb league tables and as a tool to boost research metrics (Bachelet et al., 2019; Kosyakov & Guskov, 2019).

Highly prestigious organizations and their desire to boost visibility may lead to an increase in *multiple affiliations*. Cases are on the rise when organizations are credited in publications for nothing more than offering an author their affiliation (SIRIS, 2023). Although the ethics of such practices have been questioned, we suggest that multiple affiliations will likely be more prevalent among highly visible international organizations because of these incentives.

Shared heritage can also play a role, incentivizing researchers from highly visible organizations to enter IRCs with researchers from peripheral organizations or countries due to lower barriers, shared research interests or path-dependence (Borjas & Doran, 2012). Researchers in highly prestigious organizations enjoy advantages of high visibility: they receive many collaborations offers from which they can select the most attractive ones. Shared heritage is a specific incentive for a researcher from a highly visible organization to enter an IRC, especially with researchers from peripheral countries. We formulate our final hypothesis:

> **H4.** *IRCs* via *multiple affiliation*, *transnational IRCs*, and *mediated IRCs* are more likely to include a partner from an internationally visible organization than *conventional IRCs*.

In the remainder of the article, we offer an exploratory analysis of *nonconventional IRC* compared to *conventional IRC* based on author combinations of coauthored publications. We additionally consider factors related to the geographic position of collaborating researchers, including international and internal core-periphery divisions.

3 | EMPIRICAL SETTING

To formally test our hypothesis, we select Russia, which represents a fascinating case study of research cooperation. Unlike most countries of the Global North, Russian research system remained fairly self-contained and

isolated from foreign influence for the large part of the 20th century. In the Soviet Union, scientists needed to obtain special permits to travel or collaborate internationally, and these were granted only in exceptional cases (Schott, 1992). Scientific communication was also severely limited (Karaulova et al., 2016). Yet, unlike many countries in the Global South, in some research areas the Soviet Science was widely regarded as excellent, and even world-leading, especially in physics and mathematics (Graham, 1993). Soviet scientists received the Nobel Prize in chemistry in 1956 and in physics in 1958, 1962, 1964, and 1978. As the result, after the breakup of the Soviet Union, when Russia opened to the world, it found itself in a peculiar position in relation to its international partners.

Since the 1990s, researchers left the countries of the former Soviet Union, fleeing the difficult economic conditions and/or attracted by the newly opened research opportunities (Graham & Dezhina, 2008). This exodus created significant impacts both in Russia and in receiving countries (Biagioli & Lépinay, 2019; Borjas & Doran, 2012; Ganguli, 2014; Subbotin & Aref, 2021). The Russian-speaking scientific diaspora is populous and influential, and includes some of the leading figures in their fields.

In Russia, even though some traditionally strong areas maintain high research level, science has been in a crisis. Russia has struggled to demonstrate results in emerging areas of science and technology (Karaulova et al., 2016; Moed et al., 2018; Pislyakov & Shukshina, 2014). In post-Soviet years, human resources for a long time suffered from aging and internal brain drain to other sectors of the economy (Terekhov, 2011). The government's many attempts to reinvigorate Russian science and technology have been appraised with skepticism (Klochikhin, 2012). Government talent policies that invited leading international researchers to establish research laboratories in Russia or enter collaborations with Russia-based scientists attracted mainly Russian-speaking returnees and engaged the diaspora scientists (Dezhina & Ponomarev, 2013; Ivanov et al., 2015; Turko et al., 2016).

A marked change in Russia's scientific relationship to the rest of the world came in 2014 after its military aggression in Crimea. If in the preceding period Russia experienced outward mobility of researchers, but remained open to international scientific cooperation, after 2014 Russian researchers started to face increasing difficulties in initiating and maintaining IRCs (Dezhina & Wood, 2022). These changes have both short- and long-term consequences for IRC and the Russian research system, which remain outside of this article's scope.

Russia still represents a country on the semi-periphery of the global research system. Some research fields in Russia are internationally competitive, while others are lagging behind. Moreover, even with the ongoing "brain drain," Russia remains an attractive international collaboration partner and the center of gravity for Post-Soviet and Central Asian countries (Matveeva et al., 2022). Anecdotally, diaspora scientists play (or used to play) a significant role in the country's internationalization. Finally, Russia's science diaspora can be reliably identified methodologically because Russian-speaking researchers abroad are mostly first-generation migrants, and Russian names have distinctive morphological structure, which makes it possible to reliably distinguish them in scientific databases. All these taken together indicate Russia as a suitable case study context to test our hypotheses about heterogeneity of IRCs and its influencing factors.

4 | METHODOLOGY

4.1 | Dataset preparation

We analyzed English-language publications indexed in the Web of Science Core Collection that have at least one author with an affiliation address in Russia and published in 2015.[1] After eliminating publications that do not have sufficient or reliable information, the dataset included 39,448 publications. We cleaned and classified various fields in the dataset, including countries, cities in Russia, types of author-affiliated organizations, types of funding the publications received and subject categories using the VantagePoint and OpenRefine (Verborgh & De Wilde, 2013) software.

We used three features of authors to classify the publications into various IRC groups.

First, we classified the heritage of the coauthors of Russia-based authors into two types: Russian heritage and non-Russian heritage, based on a lexicological method developed previously (Karaulova et al., 2019). Combined with the first name data, this method is highly effective (98% precision and 94% recall) in identifying the Russian heritage of authors. Of 158,864 all authors in our dataset, our algorithm classified about 58% as having Russian heritage and about 42% as not.

Second, we used the institutional address of each author to determine their country of residence. Referring to Table 1, we distinguish between domestic researchers (located in Russia and of Russian heritage), diaspora researchers (located outside Russia and with Russian heritage), and foreign researchers (located outside of Russia and without Russian heritage). As only around 1.5% of researchers in Russia are foreign nationals (Dyachenko et al., 2017), we disregard the negligible share of "immigrant researchers" and merge them into the category of "Other" along with the remaining authors combinations that are less important to our empirical context.

Third, we identified multiple international affiliations of coauthors. We classified publications which contain

one or more authors affiliated with both a Russian addressed organization and an organization outside of Russia as ICPs with multiple affiliations. We did not identify authors with multiple domestic Russian affiliations as multiple affiliation in this instance because this analysis examines multiple affiliation as the mechanism of IRC.

4.2 | Dependent variable

We classified ICPs in the dataset to key groups based on combination of their authors (see Table 2). The resulting "Types of IRC" variable is used as the dependent variable in our analysis. It groups 14,476 ICPs (about 37% all publications) to the following mutually exclusive categories, while the remainder of the publications (24,972 ICPs, about 63% of all) are excluded as they are national publications:

- *Conventional IRC*: ICPs authored by domestic and international researchers.
- *Transnational IRC*: ICPs authored by domestic and diaspora researchers.
- *Mediated IRC (excluding hyper)*: ICPs authored by domestic, diaspora and international researchers. Does not include hyper-authored publications.
- *Mediated IRC (hyper)*: ICPs authored by domestic, diaspora and international researchers with more than 100 authors. Outputs from hyper-authored collaborations have specific authorship conventions.
- *Multiple country affiliation (MCA) IRC*: ICPs classified as IRC only because at least one of the coauthors has an affiliation both in Russia and abroad. In this group, we included publications that only have diaspora and/or international authors who also have an additional home affiliation. Thus, this category does not include papers coauthored by domestic or immigrant researcher(s) (i.e., single home affiliation) and international author(s).
- *Other*: ICPs with author combinations assigned to the category of "Other."

4.3 | Explanatory variables

Guided by our hypotheses, we cleaned and classified the following set of variables in our dataset (see Table S1, Supporting Information for descriptive statistics):

- Subject categories: For our model, we grouped the 252 WoS subject categories into four main dummy variables of *Physics* (as this is a significant research area for Russia), other *Physical Science and Engineering*, *Life and Medical Sciences*, and finally *Social Sciences, Humanities and the Arts*, including Psychology.
- Number of countries and authors: We counted the distinct number of countries and authors for each publication as control variables. As these two variables are highly dispersed, we conducted a log transformation in the model.
- Funding: We created two dummy variables *Russian funding* for papers acknowledging a Russian funding source and *non-Russian funding* for papers acknowledging other funding sources.
- Document type: A dummy variable for articles and non-articles is used.
- International visibility of research organizations: dummy variable *top-100 universities* includes publications with an authors affiliated with a university ranking in top 100 by the normalized average citations (MNCS) indicator in the Leiden ranking, "*Other University*" variable includes publications with authors affiliated with all other universities.
- Organization type: we additionally created a dummy variable for publications including an author affiliated with *Academies of Sciences*. Publications with authors affiliated with all other organizations including public research organizations and hospitals are included in the variable *Other organizations*.
- Global geography: We created a series of mutually exclusive dummy variables based on the country location of author affiliations including, North America, post-Soviet countries, Europe (i.e., countries located in European continent, other than Russia and some post-Soviet countries), Asia and all other countries not included elsewhere.
- Russian geography: A dummy variable *Russian periphery* was created for publications including an author affiliated with an organization outside of Moscow or St Petersburg (peripheral regions). We used this variable as a control.

4.4 | Model specifications

To test our hypothesis, we created a multinomial log-linear regression model with the *types of IRC* as the dependent variable and control and explanatory variables listed above. We conducted our statistical analysis by using various R libraries, including nnet::multinom function (Field et al., 2012) for the regression. In our model, we used *conventional IRC* as the base category of our dependent variable to be able to illustrate the differences to the other types of IRC. In the next section, we present the results from best performing model (i.e., highest

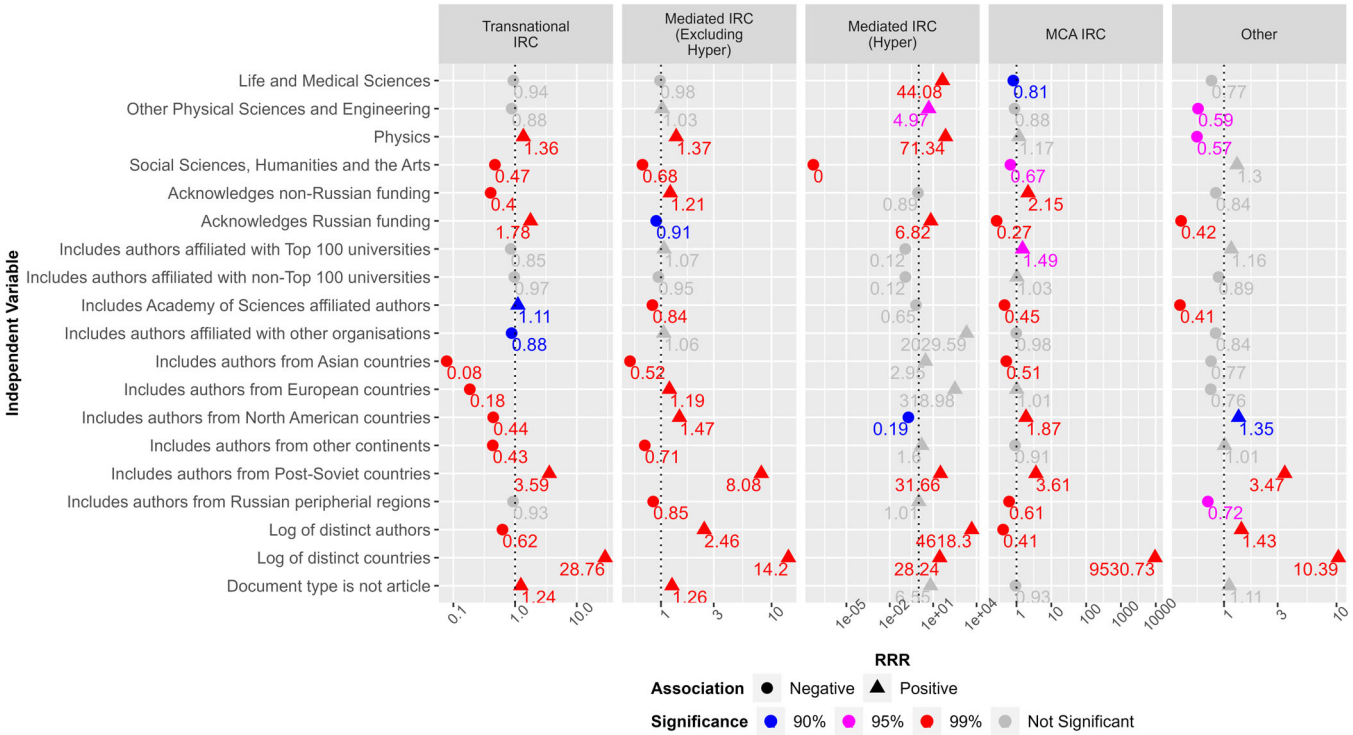

FIGURE 1 Multinomial regression model results. Multinomial log-linear regression with R nnet::multinom function. Base category = *conventional IRC*. $N = 14{,}476$ ICPs. Model performance (pseudo R^2): McFadden = 0.402, adjusted McFadden = 0.397, Cox and Snell = 0.704, Nagelkerke = 0.741

adjusted McFadden's pseudo R^2 and lowest AIC compared to alternative specifications). The visualization of the model adapted for easier interpretation is presented in Figure 1. The full model results are presented in Table S2.

5 | RESULTS

The vast majority of publications ($N = 24{,}972$; 63.3% of the total) in the dataset are not internationally collaborated (i.e., either single authored [$N = 2372$; 6% of total] or collaborated only with other authors located in Russia [$N = 22{,}600$; 57.3% of total]), while 36.23% ($N = 14{,}476$) of all publications are ICPs (i.e., includes at least one author affiliated with an organization located outside of Russia). Of ICPs,

- 31.1% are conventional IRC.
- 15.9% are transnational IRC.
- 31% are mediated IRC (of which 3.5% are mediated IRC (hyper)).
- 21% are MCA IRC.
- 1.6% are in the Other IRC category.

In effect, over two thirds of internationally collaborated publications (around 68%) include at least one diaspora author and around one-fifth are *MCA IRC*. This indicates a strong role of diaspora and multiple country affiliation in Russia's internationalization. Thus in this empirical case, Hypothesis H1 is supported (see Figure 2).

5.1 | Research fields

The results reveal significant differences of nonconventional IRC prevalence across the scientific fields. MCA IRC is negatively and significantly associated with Social Sciences, Humanities and the Arts (at 95% confidence) and with Life and Medical Sciences (at 90% confidence) compared to conventional IRC (refer back to Figure 1). While the former corresponds to our expectation, the latter does not. The association with Physics is positive, but insignificant. These findings do not support the Hypothesis H2a.

Transnational IRC and *mediated IRC* demonstrate the same strength and direction of association: positive and significant association with Physics; negative and significant association with Social Sciences, Humanities and the Arts compared to *conventional IRC*. The share of physics publications is higher in these two groups than in the whole corpus of ICPs (Figure 3). These results support the Hypothesis H2b. The Soviet, and subsequently Russian research has been world-competitive in certain

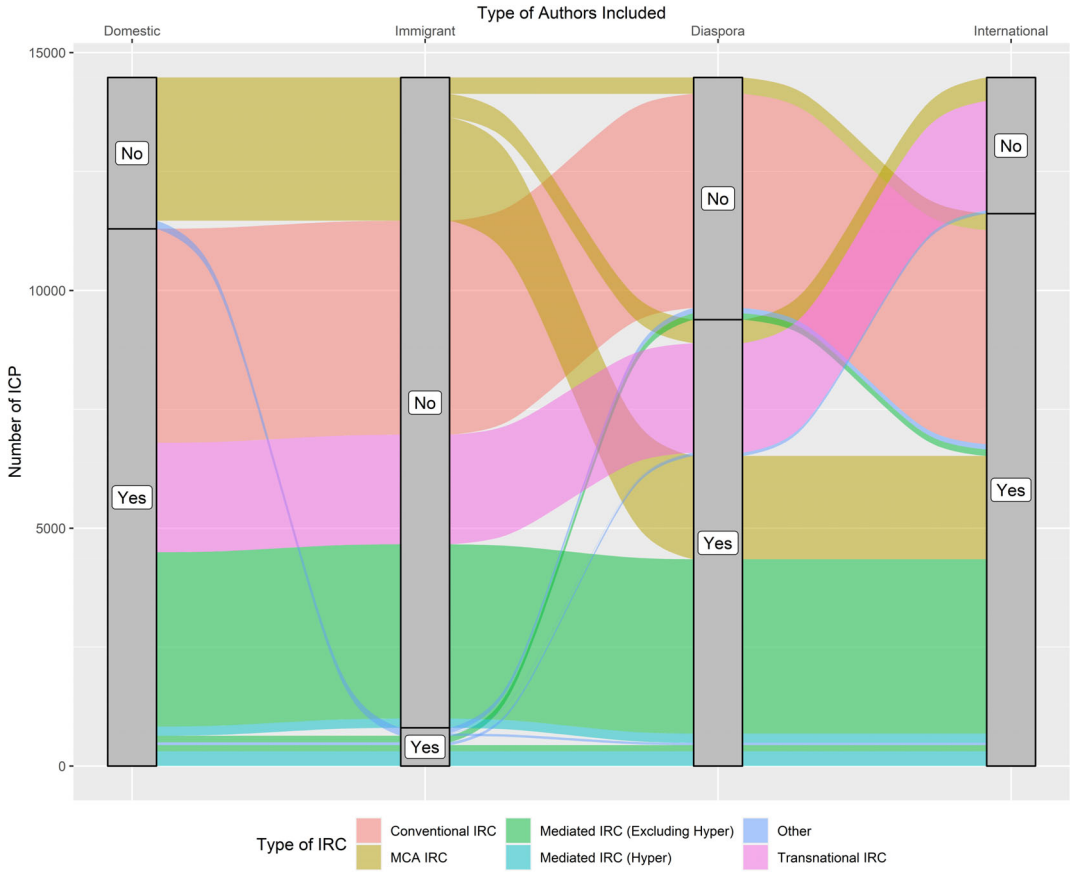

FIGURE 2 Alluvial diagram of IRC types and author combinations. $N = 14{,}476$ ICPs

fields within physics. The majority of scientists in the Russian-speaking overseas diaspora are also physicists and mathematicians. Therefore, the prevalence of *transnational* and *mediated IRC* in physics likely reflects the effect of the strong knowledge base.

As we expected, *mediated IRC (hyper)* are much more prevalent than *conventional IRC* in Life and Medical sciences and in Physics and are significantly less prevalent in Social Sciences, Humanities and the Arts. Hyper-authored publications are almost exclusively found in particle physics and astrophysics (Figure 3), supporting the grounds for separating them in the analysis.

5.2 | Funding

In alignment with our expectations, *transnational IRCs* are more likely to report a Russian funding source and are less likely to report a non-Russian funding source compared to *conventional IRC*. This result supports Hypothesis H3.

In contrast, *mediated IRCs* are less likely to acknowledge Russian funding and are more likely to acknowledge non-Russian funding source than *conventional IRC*. More nuance to these results is revealed by the breakdown of funding acknowledgements by the type of IRC (Figure 4). Over 60% of *transnational IRCs* were supported by Russian funding sources, while the ratios are much closer to 50–50 in *mediated* and *conventional IRCs*.

Hyper-authored IRCs acknowledge both types of funding to a large extent and are more likely to report Russian funding, which we attribute to the high number of authors in these collaborations and their support by long-term public grants. *MCA IRC* is significantly and positively associated with non-Russian funding and negatively—with Russian funding. Over 60% of these IRCs report foreign funding compared to 35% *MCA IRCs* supported by the Russian funding. This result may indicate where the published research took place: likely outside of Russia, meaning that the foreign affiliation of multiple affiliation authors is more likely to be their primary affiliation.

5.3 | International visibility and organizations

Our results do not indicate significant differences between *transnational IRC* and *conventional IRC* in terms of the likelihood to include an author from a highly internationally visible organization. Where we find difference

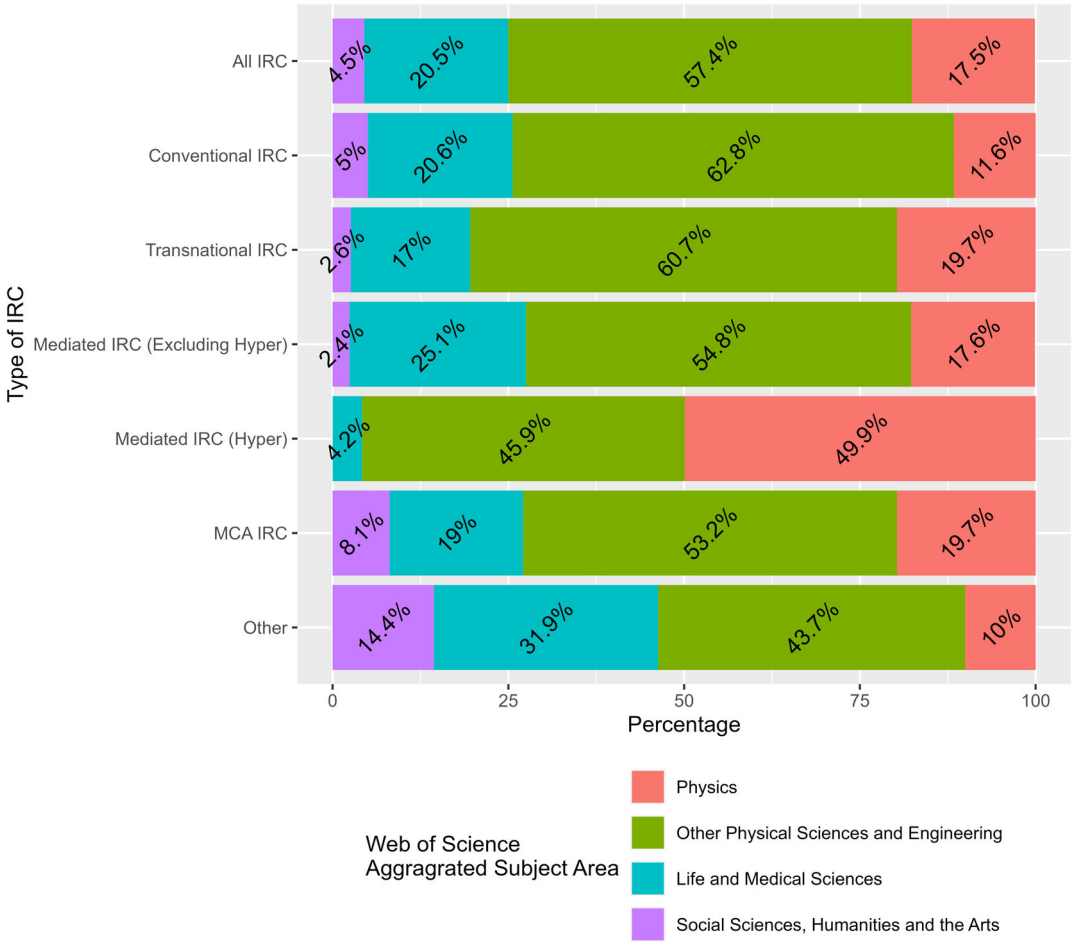

FIGURE 3 Subject categories by types of IRC. Some publications have more than one category associated. $N = 14{,}476$ ICPs

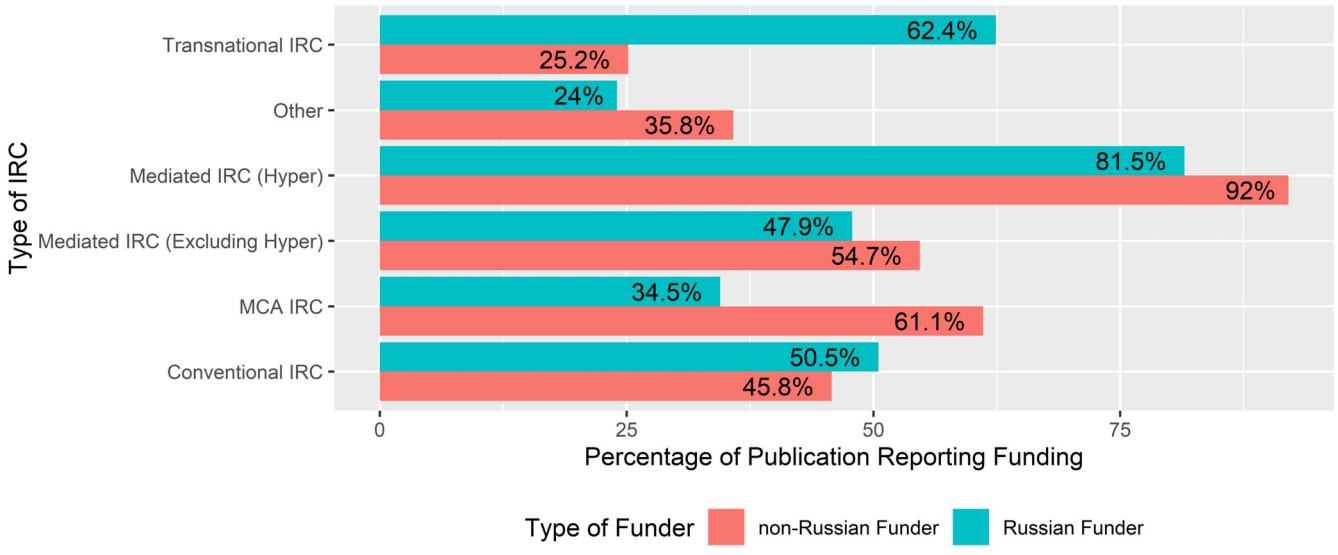

FIGURE 4 Funding acknowledgments by types of IRC. $N = 14{,}476$ ICPs

is the type of organization. *Transnational IRCs* are less likely to include authors affiliated with non-university organizations and are more likely to include authors affiliated with Academy of Sciences compared to *conventional IRC*. *Mediated IRCs* are also more likely to include a coauthor affiliated with an Academy of Sciences.

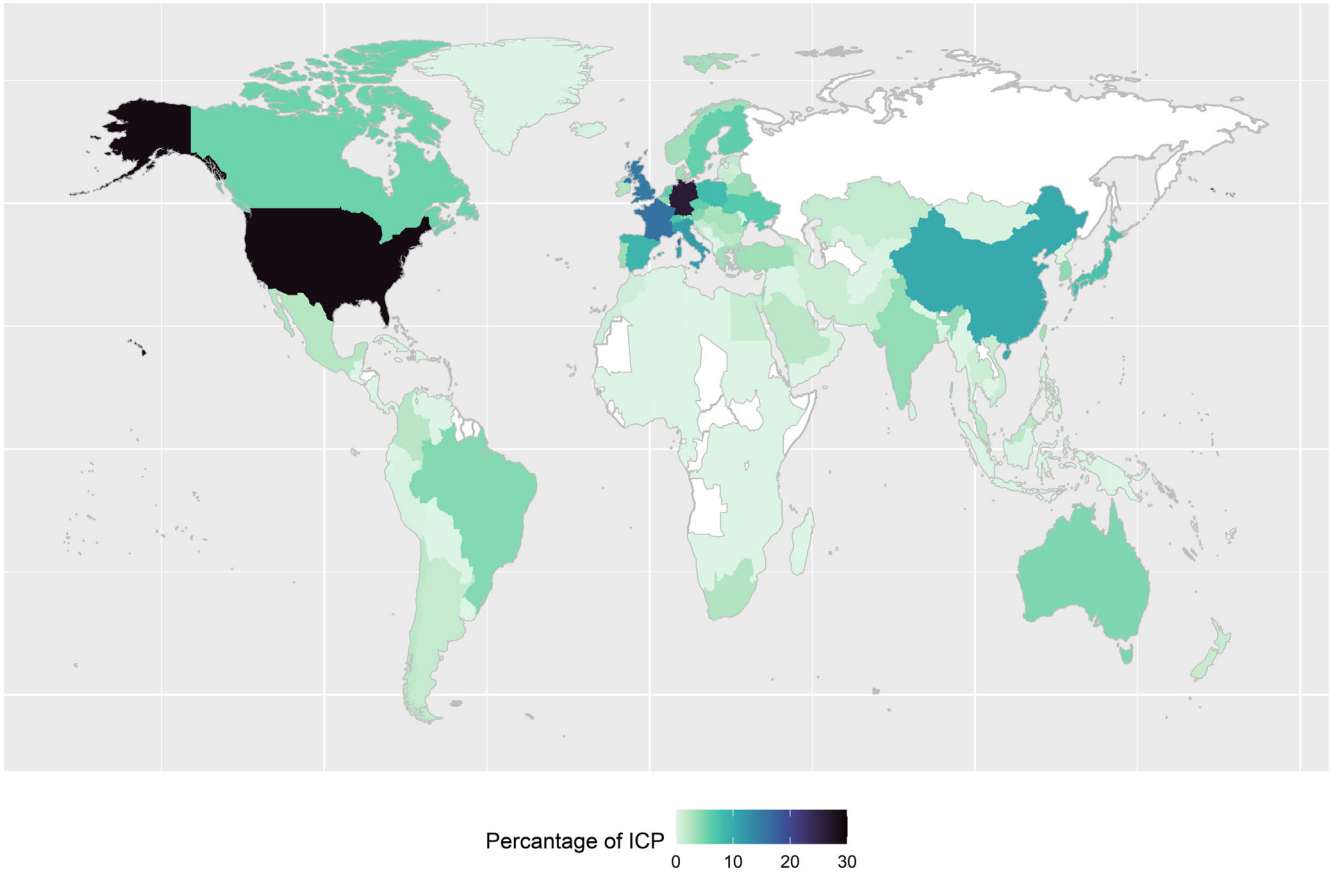

FIGURE 5 Coauthor countries for all ICP. $N = 14{,}476$ ICPs

MCA IRCs are more likely to include a coauthor from a highly visible university and are less likely to include a coauthor affiliated with an Academy of Sciences. These results partially support Hypothesis H4 and highlight the role of *transnational* and *mediated IRCs* in collaborations with the Academy of Sciences. In Russia, the Academy of Sciences is an important research-performing organization (Karaulova et al., 2017); however, researchers without Russian heritage may not understand how it works and may be reluctant to start a collaboration.

5.4 | Geography

Finally, we examine, in an exploratory way, the relationship between core-peripheral geographic divisions and prevalence of *nonconventional* forms of IRC. The majority of Russia's international publications are coauthored with researchers affiliated with European and North American countries. The United States, Germany, France, and the United Kingdom are the top collaborating countries for all types of Russian IRCs (Figures 5 and 6).

Transnational IRCs demonstrate a distinctive profile: are significantly more likely to include authors affiliated with organizations in post-Soviet countries and are significantly less likely to include authors located in Asia, Europe, and North America than *conventional IRCs*. There are no differences for Russian peripheral regions. Mediated IRCs are similar in being highly more likely to include a coauthor from a post-Soviet country, but are also more likely to include authors from European and North American countries. The association with peripheral Russian regions becomes negative. Similarly, *MCA IRCs* maintain a negative association with Asia and peripheral Russian regions. Yet, they are strongly and positively associated with coauthor location in North America. Other geography associations are insignificant.

From these results, we observe that *transnational IRC* mostly links Russian researchers with their counterparts in post-Soviet countries,[2] while other kinds of nonconventional IRC have a broader role. In *mediated IRCs*, populous Russian scientific diasporas in Europe and North America link Russian researchers with non-Russian researchers. These collaborations are more likely to unfold in central Russian regions, linking center with center. At the same time, diaspora links is not the only channel for collaboration. In Asian countries, Russian heritage diasporas are very

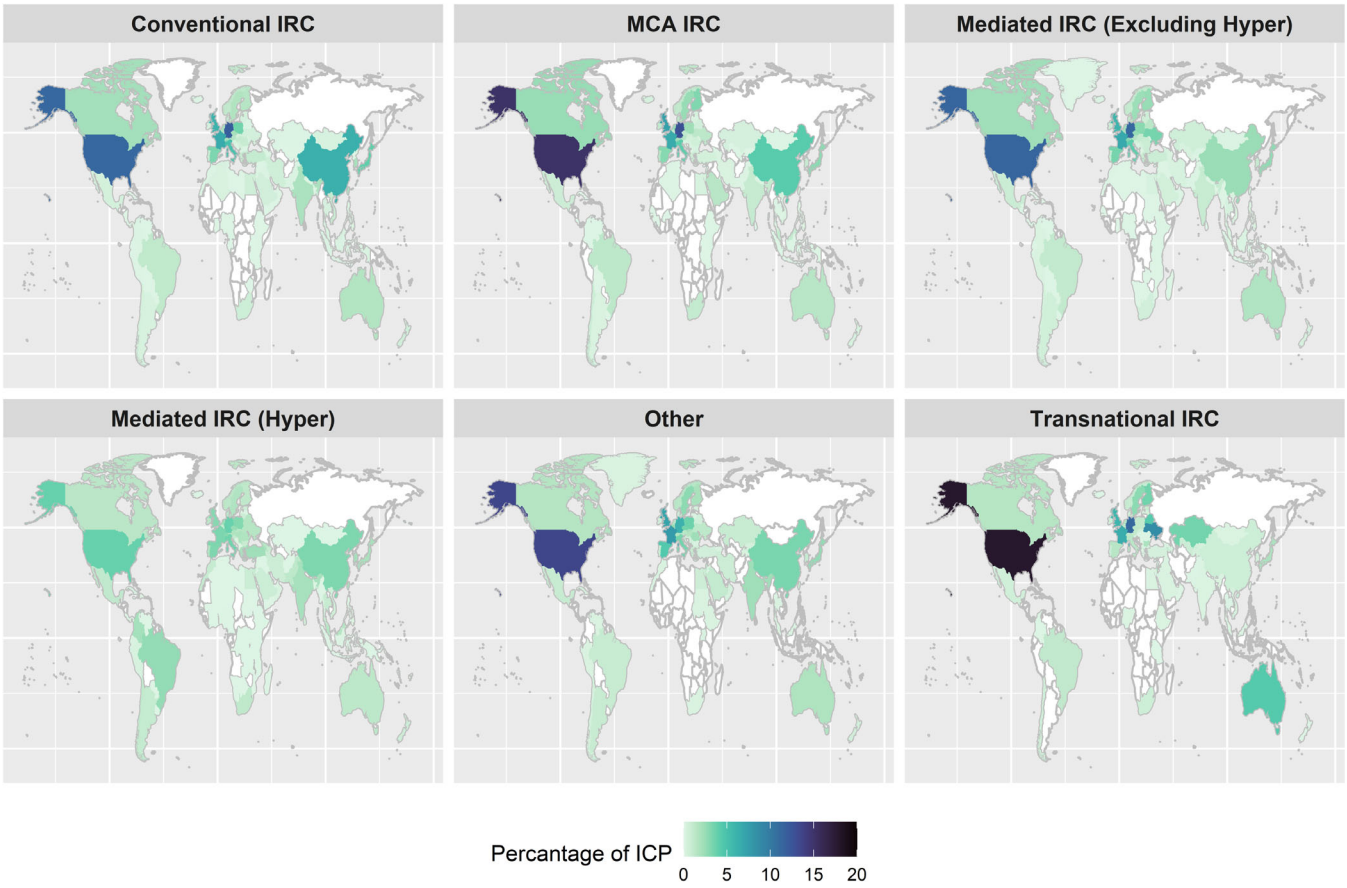

FIGURE 6 Coauthor countries by type of IRC. $N = 14{,}476$ ICPs

small and therefore *conventional IRCs* seem to be more prevalent there than other IRC types.

6 | DISCUSSION AND CONCLUSIONS

IRC is a prominent phenomenon in scientific research, which has global significance and far-reaching impacts. Previous studies investigated the dynamics and structure of IRC, its driving factors, and effects. However, concerns about the validity of using international coauthorship as a proxy for IRC measurement and the limitations of metrics-based indicators have led to inconsistent results and debates around how to address this problem (Chen et al., 2019; Katz & Martin, 1997; Luukkonen et al., 1993).

This article contributes to the debate by arguing that contradictory results may be due to the influence of non-conventional forms of IRC. *Nonconventional IRCs*, such as Shared Heritage IRC and IRC via Multiple Affiliations, are increasingly prevalent in IRC networks and should not be dismissed in analyses. On the contrary, the underlying assumptions of the kinds of knowledge exchange taking place in IRCs should be interrogated. *Nonconventional IRCs* may have different mechanisms, outputs, and effects compared to *conventional IRCs* and thus affect research results.

Our empirical analysis highlighted differences in the intellectual and social organization of *conventional* compared to various forms of *nonconventional IRC*. Drawing on the case of Russia, we found structural differences across geographies, types of institutions and funding mechanisms. We found that over two thirds of internationally coauthored publications (ICPs) in our dataset included a diaspora author—researcher with Russian heritage affiliated with an organization outside Russia. About 20% of co-publications are assigned international status only because of an author's second affiliation. The findings identified significant variations in the presence of shared heritage IRCs and collaborations via multiple affiliations across fields of science, types, locations, visibility of international partners, and funding sources.

The analysis demonstrates that *shared heritage IRC* can be a cornerstone of a country's internationalization. They are more likely, compared to *conventional IRC*, to emerge in scientific fields where the country already has some base competence, likely amplifying it via knowledge flows and improving its visibility. Shared Heritage

IRCs are also more likely to include specific local institutions outside of the higher education sector, which may be harder for global researchers to identify as potential collaboration partners. Thus, our findings support the argument that home countries require sufficient research strength in order to mobilize their scientific diasporas (Heitor et al., 2014). Domestic funding emerges as a critical factor to achieve this.

Contrary to expectations, there were no differences in the visibility of collaborating institutions in nonconventional IRCs. Here, our initial suggestion regarding lower barriers for researchers with shared heritage to enter IRCs is likely neutralized by the influence of other factors, such as the even greater willingness of diaspora researchers from less visible universities to collaborate with the home country, especially in research fields where the home country science is internationally competitive.

Significant structural differences emerged also when IRC via multiple affiliations is compared to conventional IRC. Recent contributions stressed that "affiliation compounding" may be an individual and organizational strategy to increase performance in metrics-dominated research assessment systems (Hottenrott et al., 2021). Our findings generally support this line of argument, but also reflect specific institutional conditions that influence the attainment of multiple affiliations in our empirical case. Since authors with multiple affiliations in our data tend to work in highly visible US universities and report non-Russian funding, we can characterize their "abroad affiliation" as their main affiliation. Therefore, these Russian affiliations may be "residual" affiliations, which enable emigre researchers to maintain ties with their former institutions in Russia. There is an incentive for Russian universities to offer such affiliations to high-performing diaspora alumni, especially those under pressure from performance evaluations dependent on position in league tables (Turko et al., 2016).

The two kinds of IRC analyzed in this article reflect two features of growing complexity in IRC networks. Homophily in research collaboration networks has been studied before (McPherson, 2001), but we demonstrate the extent to which it can be significant in a semi-peripheral country like Russia. Not only are *nonconventional IRCs* prevalent in Russia's overall IRC structure, but they also emerge as the result of different mechanism than *conventional IRC* and have different structural characteristics. Furthermore, *nonconventional IRCs* interact with and are confounded by national institutional frameworks, policy initiatives, and by political processes.

The article highlights the need to distinguish different types of IRC in a nuanced way, especially in policymaking where the common interpretation of ICP metrics may oversimplify the reality of IRC networks. The discrepancy between the accepted use of co-publications to measure IRC and the assumptions made in these measurements can lead to significant bias in results and, as a corollary, in advice offered to researchers, university management and policymakers.

A key implication of our research concerns the interpretation of the ICP metric. The share of ICP feeds into benchmarking tools developed by Clarivite Incites and Scopus SciVal on at least three levels: individual (e.g., in hiring and promotion), organizational (e.g., Shanghai or Leiden University Ranking) and country level (e.g., European Innovation Scoreboard and OECD Innovation Scoreboard). All these tools implicitly or explicitly assume that ICP indicates "*the quality of scientific research as collaboration increases scientific productivity*" (Hollanders, 2019, p. 5). Thus, policy measures encourage IRC. However, this assumption is simplistic as it does not take into consideration the internal heterogeneity of IRC. Policymakers and university leaders should be asking: which IRCs benefit us the most, in which way? More tailored and sophisticated policy measures should then be developed to encourage IRC for research quality and impact.

We conclude the article by discussing its limitations and opportunities for future research. Methodologically, we used a rule-based lexicological method to identify heritage of authors. This method struggles to distinguish groups with similar naming conventions. This was at an acceptable level for us (96% F1 overall) but care must be taken for applying these methods in follow-up studies. We also made assumptions about multiple affiliations to reduce the complexity. Follow-up studies can use data sources, such as ORCID, for cross validation.

Future research could systematically disambiguate the effects of shared heritage IRCs in different countries and territories, build the link between IRC of researchers of different heritage and other relevant phenomena, such as post-colonial power structures. Analyzing citation impact of various types of *nonconventional IRCs* compared to *conventional IRCs* will provide further insight. Empirically, our study sampled only 1 year, which was sufficient for an exploratory analysis. Further studies can use time-series data.

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ENDNOTES

[1] The share of Russia's internationally co-authored publications did not fluctuate significantly in 2015 compared to previous years. However, taking into account unfolding structural shifts in the network, we conduct analysis using 2015 data. Since structural change takes time, we assume that in 2015 the change was likely not yet substantial.

[2] Our results for post-Soviet countries could be influenced by similarities in naming conventions in the region and therefore contain some degree of bias.

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