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ANDERSON DA CUNHA JESUS

KNOWLEDGE FLOWS ACROSS BORDERS: migrant STEM workers' personal and professional journeys

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Thesis presented as a partial requirement for obtaining the title of Doctor in Administration, by the Postgraduate Program in Administration of the Universidade do Vale do Rio dos Sinos – UNISINOS

Advisor: PhD. Yeda Swirski de Souza

Co-advisor: PhD. Ronaldo Couto Parente

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“Wherever you go becomes a part of you somehow”

Anita Desai

RESUMO

Esta pesquisa tem como objetivo investigar como as trajetórias pessoais e profissionais de migrantes STEM influenciam a fuga de cérebros e a circulação de conhecimento. Para esse propósito, foi analisado o caso de profissionais brasileiros das áreas STEM que migraram para os Estados Unidos, utilizando uma abordagem qualitativa de pesquisa. Com base em dados secundários e entrevistas semiestruturadas com 41 migrantes brasileiros STEM, o estudo analisa como suas trajetórias pessoais e profissionais impactam a mobilidade de capital humano e os fluxos de conhecimento entre os EUA e o Brasil. A fuga de cérebros tem sido um problema crítico para o desenvolvimento de capital humano em países emergentes, enquanto *brain circulation* oferece um caminho potencial para mitigar essas perdas. Os resultados revelam que a fuga de cérebros e *brain circulation* não são fenômenos mutuamente excludentes, mas coexistem de forma complexa. A pesquisa também identifica quatro mecanismos de fluxos de conhecimento internacional por meio dos profissionais migrantes STEM: redes globais; laços étnicos e conexões pessoais; práticas de colaboração científica e inovadora; e comunidades de diáspora. Em diversas situações, mecanismos informais e relacionais viabilizam os fluxos de conhecimento, ainda que de maneira não institucionalizada. Como contribuição, o estudo propõe uma ampliação do entendimento teórico sobre a mobilidade de capital humano ao incorporar dimensões pessoais e relacionais, e recomenda o desenvolvimento de políticas públicas que construam "pontes" entre o Brasil e seus profissionais migrantes STEM no exterior.

Palavras-chave: Profissionais STEM. Migrações qualificadas. Fluxos internacionais de conhecimento. Fuga de cérebros. Circulação do conhecimento.

ABSTRACT

This research aims to investigate how personal and professional journeys of migrant STEM workers influence brain drain and brain circulation. For this purpose, it was analyzed the case of Brazilian migrant STEM workers who have migrated to the United States (U.S.), using a qualitative research approach. Based on secondary data and semi-structured interviews with 41 Brazilian migrant STEM workers, the study analyzes how their personal and professional journeys impact human capital mobility and knowledge flows between U.S and Brazil. Brain drain has been a critical problem to the human capital development of emerging countries, whereas brain circulation offers a potential pathway to mitigate these human capital losses. The results reveal that brain drain and brain circulation are not mutually exclusive phenomena, but rather coexist in a complex manner. The research also identifies four mechanisms for knowledge flows across borders through migrant STEM workers: global networks; ethnic ties and personal connections; scientific and innovative collaboration practices; and diaspora communities. In several situations, informal and relational mechanisms enable knowledge flows, albeit in a non-institutionalized way. As a contribution, the study proposes an expanded theoretical understanding of human capital mobility by incorporating personal and relational dimensions, and recommends the development of public policies that build “bridges” between Brazil and their migrant STEM workers abroad.

Keywords: STEM workers. Skilled migration. International knowledge flows. Brain drain. Brain circulation.

LIST OF TABLES

LIST OF ACRONYMS

CAPES - *Coordination for the Improvement of Higher Education Personnel*

CNPq - *National Council for Scientific and Technological Development*

ERIC - *Education Resources Information Center*

ESPM - *Higher School of Advertising and Marketing*

FAPESP - *São Paulo Research Foundation*

FIOCRUZ - *Oswaldo Cruz Foundation*

IDB LAB - *Inter-American Development Bank*

OIM - *International Organization for Migration*

PI - *Principal Investigator*

PUB - *Brazilian researchers and university students*

STEM - *Science, Technology, Engineering and Mathematics*

TCP - *Patent Cooperation Treaty*

UNISINOS - *University of Vale do Rio dos Sinos*

UN - *United Nations*

UNESCO - *United Nations Educational, Scientific and Cultural Organization*

U.S. - *United States*

USP - *University of São Paulo*

SUMMARY

1. INTRODUCTION

Professionals working in the so-called STEM areas (*Science, Technology, Engineering and Mathematics*) are essential to innovation. They are global talents with high levels of human capital and mobility, able to work in organizations intensive in knowledge and creativity, with scarce and globally contested resources (WANG, 2021). Thus, migrant STEM workers have characteristics that can facilitate transnational connections, as they are often multicultural individuals with access to international markets, networks and communities, and can play a "bridge" role between developed and emerging countries (SZYMANSKI; VILLAR; ZEPEDA, 2021; ELO et al, 2018; ETEMAD, 2018; RATTEN, 2022).

Moreover, STEM workers' human capital, combined with their multicultural backgrounds, can impact not only their new locales but also the areas they depart from. They engage with resources from both ecosystems and potentially outperforming skilled local workers. This dynamic foster innovation, transnational entrepreneurship, and international business (BARON & HARIMA, 2019; DUAN et al., 2021).

This study analyzes how personal and professional journeys of migrant STEM workers impact human capital mobility and knowledge flows between U.S and Brazil – an advanced economy as the host country, and an emerging economy as the country of origin of the STEM workers. This is done considering the phenomena of brain drain and brain circulation, in which STEM workers are key actors.

Migration is a longstanding facet of human history. Historically, migrations were driven by survival or instinctual needs, whereas contemporary migrations also encompass aspirations for social mobility (FAGGIAN et al., 2017). In the 21st century, the complexities of global migration continue to attract the attention of governments, scholars, and practitioners across various disciplines, including business management, sociology, and human geography (DHEER, 2018; JIANG et al., 2020; ZWEIG et al., 2020). The International Organization for Migration (IOM, 2020) reports a notable increase in global migrants, rising from 258 million in 2017 to 272 million in 2020.

The academic discourse on migration differentiates between involuntary migrants, such as refugees, and those migrating by choice, including highly skilled workers, like STEM. This distinction extends to the level of qualification, separating highly qualified migrants from those with limited formal education or vocational training (HAJRO et al., 2021). These distinctions are crucial for shaping public policies, organizational strategies, and research agendas.

This research specifically focuses on highly qualified migrants within STEM fields, whose expertise and creativity are invaluable in knowledge-intensive contexts. The global scientific community has shown increasing interest in migration of skilled professionals for several reasons. Firstly, through discussions on the role of migrants in economic development of countries, that is, how much these migratory movements can impact the national economy and development, triggering various actions such as programs, strategies and national public policies focused on the topic (RACZYNSKI, 2020). Countries and organizations can consider skilled migrants as sources of resources that, combined with other innovation factors, can lead to sustainable future growth (MIRANDA-MARTEL et al, 2017).

Second, due to the impact of skilled migration on the production and dissemination of knowledge, especially when it comes to professionals in the STEM areas, who, through their personal and professional networks, play a crucial role in creation and transfer of knowledge, contributing to innovation and entrepreneurship in countries of destination and origin (MIGUELEZ; TEMGOUA, 2020).

Third, for innovation and entrepreneurship ecosystems, as the diversity, multiculturalism and creativity arising from qualified migrants enrich the destination ecosystems with new resources and capabilities. This is reflected in new interactions, development of new products, services and the capacity for innovative entrepreneurship through *startups* and transnational businesses, which take advantage of the human and social capital of skilled migrant talents (SZYMANSKI, 2021; SCHAFER; HENN, 2018; SANDOZ et al, 2021; BARON; HARIMA, 2019).

The global mobility of human capital constitutes a key mechanism for the knowledge economy, in terms of transferring knowledge across borders. Migrant movements attract the attention of scholars because they take their experiences and knowledge acquired from one territory to another (LAM; RUI, 2022). In essence, the global mobility of human capital is a cornerstone of the knowledge economy, facilitating cross-border knowledge transfer. Skilled migrants are vital conduits for accumulating human, cultural, and economic capital, establishing transnational networks essential for both economic development and social well-being (PETROVIC; TOKOVIC, 2020).

Research on skilled migration and innovation has increasingly focused on the global competition for talent, examining national and international labor and immigration policies, knowledge management practices, and urban development strategies that aim to leverage the skills and capabilities of qualified talent (EWERS et al., 2021). This intersection between global migration of skilled professionals and innovation represents a multifaceted

phenomenon. The complexity of this relationship has led some scholars to struggle in establishing a definitive positive correlation, suggesting a need for further investigation to overcome challenges related to data accessibility, migrant identification, and to explore the nexus between migration and innovation from diverse angles (CAVIGGIOLI et. al., 2020). Additionally, research specifically addressing the impact of STEM migrants on innovation remains limited (BONGERS et. al., 2022).

A critical theoretical discussion within this domain concerns the effects of international migration of STEM talents on their countries of origin – the places where these individuals' human capital was initially developed and which subsequently experience a loss due to their emigration. Two predominant perspectives emerge in this debate: one centered on the brain drain phenomenon and the other on brain circulation.

The brain drain perspective focuses on the human capital losses incurred by a country or region due to the emigration of talented individuals to other locales (DE LA VEGA HERNÁNDEZ; BARCELLOS DE PAULA, 2020; VEGA-MUÑOZ et al., 2021), positing a zero-sum scenario where one country's gain is another's loss. In contrast, the concept of brain gain explores the benefits accruing to countries that attract and retain skilled migrants (Bacchi, 2016; Siekierski et al., 2018). Moreover, Saxenian (2005) introduced the notion of brain circulation to describe the dynamic exchange of knowledge, resources, and capabilities facilitated by the mobility of skilled individuals and their extensive international networks, suggesting benefits can also accrue to the regions they leave.

Analyses of the brain drain's impact often highlight the resultant depletion of human capital and its implications for economic development (KASNAUKSIENE; PALUBINSKAITE, 2020). Yet, a more nuanced examination of skilled professional migration (brain circulation) reveals its potential to drive innovation, science and entrepreneurship, with migrants establishing business opportunities and knowledge exchanges in global markets, particularly within technology-intensive and digital sectors (SAXENIAN, 2005; SAXENIAN, 2010).

However, identifying the positive contributions of STEM talent migration to their countries of origin poses significant challenges. While patent filings have served as a common metric for assessing migration's impact on innovation (TANRIKULU, 2020; MIGUÉLEZ, 2019), this approach overlooks various knowledge assets not easily quantifiable through patents or bibliometric indicators. Additionally, such data often fails to capture the full spectrum of innovation systems, notably in sectors like software services and the creative industries, which rely less on patenting yet contribute significantly to economic activities

linked to innovation (BRESCHI et al., 2020). The use of citations as proxies for knowledge flows has also faced criticism for its limitations (DI IASIO; MIGUÉLEZ, 2021).

Consequently, the prevailing scholarly approach, which predominantly utilizes quantitative secondary data from patent offices or citation databases to correlate the global connections of scientists, inventors, R&D professionals, and similar roles with innovation, is recognized as limited. This perspective falls short of fully understanding how the migration experience influences innovation outcomes (BRESCHI et al., 2020).

Reinforcing these ideas, it can be observed the excerpt below taken from the studies by Di Iasio and Miguelez (2021). The authors recognize the limitations of their research results and suggest recommendations for future studies:

> "Our data provides detailed information about the location of large numbers of patent families around the world. However, they do not allow us to identify the specific channel through which migrants transfer knowledge from destination areas to their countries of origin. Our hypothesis is that highly qualified migrants maintain contacts with their countries of origin and transfer the knowledge acquired at destination to their social networks in the country of origin. They may return home, permanently or temporarily, after time abroad, with new skills and contacts. Future research, possibly at the micro level, could investigate the specific mechanisms behind our results."

The phenomenon of global migration of skilled professionals is not merely a transient or isolated occurrence; it represents an ongoing process of identity evolution, shaped by diverse experiences and cultural integrations. This journey often leads to the emergence of a hybrid cultural identity, as individuals navigate and assimilate various global contexts. Breschi et al. (2020) advocate for a research approach that transcends the traditional view of migrants as outsiders with static and disjointed identities. Instead, they propose an in-depth examination of migrants' life trajectories and professional journeys. Such an approach aims to uncover the intricate ways in which these individuals contribute to innovation in both their host countries and countries of origin. This would involve utilizing methodologies such as interviews, direct observations, and testimonials from STEM talents, thereby providing a richer understanding of the multifaceted benefits migration brings to the science and innovation landscape.

Adopting such a methodology enables a deeper exploration into the specific processes by which knowledge transfer and dissemination occur through migrant STEM talents, assessing the benefits for countries of origin and identifying strategies to enhance these knowledge flows and, consequently, their benefits. This necessitates augmenting secondary and quantitative data with primary data that encapsulate the tacit, social, and cultural

dimensions inherent in the migration context (HU et al., 2022; LAM; RUI, 2022). Given the increasing mobility of highly skilled labor and concerns over brain drain phenomena, it is imperative to thoroughly understand migration's outcomes. This raises questions about whether countries and organizations should engage in a global competition for talent or if migration could potentially benefit all involved countries and ecosystems (FACKLER et al., 2020). In that regard, Saxenian (2005) advocates for the concept of brain circulation, illustrating how Chinese and Indian scientists in Silicon Valley have significantly contributed to the economic development of their home countries by transferring knowledge to local entrepreneurs and startups.

Recent studies have aimed to decipher the extent and mechanisms of knowledge and experience exchange between international migrants and their compatriots in the countries of origin, focusing on identifying processes and measuring impacts back home (LAM; RUI, 2022; FACKLER et al., 2020; MIGUELEZ; TEMGOA, 2020). Yet, the comprehension of knowledge flow dynamics in the global migration of STEM workers remains incomplete. Knowledge mobility may involve returning migrants who must contextualize the skills and insights they gained abroad for application within their home country's context. Alternatively, it might involve migrants who remain in the destination country yet engage with networks, communities, and technologies to share and transfer knowledge. The complexity of these knowledge flows, characterized by their non-linear nature and the need for adaptation to ensure the transfer of relevant and actionable knowledge to peers in the origin country, highlights existing gaps in this topic (LAM; RUI, 2022).

Significant work in this field has predominantly concentrated on the role of migrants within transnational networks and communities, while the intricacies of transnational learning and knowledge transfer have received less attention. It is critical to recognize that the mere existence of networks and communities does not guarantee the seamless transfer of new knowledge, ideas, and practices from one country to another. The assimilation of these elements necessitates thoughtful reflection, active interaction, and negotiation among the social actors involved. The literature has yet to thoroughly explore the complexity of these interactions across diverse social contexts (LAM; RUI, 2021).

Recent studies on innovation have highlighted several mechanisms that facilitate the cross-border transfer of technologies, primarily through trade and investment. However, the contribution of STEM migrants as pivotal agents in the generation of knowledge-intensive technologies remains underexplored. Research by Bahar and Choudhury (2018) points to the significant role of human capital exchange, facilitated by global migration, in enhancing

transnational knowledge mobility and fostering the production and acquisition of knowledge-intensive technologies.

From the standpoint of innovation, the processes through which resources and ideas are integrated into the innovation and entrepreneurship ecosystems of the migrants' countries of origin have received limited attention (Schmutzler et al., 2021). Analyzing the relationship between highly skilled migration, particularly from STEM fields, and the technological diversification in migrants' home countries is crucial. Specifically, it is worth investigating whether migrants contribute productive knowledge back to their home countries and stimulate the development of new technologies, especially those in which their destination countries specialize (DI IASIO; MIGUÉLEZ, 2021).

Despite some consensus in the literature that has facilitated progress, there remains a clear need to further develop this area of research. For instance, the extent to which social connections between migrants in their destination countries reach back to their countries of origin, thereby aiding in the international knowledge transfer, is not fully understood. Additionally, official statistics fall short in providing detailed information regarding the specific skills or occupations of highly skilled migrants, highlighting the importance of gathering micro-level evidence on an international scale (BRESCHI et al., 2017).

Therefore, this research aims to address the following question: How do the personal and professional journeys of migrant STEM workers influence brain drain and brain circulation?

Based on the research problem outlined above, the study sets forth the following objectives:

a) Main goal:

To investigate how the personal and professional journeys of migrant STEM workers influence brain drain and brain circulation.

b) Specific objectives:

- To analyze migrant STEM workers' personal and professional journeys.
- To analyze personal and professional journeys of migrant STEM workers in brain drain's effects.
- To analyze personal and professional journeys of migrant STEM workers in brain circulation's effects.

Migration encompasses the exploration of who migrates, their reasons for migrating, their destinations, what they bring with them, and their impact on both new and former locations. For professionals in the STEM fields, these migrations notably influence the development of cities, regions, ecosystems, and countries, highlighting the profound effects these movements have on societal and economic landscapes (BRESCHI et al., 2020).

The global migration of highly qualified professionals, particularly scientists and engineers, represents a rapidly expanding demographic worldwide, reflecting a significant shift in labor mobility patterns (KERR et al., 2016). This trend is partly driven by the migration policies of high-income countries, which aim to attract such talent to bolster research, development, and innovation efforts (BONGERS et al., 2022).

Evidence of the scale and impact of this migration can be found in UNESCO data from 2015, which showed an increase from approximately 3 million international students in 2005 to 5 million in 2017, with a significant proportion of these students pursuing degrees in science or technology. Notably, this trend is even more pronounced at the doctoral level, where 63% of foreign students are in science or technology fields.

In the United States, a key destination for such migrants, immigrants constitute a substantial portion of the STEM workforce. Data from Hanson and Slaughter (2017) indicated that in 2013, foreign-born individuals made up 19.2% of STEM workers with bachelor's degrees, 40.7% with master's degrees, and a majority (54.5%) of those holding doctoral degrees. This demographic shift underscores the critical role of immigrant talent in maintaining and advancing the STEM fields within high-income countries.

To demonstrate the interest some countries have in attracting foreign STEM workers, they have implemented specific migration policies. Notably, the H-1B visa program and the Optional Practical Training (OPT) program in the United States are prime examples (BONGERS et al., 2022). According to the United Nations' 2013 World Population Policy report, 40% of countries have adopted policies aimed at increasing the immigration of highly skilled workers, marking a significant rise of 22% since 2005 (KERR et al., 2016). For host nations, the influx of highly skilled immigrants is closely associated with clusters or ecosystems of technology and knowledge production, which are vital for local and national economic growth. For instance, over half of Silicon Valley’s highly skilled technology workers and entrepreneurs were born outside the U.S. (KERR et al., 2016). Consequently, countries have been enacting policies to address this trend for many years.

In terms of wage equality, STEM field foreign workers achieve pay parity with their native counterparts much quicker than those in non-STEM fields. Whereas foreign-born

workers in non-STEM occupations may require over twenty years in the United States to attain pay parity with natives, those in STEM fields typically achieve this within a decade (HANSON; SLAUGHTER, 2018). This underscores the unique importance of this group of migrants on the global stage, necessitating focused attention from scientific, practical, and governmental sectors.

Academically, the dissemination of innovation was a primary focus of early research on migration and innovation and remains a cornerstone of modern innovation studies. This research emphasizes the importance of mobility and networking in the spread of knowledge. However, the diffusion of certain knowledge assets, especially those not quantifiable through patents or bibliometric indicators, remains underexplored (BRESCHI et al., 2020).

The research by Bahar et al. (2018) highlights the pivotal role migrants play in the knowledge diffusion process, thereby contributing to economic growth through innovation. The interaction among individuals is key to understanding productivity on both individual and aggregate levels, factors that are conducive to innovation. Akcigit et al. (2018) found that organizations with limited access to external knowledge tend to have lower quality ideas and slower growth in individual productivity.

There are scenarios where individuals have limited exposure to external sources of knowledge. Often, there is a strong clustering and geographical concentration of talent, leading to frequent interactions within a homogenous group but minimal introduction of new knowledge. This phenomenon, known as the “proximity paradox,” suggests that excessive cognitive or geographical closeness to a similar group of individuals, without new knowledge inflows, can hinder innovation (AKCIGIT et al., 2018). Hence, the global migration of skilled talent is crucial. As a result, not just organizations and industries, but entire innovation ecosystems become interconnected and interdependent (WANG, 2021).

This research aims to make a scientific contribution at the intersection of qualified talent migration, brain drain, brain circulation, and innovation. It will facilitate theoretical advancements by leveraging data on the highly relevant contemporary phenomena stemming from the international mobility of workers. Additionally, it will highlight theoretical-practical aspects that warrant further investigation and scientific elucidation.

From an applied perspective, the research will offer governments and policymakers in emerging countries valuable insights on how to mitigate the local effects of brain drain and maximize the potential benefits of global connections with migrant STEM workers (brain circulation).

The structure of this thesis is as follows: Section 2 presents the theoretical framework underpinning the research. Section 3 details the methodological procedures employed in the study. Section 4 describes the research findings. In section 5, the findings are discussed. Finally, in section 6 there are the conclusions of the study.

2 THEORETICAL FOUNDATIONS

In this section, we explore theoretical foundations for the present study, focusing on issues of human capital mobility, relations between migration and innovation, brain drain, brain circulation and diaspora phenomena. This exploration of extant academic studies gives rise to three main assumptions of this study as well as to preliminary analysis dimensions.

2.1 HUMAN CAPITAL MOBILITY

In a knowledge economy, human capital emerges as a paramount factor in driving economic development and enhancing social well-being (RACKZYNSKI, 2020). Highly qualified professionals are at the forefront of this dynamic, making substantial contributions to disruptive innovations and scientific breakthroughs. They engage in coordinated actions with peers and organizations, pushing the boundaries of knowledge and catalyzing economic expansion (KERR et al., 2016). Becker (1962) defined human capital as knowledge, ideas, information and health of individuals. Schultz (1961) argued that one country is superior from another by the human investment and human capabilities in productivity. Human capital mobility is one of the ways to invest in human capital (BOMAN, 2011).

Consequently, the mobility of skilled professionals is a key factor in boosting the performance and productivity of organizations, regions, and nations alike. This mobility encompasses intricate flows, including multinational corporations, employers in search of rare talents, governments crafting policies to attract and retain such talent, and individuals pursuing optimal working conditions in line with their qualifications (KERR et al., 2016).

The prevailing theory on the migration of skilled professionals identifies push and pull factors that drive individuals from one country to another. This reflects an economic equilibrium between "exporting" countries (typically emerging economies) and "importing" countries (generally developed nations). Research confirms that welcoming qualified migrants - whether professionals, students, or researchers - economically benefits the host country, contingent upon the migrants' motivations, which hinge on a cost-benefit analysis (MIRANDA-MARTEL et al., 2017).

Global migrations are invariably linked to the socio-economic and political landscape, making their study multi-faceted and of interest across various fields. The recent COVID-19 pandemic has had short, medium, and long-term effects on migration patterns. Despite the

pandemic's significant impact on the early 2020s, forecasting future migration trends remains challenging, underscoring the ongoing need for research (HAJRO et al., 2021).

The migration of skilled professionals is diverse in nature, encompassing permanent or temporary relocations, occurring within or outside the framework of multinational corporations, and driven by economic, familial, or socio-political motives in the country of origin (TOKOVIC; PETROVIC, 2020). Moreover, recent studies have shed light on the personal profiles of these migrants, particularly emphasizing 'multicultural individuals'. Through their mobility, these global citizens gain exposure to various countries, cultures, and organizations, enhancing their ability to adapt and thrive in diverse cultural settings. This adaptability fosters learning, challenges, and personal growth, enabling them to assimilate multiple cultures (SZYMANSKI et al., 2021).

Such multicultural individuals may exhibit cognitive and behavioral distinctions compared to their monocultural or local counterparts. Research focusing on these differences has gained momentum, especially in the domain of international business, highlighting the potential of multicultural individuals to become international entrepreneurs (SZYMANSKI et al., 2021).

It's crucial to delineate various classifications of global migrants that scholarly literature has recently explored, including expatriates, skilled migrants, migrant entrepreneurs, transnationals, and diasporas. Expatriates are individuals assigned to work in a different country while remaining employed by the same organization, often within multinationals, facilitating smoother integration due to organizational support and potentially temporary stays (HAJRO et al., 2021).

Skilled migrants are professionals who relocate to pursue new career opportunities abroad, facing a generally more challenging integration process than expatriates (DUTTA et al., 2021; HAJRO et al., 2021). Migrant entrepreneurs are those who establish new ventures outside their home countries. Transnationals maintain connections with at least two different countries, whereas diasporas sustain ties between their destination and origin countries (DHEER, 2018).

The motivation behind migration often differs; low-skilled migrants are typically driven by necessity, whereas high-skilled migrants seek opportunities. Skilled migrants are defined as individuals possessing at least a bachelor’s degree, with their roles and tasks demanding specialized knowledge and higher education (LAM; RUI, 2022).

Recent research on international talent mobility highlights several trends, including studies on economic geography and innovation focusing on the role of social, community, and

network connections in facilitating cross-border knowledge diffusion. Other research emphasizes the contributions of skilled migrants to innovation, entrepreneurship, and development in their countries of origin through international knowledge flows (BRESCHI et al., 2017). Given its complexity, global talent mobility is examined through various theoretical and conceptual lenses, such as human capital, brain drain, brain circulation, diasporas, and entrepreneurial approaches. These perspectives aim to deepen our understanding of migration phenomena (ABOITES; DÍAZ, 2018).

Until the late 1990s, research on international talent mobility largely concentrated on the potential returns of migrants to their home countries, with a significant focus on financial remittances. In the 21st century, the migration of skilled professionals and the transfer of knowledge have become increasingly prominent topics of study (BRESCHI et al., 2017).

The process of knowledge transfer between countries can manifest in three distinct, yet interconnected, ways. Firstly, knowledge flows can be driven by ethnic proximity, wherein highly qualified professionals maintain social ties with associations, companies, and educational institutions, facilitating the transmission of technical knowledge either cooperatively or contractually. Secondly, global transfers orchestrated by multinational corporations encourage their employees to relocate, immersing them in varied cultural and institutional settings. Thirdly, migrants returning to their countries of origin can directly contribute by applying the knowledge and experiences garnered abroad, potentially initiating entrepreneurial ventures while sustaining connections with the knowledge and resources of their previous destinations (BRESCHI et al., 2017).

The efficacy of knowledge transfer, especially that mediated by qualified migrants, is contingent upon the relevance of the knowledge transferred. This relevance is determined by the potential of external knowledge to integrate with local knowledge systems. Consequently, external knowledge often necessitates reconfiguration and recontextualization to align with local contexts, presenting significant challenges when substantial institutional or knowledge disparities exist between countries (LAM; RUI, 2022).

Lam and Rui (2022) contend that the transnational learning and experiences of skilled migrants do not automatically translate into locally relevant knowledge upon their return. The utilization of this knowledge and its adaptation to local realities are crucial. Fackler et al. (2020) introduce the concept of "knowledge remittances," suggesting that skilled migrants can, in various ways, transfer knowledge back to their homeland, potentially spurring innovation and mitigating the depletion of the nation’s human capital.

Overall, global mobility is seen as increasingly beneficial, aligning talent with opportunities. The ramifications of the worldwide movement of qualified professionals are profound, impacting areas ranging from business and politics to religion, culture, and entertainment (KERR et al., 2016).

These insights into the mobility of skilled professionals the first assumption of this research:

The migration of human capital, characterized by skilled professionals, is associated with the performance and productivity of organizations, regions, and nations. The movement of such professionals, across different modalities, influences the knowledge flow among the involved organizations, countries, and regions.

2.2 MIGRATION, SCIENCE AND INNOVATION

Migration, particularly of highly qualified individuals, has become a prevalent global phenomenon, fueled by globalization and the opening of new pathways for reallocating human capital. This trend has led to an uptick in international migration among workers with advanced education, sparking a burgeoning body of research on the impact of skilled migration on innovation both in host countries and in the countries of origin (KERR et al., 2016; DI IASIO; MIGUÉLEZ, 2021).

The education and human capital of migrants are not merely drivers of productivity; they also play a crucial role in idea generation and innovation, serving as an additional vector for productivity growth (BONGERS et al., 2022). By maintaining connections with their original ecosystems and countries, skilled migrants facilitate the dissemination of knowledge and ideas across companies, regions, and territories (MIGUÉLEZ, 2019). Understanding the dynamics of how innovation processes are integrated within inter-organizational and interpersonal relationships is significantly important to academia, the private sector, government, and policymakers (FISCHER et al., 2022).

Given the pivotal role of innovation in economic and regional development, it is imperative to discern the specific contributions of different migrant groups based on their skills. The relationship between migration and innovation, particularly whether it is positive, is a crucial empirical question. It necessitates examining the roles of highly skilled migrants as a distinct category (PINATE et al., 2022).

Recent trends in international labor mobility, shaped by migration policies in high-income countries, indicate that the migration of certain highly qualified workers, such as

STEM professionals, plays a vital role in bolstering research, development, and innovation activities. Despite this, research on the innovation effects of STEM migrants remains limited. While some studies have explored the contributions of migrant scientists and engineers to innovation, there remains considerable scope for further exploration in this area (BONGERS et al., 2022).

It's essential to acknowledge that patterns of skilled migration vary significantly across different economic sectors. Kerr et al. (2016) found a strong concentration of skilled migrants in specific industries, indicating that their impact on innovation is not uniform across the economy but is instead concentrated in sectors where their expertise is more directly linked to innovative efforts. This is particularly true for STEM professionals, who are often employed in innovation-centric fields and sectors.

The literature on the international mobility of STEM professionals reveals two main streams of research. The first involves studies on the geography of innovation, which examine the role of social ties in facilitating knowledge diffusion and defining its spatial extent, including the connections STEM professionals maintain within their ethnic communities. The second stream focuses on migration and development, investigating the extent to which skilled migrants contribute to innovation in their home countries through international knowledge flows, foreign direct investment, and the entrepreneurial endeavors of returning migrants (BRESCHI et al., 2017).

Migration studies have a rich history of evaluating the benefits of emigration for countries of origin, particularly in compensating for the loss of human capital. Initially, the focus was on the financial remittances of emigrants and their role in capital formation in less economically developed regions. With the increasing prominence of highly qualified migration, recent attention has shifted towards assessing emigrants' contributions to knowledge development and innovation (BRESCHI et al., 2017).

Lissoni (2018) distinguishes four main research themes regarding the direction and geographic spread of knowledge and innovation flows: from origin to destination; from destination to origin; across multiple destinations; and within the destination itself.

Recent studies on migration have aimed to uncover the positive impacts of the emigration of skilled professionals back to their home countries. While initial research primarily addressed financial remittances, there's now a growing focus on the role of highly skilled migrants in transferring knowledge (BRESCHI et al., 2017). The literature suggests three principal mechanisms of knowledge "remittances," which are not exclusive to one another:

a) Ethnically driven knowledge flows, where migrant STEM professionals maintain connections with professional bodies and educational institutions in their origin countries, enabling the exchange of scientific and technical expertise in friendly or formal ways.
b) Knowledge transfers through multinational corporations, facilitated either by internal staff mobility or through cross-company collaboration.
c) Direct contributions from returning migrants, who, upon returning to their home countries, may initiate entrepreneurial ventures in local ecosystems while keeping ties with knowledge sources from their former countries.

The transmission of knowledge, particularly tacit knowledge, inherently requires personal interaction. The exchange of expertise among highly qualified professionals is more effective when there's proximity to related activities, underscoring the need to foster such closeness even in the face of physical distance (CAVIGGIOLI et al., 2020).

Miguelez (2018) investigates the impact of the highly skilled diaspora on patent collaborations between developed and developing countries, finding a significant positive effect. Similarly, Choudhury (2016) examines the influence of migrant managers who returned to India on the patent output of Research & Development centers belonging to 50 North American multinationals in India, concluding that these managers enhance innovation among their local teams by linking them with ideas and resources from U.S. headquarters.

The diaspora of highly skilled professionals plays a crucial role in enabling developing economies to tap into foreign knowledge and align with countries at the technological forefront. Additionally, through the promotion of diversification, knowledge remittances are instrumental in driving innovation and fostering long-term development in these economies (MIGUÉLEZ; TEMGOUA, 2019).

Akcigit et al. (2018) introduced a model focusing on learning and human capital formation via interactions, or knowledge diffusion, with an emphasis on innovation. Prior research predominantly examined the roles of innovation, knowledge, and human capital accumulation as drivers of economic growth. Their analysis underscores the critical contribution of scientists and "inventors" as individuals to the innovation process.

Migrant scientists serve as alternatives to local intermediaries, effectively lowering the barriers for knowledge-intensive organizations to enter foreign markets. Miguélez (2016), for instance, used data on scientists' nationalities from Patent Cooperation Treaty (PCT) applications to assess the impact of migrant scientists on international technological

collaborations between origin and destination countries. The results indicate a positive and significant effect across all countries of origin considered.

Hence, migrant scientists emerge as a distinct asset, being highly skilled individuals with a dense social network and deeply engaged in knowledge creation and dissemination. Additionally, their social connections, often rooted in innovation-centric cities or influential groups, further their impact (Useche et al., 2019).

STEM professionals are part of various social circles and can significantly influence knowledge flows back to their countries of origin. Many innovations are attributed to their expertise. By integrating their peers and employers into diverse social networks, these professionals facilitate access to specialized knowledge and connections. These networks range from sharing basic language and lifestyle insights to providing administrative, legal advice, business contacts, and insights into market knowledge assets (USECHE et al., 2019).

STEM professionals often exhibit high levels of connectivity, organized around larger objectives, blending close interpersonal relationships with high clustering coefficients (LISSONI, 2018). This dynamic allows for the preservation of localized knowledge flows while supporting the geographical dispersion of individuals connected through ethnic or professional ties (LISSONI, 2018; USECHE et al., 2019).

In essence, innovation on a global scale necessitates "knowledge carriers" to facilitate its geographic transfer (BRESCHI; LISSONI, 2009). Consequently, the international mobility of human capital, particularly through highly skilled migrants, has gained recognition as a vital conduit for the global dissemination of knowledge.

This discussion informs the second assumption of this study:

The influence of skilled migrants on innovation is especially pronounced in certain economic sectors, notably those within STEM fields. Thus, the behaviors and contributions of STEM workers become pivotal areas of interest in innovation studies.

2.3 BRAIN DRAIN AND BRAIN CIRCULATION

The mobility of global talent is analyzed through various theoretical and conceptual frameworks, including human capital, brain drain, brain gain, brain circulation, diasporas, and certain entrepreneurial approaches. These perspectives aim to deepen our understanding of migration phenomena (ABOITES; DÍAS, 2018). Specifically, the concepts of brain drain, brain gain, and brain circulation shed light on the mobility effects on regions and countries and their impact on knowledge flows.

Research often focuses on evaluating the negative impacts – such as loss of talent – that countries experience due to the emigration of students, qualified professionals, and academics, typically to more developed nations. This exodus was seen as a depletion of human capital, detrimental to the origin countries left bereft of talent, termed as “brain drain.” From this viewpoint, the brain drain signifies a failure to leverage the potential of skilled professionals in terms of labor contributions, productivity, and tax revenues (BACCHI, 2016; TENEY, 2021).

The discussion around brain drain has evolved into the concept of brain circulation, recognizing not just the loss or gain of human capital but also the exchange of it. Saxenian (2005) significantly contributed to this discourse, proposing that knowledge, skills, and experiences could circulate between regions and countries in a non-linear manner.

This perspective transforms the understanding of global skilled migration into a continuous, multidimensional process that connects the origin and destination countries. Migrants contribute to their home countries by transferring knowledge and skills through various means, such as remote collaborations and participation in international networks, thereby transforming brain drain into brain circulation (BACCHI, 2016; CHRYSOSTOME; NKONGOLO-BAKENDA, 2019).

Initially, in the 1960s and 1970s, brain drain emerged as a framework to explain the transfer of human capital between countries (DOCQUIER; RAPOPORT, 2012; MENDOZA, 2022), focusing on the loss experienced by the origin country.

The Education Resources Information Center (ERIC) defines brain drain as the migration of highly skilled individuals in search of better remuneration, living conditions, and opportunities, which results in the deprivation of essential human capital needed for innovation and knowledge-intensive activities in their home regions (VEGA-MUÑOZ et al., 2021).

Subsequent academic discussions have explored the influence of transnational businesses on regional or national economic development, analyzing the effects of skilled migration from developing to developed countries and considering resource flows, knowledge transfer, foreign investments, and job creation (SANDOZ et al., 2021).

Studies include migrations from Latin American countries to the United States, from Asian countries to the United States and Europe, and from Eastern European countries to Western Europe, indicating a broader pattern of migration towards nations offering more attractive conditions for skilled individuals (RACZYNSKI, 2020).

Docquier and Rapoport (2012) highlight that skilled migration has intensified and accelerated significantly, a trend attributed to globalization. They identify three distinct phases in the study of brain drain, starting in the 1960s with a focus on the global economic benefits of migration, often viewing the impact on migrants' home countries as neutral.

The second wave of research into brain drain emerged in the 1970s, focusing on its impact on the institutional frameworks of countries. This period adopted a more pessimistic view of the effects on countries of origin, introducing market rigidities, institutional imperfections, and other externalities into the academic discourse. Subsequently, the third wave, starting in the 1990s, began to assess the balance between the detrimental and beneficial aspects of brain drain for the home countries of skilled emigrants. This era's contributions emphasize that skilled migration can, under certain conditions, yield benefits for origin countries, especially when considering the economic and technological factors that were the focus of the more pessimistic 1970s studies (DOCQUIER; RAPOPORT, 2012; DI IASIO; MIGUÉLEZ, 2021).

Brain drain represents a significant challenge as it entails the loss of crucial human capital necessary for development and innovation. It can initiate a detrimental cycle of underdevelopment, where the departure of qualified professionals exacerbates the country's challenges, further driving the migration of talent. Conversely, the influx of human capital enhances the situation in another country, thereby attracting more skilled professionals to migrate there (CIUMASU, 2010).

Talented and motivated individuals, representing critical human capital, are inclined to move to countries where they perceive greater opportunities for self-development and success (CIUMASU, 2010). The movement of highly qualified human capital and knowledge tends to be asymmetric, with developed countries attracting talent from developing nations, while the reverse is rare (ABOITES; DÍAZ, 2018).

The counterprocess to brain drain is known as brain gain, referring to the accumulation of human capital in a country through the immigration of highly skilled individuals from less developed nations (CIUMASU, 2010). This phenomenon exacerbates the disparity in human capital, making it "scarcer where it is already scarce and more abundant where it is already abundant" (DOCQUIER; RAPOPORT, 2012).

For destination countries, brain gain represents an augmentation in human capital, utilizing migrants' skills without having invested in their education, to alleviate local skilled labor shortages and enhance their knowledge economies. However, for origin countries, the emigration of highly qualified individuals signifies a loss of investment in education

(TENEY, 2019). Public policymakers face the challenge of addressing brain drain. Solutions must acknowledge global mobility as a fact and consider the benefits of international migration for talented individuals and the communities they join. Recognizing the ineffectiveness of restrictive migration policies is crucial (CIUMASU, 2010).

Additionally, brain drain could serve as an impetus for a country to expedite the development of its human resources, potentially leading to a reverse talent flow that accelerates technological advancement in developing countries beyond pre-drain levels. Overcoming brain drain necessitates substantial effort, resources, and a favorable convergence of political, national, and international factors (CIUMASU, 2010).

The global migration of skilled professionals does not invariably lead to brain drain. Through effectively implemented measures, win-win relationships can be fostered among the countries, institutions, companies, and researchers involved. This collaborative approach facilitates a reciprocal flow of human capital and knowledge, laying the groundwork for the generation of new knowledge (ABOITES; DÍAZ, 2018). Globally, migrants contribute to their host countries by bringing experiences, social networks, business acumen, avenues for foreign investment, and other valuable resources (CZINKOTA et al., 2021; SAXENIAN, 2005).

This phenomenon is also conceptualized as brain circulation or diaspora, acknowledging the continuous movement of human capital across borders within an increasingly globalized economy. This circulation, driven by talents seeking optimal professional opportunities and companies vying to attract such talent, enhances knowledge transfer and innovation in both developing and developed countries (SAXENIAN, 2005).

Saxenian (2012) highlights migrants known as the “new Argonauts,” who facilitate skill and expertise transfer to their countries of origin while maintaining strong links with their destination countries. This shift from brain drain to brain circulation can lead to the diaspora effect, where investment and entrepreneurship in migrants’ home countries contribute to technological diffusion, the enrichment of productive knowledge, and the internationalization of local firms (LIN et al., 2019).

As the dialogue evolved from brain drain to concepts like brain circulation or brain exchange, it underscored the dynamic nature of international skilled migration. This shift implies that migration can enhance human capital both in the countries receiving migrants and in their countries of origin, illustrating the complex, multidirectional flows characteristic of a highly globalized world (MENDOZA, 2022; ABOITES; DÍAZ, 2018).

While the loss of skilled professionals, viewed through the lens of brain drain, raises significant concerns for countries of origin in terms of business growth and economic development, the brain circulation perspective offers a more optimistic outlook. Skilled migrants forge strong ties with global knowledge and capital sources, often returning to their homelands with enriched human and social capital (KERR, 2016).

Proponents of flexible migration policies for skilled professionals highlight the benefits that qualified immigrants bring to native workers with complementary skills. This is particularly evident in environments where professional clusters form or through the positive impacts of immigrant entrepreneurship and innovation (KERR, 2016).

Building upon Saxenian's (2005) propositions, subsequent researchers have explored the positive effects of brain circulation, where transnational business activities benefit both origin and destination countries. For instance, a business incubator in the Netherlands supports transnational entrepreneurs from various countries, facilitating international businesses that create jobs and investments in both the Netherlands and the entrepreneurs' home countries (Sandoz et al., 2021). However, some studies caution that Saxenian's (2012) findings in Silicon Valley may not universally apply to other regions of the world (ABOITES; DÍAZ, 2018).

The migration of skilled professionals presents a dual aspect: it weakens local knowledge networks yet provides an opportunity for talents to engage with and learn from knowledge accumulated abroad. Aboites and Díaz (2018) suggest that this dynamic turns positive primarily when these professionals return to their home countries, thereby integrating external knowledge into the local context.

Investigations into the economic and societal impacts of transnational entrepreneurial activities by skilled migrants have yielded mixed results. For instance, a study on Colombian entrepreneurs in the United States revealed that, in the absence of cohesive transnational networks and adequate governmental support, such activities scarcely influence the economy and society of the origin country (SANDOZ et al., 2021).

Hence, certain conditions are pivotal for the beneficial effects of brain circulation to materialize: (a) the experience gained in the destination country should enhance the migrant's existing knowledge and skills; (b) the skills acquired abroad must be applicable in the origin country, within environments like universities, knowledge-intensive organizations, and high-tech industries; and (c) migrants should be willing and able to assimilate and adapt new practices and skills from the destination country to the context of their home country (Bacchi, 2016).

Returning skilled migrants often enrich their home countries with multicultural experiences, aiding in the knowledge transfer between companies across different nations. Studies indicate that exposure to diverse cultural settings internationally can diminish institutional distance barriers, facilitating cooperation between organizations spread across different locales (LIN et al., 2019).

Loshkariov and Zakharova (2017) posit that engaging skilled migrants in collaborative international research projects can transform brain drain into a synergistic exchange of knowledge, skills, and technologies. Similarly, Schafer and Henn (2018) identify transnational migrants and entrepreneurs as vital connectors within and across entrepreneurial ecosystems. Their ability to transfer knowledge and skills, such as intercultural competencies, is crucial for the development of these ecosystems.

The movement of international talent catalyzes the cross-border flow of ideas and knowledge, as migrants relay insights on products, processes, and technologies to their networks, including former colleagues, family, and friends. This amplifies the knowledge base in their countries of origin and, through the recombination of ideas, positively influences production technologies. Fackler et al. (2020) discuss the nuanced effects of migration on patenting in migrants' home countries, highlighting both direct negative impacts and indirect positive contributions.

Knowledge transfer occurs through various mechanisms in practice. For instance, migrants can introduce new knowledge or technologies, often occurring during interactions at congresses or conferences with peers from their countries of origin. Additionally, the exchange of tacit knowledge is facilitated through close contact among professional colleagues, enhancing the transfer process. Return migration further stimulates innovation in home countries, with skilled migrants frequently initiating startups, thereby bolstering entrepreneurship and innovation within their home nations (FACKLER et al., 2020).

Fackler et al. (2020) explored the impact of the emigration of qualified professionals on patenting levels in their countries of origin, discovering an increase in patenting activities. They attributed this to international talent mobility, which broadens the dissemination of knowledge and technology, as indicated by citations of transnational patents. Key factors in this dynamic include the transfer of tacit knowledge, expansion and enhancement of inventor networks, and return migration.

Their findings suggest that the emigration of talent offers benefits to the countries of origin by reintroducing knowledge. These benefits can be amplified through fostering research networks involving emigrant inventors, such as by organizing local events and

conferences. Governments are also encouraged to develop policies and programs that maintain engagement with the diaspora and facilitate their return when feasible.

D'Ambrosio et al. (2019) examined migrant communities in Spain, concluding that migrants' social capital significantly enhances co-invention processes by lowering knowledge transfer barriers and integrating new knowledge into existing scientific and technological bases. They emphasize the importance of inclusion policies, support for bridge-building associations, and language training in promoting regional innovation through "communities on the move," which facilitate relevant knowledge exchange and collaborative initiatives.

Regarding the attraction of qualified foreign talent, many countries relax visa restrictions and launch recruitment programs. Chile, for example, gained recognition for its Startup Chile program, which offers financial incentives to foreign entrepreneurs to spend six months in the country. This initiative aims to forge global skill and knowledge connections and establish a Chilean "mini diaspora" (KERR, 2016).

While initiatives like Startup Chile, supporting approximately 200 to 250 new ventures annually, demonstrate some success, the overall impact of such programs and policies remains modest compared to the broader migration trends of qualified professionals towards Anglo-Saxon countries (KERR, 2016).

The field of brain circulation studies unveils opportunities for future research. Despite numerous studies highlighting the positive effects of migration on both host and origin countries, Breschi et al. (2017) argue for a need for consolidation within this area. Further investigation is required to comprehend how migrants' social ties in their destination countries extend back to their countries of origin, facilitating international knowledge transfer (BRESCHI et al., 2017; LIN et al., 2019). There is also a call for more systematic empirical evidence on the impact of migration on knowledge diffusion, noting that much of the existing research is focused on the United States, with potential for broader application in other contexts (MIGUÉLEZ; TEMGOUA, 2020).

Moreover, while many studies suggest that international knowledge flows counteract the negative consequences of qualified professional emigration, further research is needed to delineate the mechanisms through which these flows are established and operationalized (Fackler et al., 2020). Nkongolo-Bakenda and Chrysostome (2019) highlight that while the positive and negative impacts of global talent migrations are documented, less is understood about enhancing positive impacts and mitigating negative ones under various conditions.

Additionally, there is an overreliance on patent data when analyzing the local impacts of qualified professional emigration on innovation. This approach may not fully capture

innovative activity since patents represent only initial steps towards innovation and may not be exploited where they are generated (FAGGIAN et al., 2017; KERR et al., 2016).

The relationship between migrants and the local context of global enterprises, particularly within innovation and entrepreneurship ecosystems, warrants further attention. Qualified global migrants, whether entrepreneurs or organizational employees, engage in reciprocal exchanges of experiences and human capital, enriching both themselves and their ecosystems. These dynamic interactions merit deeper investigation (BARON; HARIMA, 2019; DUAN et al., 2021).

Shafer and Henn (2018) emphasize the importance of studying the circulation of knowledge within entrepreneurial ecosystems that include immigrant and transnational entrepreneurs, suggesting a focus on the micro-dynamics of knowledge mobility among transnational entrepreneurs and their arrangements within and across ecosystems.

The concept of diasporas closely aligns with brain circulation but emphasizes the role of family, social, and ethnic ties maintained by migrants with their origins, and the implications thereof. Chander (2001: 1005) defines diasporas as groups dispersed from their homeland but maintaining a sense of transnational community. The literature on diasporas has identified both direct and indirect effects of diaspora networks on their domestic economies, particularly in STEM fields, underscoring their potential to drive entrepreneurship in knowledge-intensive sectors (MIGUÉLEZ; TEMGOUA, 2019; BARON; AKI, 2019).

Diasporas, as “information intermediaries,” facilitate transnational knowledge links, contributing economically, for instance, in international trade. They play a crucial role in enhancing the reputation of their home countries within international business networks and in identifying business opportunities, overcoming cultural, linguistic, and geographic barriers (MIGUÉLEZ, 2018; D’AMBROSIO et al., 2019).

For diasporas to effectively contribute to the development of their countries of origin, strategic links must be established to mobilize and engage diaspora members, requiring the involvement of various entities in the countries of origin to maximize potential interactions (RACZYNSKI, 2020).

Former studies on brain drain and brain circulation, which elucidates the mobility effects of qualified professionals and their impact on knowledge flows, leads to the third assumption of this study:

The mobility of highly qualified professionals does not inherently result in a straightforward loss or gain of knowledge for the countries of origin and destination.

Knowledge flows facilitated by highly qualified professionals' connections can lead to interactive models wherein mobility benefits both the origin and destination territories.

Table 1 summarizes the above-explored theoretical foundations, highlighting specific analytical categories. These categories support the preliminary coding of data, as the next section deeply depicts.

Table 1 – Preliminary analytical categories.

Category	Definition for this study	Subcategory	Key references
Human capital mobility	The cross-border movement of individuals possessing advanced skills, education, and expertise, driven by personal, professional, or structural factors, and resulting in the redistribution of knowledge, innovation potential, and economic capacity across regions or countries.	Global talent mobility. Global migration trends. Multicultural individuals. Individual trajectories.	Hajro et al (2021). Szymanski et al (2021). Kerr et al (2016).
Brain drain	Emigration of highly skilled individuals from their country of origin to more developed countries, resulting in a loss of human capital, technical expertise and innovation capacity for the sending country.	Motivations and factors to migrate. Human capital losses for country of origin. Science, technology and innovation negative impacts for country of origin.	Docquier and Rapoport (2012). Zweig et al (2020).
Brain circulation	The dynamic and multidirectional flow of highly skilled individuals across borders, enabling the exchange of knowledge, expertise, and innovation between countries, and fostering mutual benefits for both sending and receiving countries.	International knowledge and technology exchange. Positive impacts for innovation in both home and host countries. Positive impacts for international business and entrepreneurship.	Saxenian (2005). Breschi et al (2020). Fackler et al (2020).
Mechanisms for knowledge flows	The formal and informal channels, processes and	Diaspora communities. Global networks.	Lissoni (2018). Miguelez and Temgoua

	structures through which knowledge, expertise and innovations are transferred, shared or co-created, particularly facilitated by the mobility and engagement of skilled migrant workers.	Scientific and innovative collaboration practices.	(2020). Miguelez (2018). D'ambrosio et al (2019).

Source: Developed by the author.

In the next section, methodological procedures will be presented.

3 METHOD

This section outlines the methodological procedures selected for this research, directly addressing the stated research problem. The present study aims to investigate how the personal and professional journeys of migrant STEM workers influence brain drain and brain circulation. This research problem can be summarized by the following question: How do the personal and professional journeys of migrant STEM workers influence brain drain and brain circulation?

Subsequently, the research strategies designed to support the methodological procedures and achieve the research goals will be discussed.

3.1 RESEARCH STRATEGY

As discussed in Introduction, particularly in the characterization of the research problem, studies on the relationship between global migration of skilled professionals and innovation reveal significant methodological gaps. Critics argue that traditional methods relying heavily on cross-sectional data from patents, citations, and similar systems inadequately capture the innovation activities of highly qualified migrant professionals (DI IASIO; MIGUÉLEZ, 2021; HU et al., 2022; LAM; RUI, 2022).

While secondary data on emigration and immigration exist across various countries, such as national demographic data, they often present limitations. These limitations include a lack of detail regarding the antecedents and consequences of migrant trajectories (BRESCHI et al., 2020), as well as insufficient classification of migrants' qualifications and occupations. These factors, in turn, contribute to the complex interplay of experiences and cultural influences that shape migration trajectories, evolving ties, networks, and contacts over time. Consequently, relying solely on these secondary data sources provides an incomplete understanding of the phenomenon under investigation.

To accurately capture the effects of global skilled migration on science and innovation, novel approaches are needed to track the flow of individuals across national borders. In this context, social networks like *LinkedIn* can offer valuable data and insights into career trajectories. This allows researchers to map professional movements, roles, and experiences shared by STEM professionals in various countries. Such data can enhance the understanding of brain circulation's impact on countries of origin (BRESCHI et al., 2020).

Therefore, given the methodological gaps identified in the literature, coupled with the overarching goal and research problem of this study, the case study method is deemed the most suitable approach to operationalize the research and achieve the desired outcomes. The following subsection will provide a description of the selected method.

3.1.1 Research approach and method

This research employs the case study method as its primary research strategy. A case study is an empirical investigation of a contemporary phenomenon within its real-life context, particularly when the boundaries between the phenomenon and the context are not clearly delineated (YIN, 2010). This strategy focuses on understanding the dynamics inherent within a unique context (EISENHARDT, 1989).

The case study method facilitates the comparison of theory with real-world events, utilizing diverse evidence obtained from documents, artifacts, interviews, observations, and other sources. By its nature, this method allows for analytical, rather than statistical, generalizations. The case selected for this research is not representative of a statistical sample; rather, it is chosen for its potential to provide in-depth understanding and investigation (YIN, 2010).

Qualitative research aims to develop or contribute to theories. Its objectives include constructing concepts, categories, and relationships between these categories. According to Flyvbjerg (2006), understanding the underlying causes of a problem is often more valuable than merely describing its symptoms or frequency. In case study research, researchers engage closely with data from the outset. This intimate interaction with real-world evidence enables the development of theories that closely reflect reality (EISENHARDT, 1989).

In scientific inquiry, theory-building typically relies on literature, observation, or empirical experience. However, situations arise where knowledge of a phenomenon is limited, and existing perspectives are uncertain, inadequate, or conflicting. In such cases, theory-building through case studies is particularly appropriate, as it extends beyond reliance on existing literature alone (EISENHARDT, 1989).

The unit of analysis in a case study defines the primary focus of the investigation, and it is always determined by the research problem (YIN, 2010). In this study, the unit of analysis comprises the personal and professional journeys of Brazilian migrant STEM workers and their relationship to the effects of brain drain and brain circulation in Brazil. This research aligns with the principles advocated by Eisenhardt about deductive approach, while

also incorporating the guidance provided by Gehman et al. (2018). The research case protocol is presented in Appendix A.

3.1.2 Case selection

Recent data indicate a growing trend in the migration of skilled Brazilian workers to the United States. This migration is fueled by a confluence of factors, including enhanced career opportunities and a superior quality of life compared to those available in Brazil. The U.S., with its robust economy and advanced technological infrastructure, presents great opportunities for Brazilian skilled workers, particularly in STEM fields. Conversely, Brazil experiences substantial losses due to this outflow of talent (Ministry of Foreign Affairs of Brazil, 2022).

Economically, the brain drain from Brazil to the U.S. represents a significant transfer of human capital investment away from Brazil. This exodus also impacts Brazil's socio-cultural landscape, potentially leading to a decline in domestic scientific and innovative capacity. The absence of skilled workers can impede progress in strategic sectors such as healthcare, engineering, technology, and the sciences, thereby widening the gap between Brazil and more advanced economies.

Conversely, the United States, a historical leader in global technological innovation, faces challenges in maintaining its competitive edge due to a potential shortage of STEM workforce. To address these challenges, the U.S. has seen a substantial increase in its STEM workforce, growing by 44.5% between 2000 and 2019. Immigrants constituted 23.1% of this workforce in 2019, up from 16.4% in 2000 (Bureau of Labor Statistics, 2022).

Looking ahead, the Bureau of Labor Statistics (2022) projects that the U.S. will require an additional one million STEM workers by 2030 to meet the rising demand. This scenario highlights the need to not only increase the number of U.S.-born STEM graduates but also to integrate skilled foreign workers to sustain national competitiveness in the global economy. Furthermore, the Brazilian diaspora in the U.S. makes contributions to sectors such as business, science, engineering, and health, demonstrating strong integration and potential for workforce development.

The selection of the U.S. in this case study is grounded in its prominent role as a global hub for technological innovation and scientific research. The U.S. has historically attracted an influx of highly skilled professionals from around the world, including a notable contingent from Brazil (CRUZ et al, 2023). This dynamic makes it an ideal setting to examine

the intricate interplay between brain drain and brain circulation. Furthermore, the U.S. labor market, particularly in STEM fields, presents a compelling case for understanding the factors that drive migration and the subsequent impacts on both the host and home countries. More details about the case will be presented in section 4.

3.2 DATA COLLECTION

Data collection for this study was structured around two primary components: primary and secondary data. Secondary data was compiled from a variety of sources, including public reports, applied research studies, online news articles, and specialized features in magazines and websites. The search focused on documents that provided insights into brain drain in Brazil, the emigration of Brazilian STEM workers to the USA, the lived experiences of Brazilian STEM workers residing in the USA, and the U.S. demand for immigrant STEM workers. These documents proved invaluable in providing a comprehensive understanding of the case, offering rich data, statistical analyses, and a broad overview of the relevant landscape.

For primary data collection, 41 interviews were conducted with Brazilian STEM professionals who had migrated to the U.S. The selection criteria for interviewees required them to be Brazilian STEM workers who had relocated from Brazil to reside in the U.S. To confirm their STEM professional status, their formal educational and professional backgrounds were verified. Following these criteria, an artificial intelligence tool, *Google Bard* (later updated to *Gemini*), was utilized to initiate the process of identifying potential interviewees. A prompt was used to request *Bard* to generate a list of 60 Brazilian STEM workers and their respective American institutions, using publicly available data. *Bard* provided a list, which was then formatted into a table, and each name was subsequently cross-referenced on *LinkedIn*.

During the verification process, it was discovered that many of the names provided by *Bard* presented discrepancies, such as professionals working at different institutions than indicated or those who had returned to Brazil. After processing this data, a refined list of 40 potential interviewees was compiled. Everyone was then contacted via *LinkedIn* messages, where the research objectives were presented, and they were invited to participate in interviews. As interviews were conducted, participants were consistently asked to recommend additional potential interviewees to expand the network of contacts and enhance the snowball sampling effect. Prior to each interview, a free and informed consent form was sent to ensure

participant agreement (see Appendix B). This research was registered on *Plataforma Brasil* and its execution was approved by the Scientific Ethics Committee.

The semi-structured interview technique allows the researcher to capture and understand the perspectives of research participants. Bauer and Gaskell (2008) demonstrate that interviews provide data that allow the development and understanding of relationships between social actors and their real situation. From this, researchers apply interpretative schemes to understand the actors' narratives in conceptual and abstract terms.

> In addition to the broad goals of description, conceptual development, and concept testing, qualitative interviewing can play a vital role in combination with other methods [...] Here, the in-depth understanding offered by qualitative interviewing can offer valuable contextual information to help explain specific findings (BAUER; GASKELL, 2008, p. 65-66).

Most interviews were realized remotely by virtual calls, using *Microsoft Teams*. Just one of them was realized in person. Every interview was transcribed by the platform and revised. The semi-structured interview guide is presented in Appendix C. Table 2 presents the summary of interviews is presented, considering the characterization of the informants.

Table 2 – Characterization of Brazilian STEM migrants interviewed.

Code	Fictitious name	Background and professional field	Gender	Type of organization	City and state	Duration of interview
E1	Miguel	Civil Engineer. Scientist.	Male.	University.	Atlanta, Georgia.	52 minutes.
E2	Melissa	Ph.D. in Animal Sciences. Research and Development Scientist.	Female.	University.	Columbia, Missouri.	70 minutes.
E3	Elaine	Animal Sciences. Assistant Professor.	Female.	University.	Clemson, South Carolina.	56 minutes.
E4	Heitor	Data Engineer.	Male.	Big Tech.	Austin, Texas.	48 minutes.
E5	Amália	UX Research Designer.	Female.	Big Tech.	Austin, Texas.	92 minutes.
E6	Beatriz	Senior Scientist. Bovine vaccine development.	Female.	Multinational Enterprise (MNE). Industry.	Manhattan, Kansas.	58 minutes.
E7	Heloísa	Master in English Literature. Teacher and English's books producer.	Female.	Self-employed in Education	Austin, Texas.	67 minutes.

				based in technology.		
E8	Breno	Industrial Engineer.	Male.	MNE. Industry.	Missouri.	41 minutes.
E9	Bernardo	Designer.	Male.	Big Tech.	Austin, Texas.	59 minutes.
E10	Fernando	Veterinarian. Ph.D. in Animal Nutrition.	Male.	MNE. Industry.	Columbia, South Carolina.	58 minutes.
E11	Renata	Veterinarian. Ph.D. in Immunology and Infectious Diseases.	Female.	MNE. Industry.	Dallas, Texas.	61 minutes.
E12	Daniela	Ph.D in Analytical Chemistry. Assistant Professor.	Female.	University.	Miami, Florida.	98 minutes.
E13	Pablo	Ph.D. in Cell Biology with emphasis on Human Anatomy. Post-doc.	Male.	University.	Dallas, Texas.	33 minutes.
E14	Clarice	Agricultural Engineer.	Female.	University.	Columbia, Missouri.	57 minutes.
E15	Carla	Ph.D. in Organic Chemistry. Scientist.	Female.	University.	Dallas, Texas.	44 minutes.
E16	Wellington	Zootechnist. Ph.D. in Phisiology and Nutrition of Monogastrics.	Male.	MNE. Industry.	Hendersonville. Tennessee.	103 minutes.
E17	Vinícius	Research Project Manager. Ph.D. in Swine and Poultry Nutrition.	Male.	MNE. Industry.	Iowa City, Iowa.	46 minutes.
E18	Marcelo	Ph.D. in Animal Science – Genetics and Breeding. Genetic Research Specialist.	Male.	MNE. Industry.	Hendersonville. Tennessee.	44 minutes.
E19	Fernanda	Ph.D. in Applyed Swine Nutrition. Swuine Nutritionist.	Female.	MNE. Industry.	Northfield, Minnesota.	43 minutes.
E20	Giovana	Ph.D. in Pharmaceutical Sciences, Forensic Science and Technology. Forensic Scientist – Toxicology.	Female.	University.	Houston, Texas.	33 minutes.
E21	Bento	Ph.D. in Animal Science. Statistical Geneticist.	Male.	MNE. Industry.	Hendersonville. Tennessee.	57 minutes.
E22	Joel	Ph.D. in Swine Nutrition. Swine Nutrition and Tech Specialist.	Male.	Industry.	Manhattan, Kansas.	58 minutes.
	Martina	Ph.D. in Cardiology and	Female.	University.	Columbus,	41

E23		Cardiovascular Sciences. Assistant Professor.			Ohio.	minutes.
E24	Pietro	Mechanical Engineering. Composite Design Engineer.	Male.	Industry.	Houston, Texas.	35 minutes.
E25	Iago	Production Engineer. Head of Data Management and Analytics.	Male.	Financial sector.	Washington, Columbia.	41 minutes.
E26	Adriana	Ph.D. in Tropical Medicine, Diagnosis, Epidemiology, and Control of Neglected Diseases.	Female.	Health sector company.	Houston, Texas.	75 minutes.
E27	Cecília	Ph.D. in Production Engineer. Pollution Prevention Specialist.	Female.	University.	Manhattan, Kansas.	59 minutes.
E28	Tainá	Ph.D. in Oncology and Cancer Biology. Adjunct Professor.	Female.	University.	New York, New York.	51 minutes.
E29	Graziela	Ph.D. in Biochemistry and Molecular Biology. Postdoctoral Researcher.	Female.	University.	Boston, Massachusetts.	59 minutes.
E30	Antonella	Computer Engineer. Masters Student and Innovation Lab Member.	Female.	University.	Cambridge, Massachusetts.	50 minutes.
E31	Glauco	Ph.D. in Pharmacy.	Male.	University.	New York, New York.	53 minutes.
E32	Jade	Ph.D. in Food Chemistry. Postdoctoral Researcher.	Female.	University.	Boston, Massachusetts.	49 minutes.
E33	Samuel	Master Degree in Electrical and Electronic Engineer. Software Engineer.	Male.	Technology firm.	Cambridge, Massachusetts.	30 minutes.
E34	Catarina	Ph.D. in Geophysical Sciences. Associate Professor and Consultant.	Female.	University.	Manhattan, Kansas.	50 minutes.
E35	Manuela	Ph.D. in Pharmacology. Research Assistant and Project Coordinator.	Female.	Institutes.	Boston, Massachusetts.	44 minutes.
E36	Davi	Ph.D. in Chemistry. Postdoctoral Fellow.	Male.	University.	Cambridge, Massachusetts.	38 minutes.
E37	Lívia	Ph.D. in Grain Science. Assistant Professor.	Female.	University.	Manhattan, Kansas.	38 minutes.
E38	Rodrigo	Ph.D. in Chemistry.	Male.	University.	Statesboro, Georgia.	61 minutes.

E39	Brenda	Ph.D. in Bioscience and Biotechnology. Postdoctoral Researcher.	Female.	Institute.	New York, New York.	51 minutes.
E40	Arthur	Industrial Engineer.	Male.	Industry.	Santa Monica, California.	59 minutes.
E41	Verônica	Ph.D. in Biomedicine. Postdoctoral Researcher.	Female.	Medical Center.	Los Angeles, California.	45 minutes.

Source: developed by the author.

Considering the dataset of the interviewed individuals in this study, 41 Brazilian STEM workers who have migrated to the U.S., it was found a rich diversity of backgrounds and experiences, highlighting the multi-dimensional talent pool that has moved from Brazil to many U.S. states, mainly driven by academic and industrial opportunities. Most interviewees had lived in the US for between 2 and 10 years at the time of the interview. Next, more details about the interviewees' profiles.

- 53,65% of individuals are affiliated to universities or research institutes, representing professors and scientists in different academic positions. These individuals span a range of scientific disciplines, including animal sciences, chemistry, cell biology and pharmaceutical sciences. This is consistent with a typical migration trend of skilled workers seeking advanced research opportunities and better facilities, which are more readily available in the U.S. than Brazil. The geographical distribution of these scientists spans from Florida to Texas, passing through states in the north and center of the country, showing that their expertise is spread in diverse academic environments across the country.
- 29,27% of the interviewed individuals work in the industry. Their specializations cover areas such as vaccine development, animal nutrition and genetics, with an important performance that impacts industry practices, particularly in animal health and food productivity. Brazilian talented individuals underscore the USA's capacity to leverage specific knowledge in critical fields to both national and global food systems.
- 17,08% of the interviewed individuals work in technology fields, specially performing in Big Techs, as well in other sectors like financial, health and education.

Interviews were conducted until theoretical saturation was reached, at which point no new relevant themes or insights were emerging from the data. Thus, an important concept to highlight is that of triangulation. In qualitative research, this concept involves adopting multiple perspectives on a given phenomenon. The most commonly used form of triangulation is the search for different sources of evidence. Thus, a study is not dependent on a single main data source, but has different perspectives on the same object of study (YIN, 2010).

To achieve source triangulation, this research incorporated secondary data, including reports from governmental and non-governmental organizations concerning migration, technical studies on skilled migration, reports, news articles, laws, and regulations related to qualified migration, as well as scientific articles and books.

Publicly available data on Brazilian STEM workers who have migrated to the United States exhibit significant limitations in detail, a common challenge worldwide. This lack of detailed data impedes the development of a comprehensive profile of skilled migrants and their activities. Consequently, this study has supplemented secondary data with primary data collected through semi-structured interviews, aiming to enhance the understanding of the role of individual migrants in the phenomenon studied.

3.3 DATA ANALYSIS

Given the willingness of highly skilled professionals to migrate (human capital mobility), the efforts of emerging countries to mitigate human capital losses (brain drain), and the attempts of global nations and companies to leverage worldwide knowledge diffusion (brain circulation), the data analysis was designed to maximize the insights gained from the collected data. By integrating the previously established research categories with the data collection instruments, a logical and structured sequence was created, effectively bridging theoretical and empirical aspects, what is shown in table 3.

Table 3 – Research categories and data collection.

Category	Subcategory	Data and evidence collection	Key references
Human capital mobility	Global talent mobility. Global migration trends. Multicultural individuals.	Secondary data (reports, news, public information). Interview questions: What barriers or	Hajro et al (2021). Szymanski et al (2021). Kerr et al (2016.

	Individual trajectories.	difficulties did you encounter in securing employment in your field in the USA? What are the biggest advantages and disadvantages of being a qualified migrant in the USA? After securing your job, what strategies did you adopt to optimize your integration into the professional environment?	
Brain drain	Motivations and factors to migrate. Human capital losses for country of origin. Science, technology and innovation negative impacts for country of origin.	Secondary data (reports, news, public information). Interview questions: What factors were decisive in your decision to migrate abroad? Please provide your academic background, the organization you work for, your current position, and how long you have lived in the United States? Do you intend to return to Brazil one day? When and why?	Docquier and Rapoport (2012). Zweig et al (2020).
Brain circulation	International knowledge and technology exchange. Positive impacts for innovation in both home and host countries. Positive impacts for international business and entrepreneurship.	Secondary data (reports, news, public information). Interview questions: Do you maintain a professional contact or network in Brazil, even from a distance? If so, do these two networks connect in any way? Do you play a role that contributes to this?	Saxenian (2005). Breschi et al (2020). Fackler et al (2020).
Mechanisms for knowledge flows	Diaspora communities. Global networks. Scientific and innovative collaboration practices.	Secondary data (reports, news, public information). Interview questions: Are you able to transfer	Lissoni (2018). Miguelez and Temgoua (2020). Miguelez (2018). D'ambrosio et al

		any knowledge/technology acquired from your experience abroad back to Brazil? How? Do you participate in any collaborative projects or work that involves professionals from your field in Brazil? Can you talk about them? Would you like to contribute more to Brazil in some way? What barriers do you face in this regard? How could the chances of this contribution be increased?	(2019).

Source: Developed by the author.

Consequently, the presented categories were further delineated into codes and sub-codes to facilitate the analysis of documents gathered from both primary and secondary data sources. For this purpose, *Atlas.ti* software was employed, which simplifies the creation of codes and the organization of documents. The documents were coded using thematic analysis, grouping text segments that correspond to the themes within the categories outlined in the table above. *Atlas.ti* is widely recognized for its utility in data analysis for qualitative research. It enables the consolidation of all collected evidence into a unified database, where these sources are converted into documents and imported into the program.

Thematic analysis is a versatile method used in qualitative research to identify, analyze, and interpret patterns of meaning. It is a flexible tool that can be applied across various research paradigms. It ranges from positivist approaches that emphasize coding reliability to more qualitative-focused versions that prioritize an organic approach and the researcher's active role in theme development. This approach has become widely recognized and utilized (CLARKE; BRAUN, 2017).

The goal of thematic analysis is not merely to summarize data but to identify and interpret key features, guided by the research question, which can evolve during the analysis. It effectively captures patterns within and across data, reflecting participants' lived experiences, perspectives, behaviors, and practices (CLARKE; BRAUN, 2017).

During the data analysis, *Atlas.ti* was initially configured with codes derived from the categorization previously established in this study. As the coding process progressed,

particularly with primary data, additional codes were necessary to capture emerging relevant elements from the empirical field, while still respecting the established categorization structure. These new codes were essential for documenting relevant insights that arose from the fieldwork.

Table 4 presents an updated categorization of the research, incorporating both the initially defined codes and the new codes that emerged from the empirical data. The data coding required the creation of new subcategories, while some others did not prove consistent considering our findings and were eliminated from this new version. Therefore, table 4 presents a revised version of the table of research categories, retaining empirically confirmed ones and adding new categories that emerged from the fieldwork.

Table 4 – Research categories considering empirical fieldwork.

Category	Subcategory	Key references
Human capital mobility	Multicultural individuals. Personal and professional trajectories. Family and personal topics. Integration process.	Hajro et al (2021). Szymanski et al (2021). Kerr et al (2016).
Brain drain	Motivations and factors to migrate. Human capital losses for country of origin. Science, technology and innovation negative impacts for country of origin.	Docquier and Rapoport (2012). Zweig et al (2020).
Brain circulation and mechanisms for knowledge flows	International knowledge exchange. Benefits for country of origin. Global networks. Ethnic ties and personal connections. Scientific and innovative collaboration practices. Diaspora communities.	Saxenian (2005). Breschi et al (2020). Fackler et al (2020). Lissoni (2018). Miguelez and Temgoua (2020). Miguelez (2018). D'ambrosio et al (2019).

Source: Developed by the author.

According to research categories considering empirical fieldwork, family and personal topics, integration process, and ethnic ties and personal connections are subcategories that

emerged inductively from empirical evidence and become part of the research categorization. The next sections will present more details about these topics.

The following section will present the study's results.

4 FINDINGS

We organized the description of the findings in four sub-sections. In the first sub-section, we describe economic, institutional, and political elements that provide an understanding of the back scene wherein the professional journeys of Brazilian STEM workers take place. In the second sub-section, we describe Brazilian STEM workers' narratives and professional journeys, including details related to identity and adaptation in the host country elements. In the third and fourth subsections, we depicted data related to the brain drain and brain circulation phenomena.

4.1 BRAZIL AND U.S. CONTEXTS

The analysis of migrations between Brazil and USA must consider trends in global migratory movements. The *WorldWide Immigration Trends Report* (2024) reveals that many regions around the world face labor scarcity problems driven by the high average age of the population, declining birth rates, and a lack of human capital in certain professional areas. Thus, the immigration of skilled talent is seen as a solution, with countries adopting immigration policies that prioritize the entry of highly educated talent into their territories. Western countries have implemented expressive flexibilizations to address their human capital needs. For instance, a survey of 39.000 employers across 41 countries reveals that, while globally, there is a 77% difficulty in finding qualified talent to fill positions, in the U.S., this figure stands at 75% (*WorldWide Immigration Trends Report*, 2024).

Historically, Brazilian migration movements represent responses to economic crises. The first periods of emigration in Brazil were in the 1960’s, which was intensified by the 1980’s because the hyperinflation that the country experienced at these times (Cruz et al, 2023).

The migration of Brazilian STEM workers abroad has become a significant trend over the last decade, driven by a combination of economic, sociopolitical, personal and professional factors. According to the Pew Research Center (2021), Brazil with its uncertain economic conditions and underfunded research structures, has seen a notable exodus of such workers. For example, the lack of investments in science and technology research encourages migration trends. Federal spending on science has been cut since 2013, leading to a 20% decrease in the number of research scholarships between 2015 and 2019 (Ministry of Science, Brazil, 2020).

Migration trajectories for Brazilian STEM workers often involve educational channels. Many Brazilian professionals have moved abroad for higher education opportunities, especially for Master and Ph.D. programs, and subsequently transition into the American workforce, taking advantage of their valuable skills. Furthermore, skilled workers like Brazilian STEM can apply to some specific visa programs, such as H-1B and EB visa in U.S., offering a route to employment through sectors experiencing workforce shortages (U.S. Citizenship and Immigration Services, 2023).

Over the last decade, Brazil has been recording record numbers of emigration of skilled workers, particularly to countries such as the United States, Portugal, New Zealand, and Australia. Essentially, the reasons revolve around the search for higher salaries abroad, better career opportunities, improved quality of life, balancing safety and higher levels of education for their children. Moreover, with the increase in polarization in recent years, political motivations have also become factors that contribute to the decisions of talents emigrating from Brazil to abroad. (Correio Braziliense, 2023).

Brazil has been experiencing the loss of valuable skilled professionals across various fields, particularly in strategic sectors such as scientific research and information technology. These sectors are critical, and their lack of talent has the potential to hinder the country's economic growth and development. Following the Covid-19 pandemic, Brazil observed a notable increase in the emigration of skilled professionals. Many media outlets, such as *Correio Braziliense* (2022) and *Revista Exame* (2018), have highlighted factors such as career opportunities, the search for safety, quality of life, as well as economic, social, and political aspects that influence the decision of STEM workers to migrate abroad.

It appears to be more pronounced among younger skilled workers. According to the international consultancy Fragomen (2022), the unemployment rate among professionals aged 15 to 29 is approximately 20%, compared to a national average of 8.30%. The consultancy notes that this age group has its own timing: if they do not find or foresee good opportunities in their home country, they tend to migrate abroad in search of better job prospects. Close to 47% of young Brazilians aged 15 to 29 would leave the country if they could, reflecting a significant disillusionment among the youth regarding the country's current economic and social situation. (POLETTO et. al., 2021).

Regarding Brazilian scientists, Brazil faces great challenges due to government budget cuts in science and research funding, what is observed since around 2013 and the subsequent years, with some alternances. It means that such financial constraints not only diminish scientific progress but also contribute to the brain drain phenomenon, as Brazilian scientists

seek better opportunities and funding conditions for their research abroad (Nexo Journal, 2021).

In the Brazilian context, there is a concrete issue that has contributed to the brain drain, particularly among scientists: from 2014 to the post-Covid-19 pandemic period, successive cuts in public funding and resources allocated to science and technology were implemented. For instance, just in 2021, the federal government cut over 600 million reais from the budget of the Ministry of Science, Technology, and Innovation to reallocate to other areas. This trend was repeated in other years as well. Clearly, this scenario has contributed to the migration of qualified scientists from Brazil to other countries, particularly in fields of knowledge that require advanced resources and infrastructure to carry out their work. In a country unable to provide such conditions, scientists are compelled to relocate to continue their research (Brazilian Society for the Advancement of Science, 2021).

Brazil is a country where investment in science and technology is below 1% of its Gross Domestic Product (GDP), whereas this percentage reaches 2.4% in more economically advanced countries (Nexo Jornal, 2023). The phenomenon of brain drain is global; however, a country like Brazil is particularly concerned with this issue, as it has struggled in recent years to retain professionals in critical sectors such as science, technology, and education (Jornal da USP, 2023). In 2022, there was a record number of Brazilian applications for visas and residency abroad, surpassing pre-pandemic levels (Fragomen, 2022).

By losing valuable human capital in the field of science, Brazil faces worrisome uncertainties regarding its future in science and technology. Currently, the country’s master's and doctoral scholarships are insufficient to cover the cost of living that students face in major cities. Additionally, after completing their studies, scientists encounter further challenges due to successive research funding cuts and infrastructure gaps. In parallel, Brazilian emigration for work purposes increased by 184% between 2011 and 2018. Similarly, the emigration of Brazilian scientists to the United States grew by 40% between 2019 and 2020 compared to the 2017–2018 period.

It's important to discuss the long-term implications of this trend of “talent’s exodus”, where Brazil is "financing" wealthier countries by losing its qualified workforce. Reverse this trend would require expressive changes in funding policies and strategies to create partnerships with Brazilian scientists abroad. However, as funding issues continue and the Brazilian scientific community struggles, this exodus is likely to persist, leaving Brazil’s science and technology sectors critically understaffed and underfunded (Brazilian Academy of Sciences, 2022).

Some data are symptomatic in illustrating the deficiencies in Brazil's science and technology system. Funding for CAPES dropped from R$ 5.13 billion in 2012 to R$ 2.48 billion in recent years. Similarly, the CNPq budget was cut in half, decreasing from R$ 2.04 billion to R$ 1.02 billion (Brazilian Academy of Sciences, 2022). Graduate scholarships had not been adjusted since 2013, receiving an increase only in 2023.

The Brazilian government has recognized the need to reverse this brain drain and has implemented programs aimed to improve working conditions for the skilled workforce (CNPq, 2024). However, considerable efforts are still required to retain human capital and attract Brazilian talents back from abroad. Migration of Brazilian STEM workers is shaped by a complex interplay of economic and political landscapes, professional opportunities and conditions, and educational pathways. As Brazil seeks to improve its position in the global innovation scenario, addressing brain drain issues is crucial to retaining and leveraging its scientific and technological capabilities.

In this study, the main factors identified by the interviewees as reasons for emigrating from Brazil align with the factors highlighted in the secondary data. Namely, financing, resources, infrastructure, and job opportunities are critical factors that "push" many Brazilian STEM workers abroad.

Almost all interviewees report working in activities consistent with their formal education in U.S., reinforcing what the literature on skilled migration reports about the differences in conditions between skilled migrants and those with low qualifications. As barriers faced when immigrating to the U.S., most cite language, visas, and legal restrictions that immigrants encounter until they reach the level of citizenship. These restrictions impact many simple everyday activities, such as renting a house or opening a bank account.

According to the data collected from the interviews, career opportunities are one of the main factors driving the migration of Brazilian STEM workers to the United States. Many interviewees report expressive dissatisfaction with the Brazilian job market, citing a lack of growth prospects, structural constraints, and limited opportunities in their fields of expertise. Some accounts reflect a widespread sentiment that professional development in STEM fields in Brazil is hindered by factors such as the low appreciation of technical knowledge, high institutional bureaucracy, and difficulties in accessing relevant positions in academia and industry.

Beyond the pursuit of better opportunities, interviewees also mention a desire to expand their professional horizons and work in environments that value knowledge and educational qualifications. In the U.S., Brazilian STEM migrants find leading institutions and

universities with substantial investments in education and research, well-equipped laboratories, and networks that broaden their professional perspectives as well as foster the development of new competencies.

Another recurring theme in the interviews is the stark difference between Brazil and the U.S. in terms of infrastructure and investment in research and the technology sector. Numerous accounts highlight these aspects, with STEM workers emphasizing the high level of investment, particularly in American universities, as well as the greater availability of funding for projects and research. In practice, this means that for many STEM migrants, migration represents not only an opportunity for career advancement but also a chance to participate in and contribute to high-impact scientific and technological projects.

Table 5 presents evidence from the interviews regarding issues of professional growth, recognition, infrastructure, and investment.

Table 5 – Professional growth, recognition, infrastructure and investment in the U.S.

Source in interviews	Report (empirical evidence)
Miguel (E1)	*"... I came with her before she entered so we could visit the possible universities, [...] I also visited the ones I was accepted to see where I would go. Man, when you visit a campus here, it's just... There's no comparison, man, I can go to any of them."*
Miguel (E1)	*"You can't do science with crumbs, right? You can't do science working three jobs, having to teach in the morning, afternoon, and evening, having to teach in a prep course, having to... How do you expect a guy to do even more research?"*
Melissa (E2)	*"... Because of the money, it is difficult to compete with American values, as well as with technology, which can be applied here. Why? Because of the investment."*
Melissa (E2)	*"In these areas, spending on education or development is planned. So, money is allocated just for that. At the first conference I went to, I said, "Wow, I'm going to set aside money here, see about the ticket, how are we going to pay for this registration fee?" Then my boss said, "What do you mean? I'm the one who pays for you."*
Melissa (E2)	*"... Label-making machine online, right? I was like, wow, it's cheap, I'm going to buy it for the lab. Because that's what I did in Brazil, I didn't have the money to buy a machine. I bought it and left it there, I didn't say anything. A year later he (the boss) noticed [...] and asked, do you still have the receipt? Send me the receipt and I'll reimburse you."*
Melissa (E2)	*"The wage gap is huge."*
Elaine (E3)	*"... funding opportunities for research... I closely followed the difficulties in obtaining financial resources in Brazil."*
Elaine (E3)	*"... I was looking at places that provide a greater investment in research, so that I could have greater opportunities to develop my career."*
Heitor (E4)	*"... Even if I spend more, I know that the cost of living is higher, but one thing is having 5% of my salary left here is worth much more than having 40% of my salary left in Brazil, so that was also a factor, right?"*

Heitor (E4)	*"The structure of an American university is something that drives you crazy, like, it has a lot of money, but I think the knowledge itself is very comparable."*
Breno (E8)	*"Linkedin, for example, is a tool that, man... In the first 3 months that I was here, I updated the city where I live, but I hadn't updated mine... I hadn't changed my position on Linkedin at all, just the place where I lived. In 3 months, I received four offers to be an engineer at other companies here."*
Bernardo (E9)	*"I don't think it's even a question of lack of opportunity, I don't think it's just a question of opportunity, it's about being able to be in a place where things are fairer, right?"*
Fernando (E10)	*"Sometimes here you can do a lot more things in less time."*
Renata (E11)	*"I think one of the reasons I have trouble seeing myself returning to Brazil is the fact that professionals are valued in Brazil. A professional who is qualified, who has a doctorate, right? I know that if I get there, I will have trouble finding a job. I will have trouble being valued financially as much as I am here."*
Pablo (E13)	*"In research we have fewer barriers to achieving things, so I think that this is an advantage, that we arrive here with a lot of desire and we have a lot of ideas..."*
Pablo (E13)	*"Yes, it is very important, because it is basic research, basic science in biological sciences, molecular biology, cellular biology, structural biology. Yes, we end up being very dependent on technologies and chemical reagents, antibodies and animal models as well. So, we need a large structure to be able to support and maintain this type of animal model, equipment and we need the goods, the materials to be able to do things, right? So it turns out that it's a... We need a lot of resources."*
Pablo (E13)	*"When you leave your country and come to a place where things really work, where you have resources and you can put your ideas into practice and make them concrete, it's very different, you know?"*
Joel (E22)	*"Yes, advantages, definitely, so what I said, worked hard: the chance of doing well is much greater than if this scenario were in Brazil."*
Antonella (E30)	*"I think that being at Harvard provides me with a very privileged networking environment."*
Catarina (E34)	*"We have much more freedom to do things the way we want. It's about seeking funding. In fact, seeking external funding is highly encouraged. And there is a part of the university that is exclusively dedicated to helping researchers do all the administrative work of seeking and controlling grants. This external funding, then, provides support for research, administrative and financial support for research, which is wonderful, something we don't have in Brazil, which is sorely missed, right?"*
Davi (E36)	*"There are many things that I have to weigh up, mainly, I think that having a son born here, and of course I would like to give him a better opportunity and, whether you like it or not, you would have to stay here to have better access to institutions, like better infrastructure and everything."*
Brenda (E39)	*"First, I would say faster access to equipment and reagents, right? Because here it's a lot, it's even unfair, right, people? You order an antibody and it arrives in 2 days. In Brazil, it takes 6 months, there's no way around it, right?"*
Brenda (E39)	*"Yes, I think it's the ease of developing and being able to use more advanced methodologies than in Brazil. Sometimes, the infrastructure of universities is not a strong point, right? These*

	are research laboratories that are struggling to stay alive, not to mention anything else, right? Basically that, and I think that all of this certainly culminates in finance. I think there's much more investment here, there's much better infrastructure here. You have the opportunity to develop and learn other more advanced techniques, which certainly makes a huge difference, right?"

Source: Developed by the author.

Infrastructure for work is particularly critical for scientists in fields that require specific resources and equipment for their activities. Interviewees from these fields report significant difficulties in Brazil regarding this matter, such as the lack of adequate equipment, outdated laboratories, and shortages of research supplies. These limitations directly impact the productivity and innovation capacity of STEM professionals, prompting them to seek career alternatives in countries with better working conditions, such as the United States.

Brenda (E39) reports, for example, that an experiment that would take six months to get the reagents in Brazil can be obtained in just two days in the U.S. This also extends to bureaucratic processes, which are more efficient in the U.S. and significantly slower in Brazil, as well as economic factors, where acquiring necessary supplies in Brazil is challenging, whereas in the U.S., such acquisitions are carried out with ease.

In the other side, the U.S. has historically held a technological edge over global competitors. However, this advantage is at risk due to a perceived shortage in STEM workforce. According to NDIA's Emerging Technologies Institute (2023), 82% of American companies in the defense industrial consider hard to find skilled STEM workers. By 2025, Chinese universities are expected to produce over 77.000 STEM Ph.D. graduates annually, while the U.S. universities are expected to produce 40.000. This evidence indicates that U.S. can face critical challenges about competitive standing in global technology and innovation sectors.

Immigration could be a crucial part of a solution for the U.S., which remains a more attractive country for foreign-born talent, in comparison to China or Russia, for example. Nevertheless, strict immigration policies, even for skilled workers, hinder the retention of these foreign talent. Current legislation imposes limitations to immigrant skilled workers, which affects foreign STEM graduates in U.S. This situation forces approximately 90% of foreign STEM graduates to leave U.S. after their education, decreasing this workforce in the country (NDIA's Emerging Technologies Institute, 2023).

A solution for competitive standing in innovation sectors could be related to U.S. immigration policies. The country has been more attractive country for foreign-born talent, in

comparison to China or Russia, for example. Nevertheless, strict immigration policies, even for skilled workers, hinder the retention of these foreign talents. Current legislation imposes limitations to immigrant skilled workers, which affects foreign STEM graduates in U.S. This situation forces approximately 90% of foreign STEM graduates to leave U.S. after their education, decreasing this workforce in the country (NDIA's Emerging Technologies Institute, 2023).

Immigrants made up 23,10% of all STEM workers in U.S., increasing from 16,40% in 2000. The overall number of STEM workers in U.S. increased by 44,50% from 7,5 million in 2000 to over 10,8 million in 2019. In general, immigrant STEM workers in U.S. are highly educated, with 86,50% holding at least a bachelor's degree in 2019, compared to 67,30% of local STEM workforce. Moreover, 49,30% of immigrant STEM workers held an advanced degree, notably higher than 21,80% among U.S.-born counterparts. The share of immigrant STEM workers varies a lot by state. For example, immigrants make up more than 42% of all STEM workers in New Jersey and almost 40% in California (American Immigration Council, 2022).

STEM workers in U.S. usually earn higher median wages compared to non-STEM occupations. In 2019, according to Pew Research Center (2021), the median annual earnings for STEM jobs were about $77,400, compared to $46,900 for non-STEM jobs. However, it's important to say that there are substantial differences within STEM professions, with Asian men earning the highest and Black and Hispanic women earning the lowest. In this sense, it's clear that there is a disparity between genders in STEM occupations. For example, women represented only 27,20% of immigrant STEM workers in U.S. in 2019 (American Immigration Council, 2022).

According to forecasts from the Bureau of Labor Statistics in 2022, it is estimated that by 2030 the U.S. will need approximately one million additional STEM workers in relation to the numbers of 2020. To address this escalating demand, there is a need to augment the pool of students in STEM fields at both undergraduate and graduate levels. Although enhancing U.S.-born individuals in STEM fields is essential, demographic trends suggest that incorporating foreign-born STEM students and workers will be crucial for the country to meet its future labor demands and keep its competitiveness in the global economy (American Immigration Council, 2022).

In 2021, the Brazilian population in U.S. was estimated in about 1,9 million individuals. This demographic is mainly composed by migrants from southeast Brazilian regions, like Rio de Janeiro (32,67%), São Paulo (30,67%) and Minas Gerais (9,66%) (MRE,

2021). The educational level of Brazilian migrants is notably high: 92,55% then have completed higher education in Brazilian universities, split between private (50,28%) and public (42,27%). Only 5,96% have studied in American universities, indicating that Brazilian migrants' workforce to USA is formatted with Brazilian investments (Cruz et. al, 2023).

According to a survey conducted by Cruz et al (2023), Brazilian migrants in U.S. predominantly work in sectors like business and law (41,15%), engineering, production and construction (13,59%), health and welfare (11,55%), education (4,84%), natural sciences, math and statistics (3,91%), computing and IT (2,79%) and agriculture, silviculture, fishing and veterinarians (1,68%). Moreover, employment of Brazilian migrants in U.S. is robust, with 42,02% solely working and an additional 16,87% both working and studying. These numbers indicate a strong integration into the U.S. labor market, where Brazilian professionals not only find employment opportunities, but also enhance their educational level in American institutions.

In the next section, the findings related to human capital and the trajectories of Brazilian STEM workers in the U.S. will be explored.

4.2 HUMAN CAPITAL: THE JOURNEYS OF BRAZILIAN MIGRANT STEM WORKERS

Interviewees suggest that for Brazilian migrant STEM workers there are two mainly ways entering into U.S. labor market: academy and industry. These two ways have substantial differences, but STEM workers can alternate between one and another. Sometimes, academia works like an entrance gate for immigrant STEM workers, and after some time part of them shift their careers to the American industry.

Some personal and professional trajectories of Brazilian STEM migrants who moved to the U.S. will be briefly presented. The aim is to highlight the paths of Brazilian STEM workers with nuances that only qualitative research can capture, and to show how these trajectories contribute to the effects of brain drain and brain circulation through human capital, making the research findings more humanized and tangible.

The first trajectory to be shared is that of Melissa (E2). She graduated in Veterinary Medicine and completed her Master's degree in Brazil. She wanted to pursue an academic career; however, upon finishing her Master's, she witnessed a significant reduction in available scholarships due to the cancellation of several funding calls. She experienced many financial and structural challenges within Brazilian academia: *"I wanted to stay in academia,*

but I just couldn't see a way forward." As a result, she decided to invest her efforts in applying for a Ph.D. opportunity in the U.S. For her, the fact that she was unmarried and did not have children at the time made the decision easier. She was accepted into a Ph.D. program in Animal Sciences at the University of Florida and later transferred to the University of Missouri-Columbia, where she completed her doctorate.

Melissa (E2) conducted research on pulmonary immune responses to viral infectious diseases in pigs, as well as virology and animal, molecular, and cellular biology. After completing her Ph.D., she began a postdoctoral fellowship at the University of Missouri-Columbia as a way to continue her research while earning a salary, as the postdoc position provided financial support. After establishing herself in the U.S., Melissa got married there and maintains some connections with Brazil to encourage other Brazilian colleagues to seek international experience in her field. At the time of the interview, she was planning to transition from academia to the American industry and continue her career in the U.S.

Fernando's (E10) trajectory reveals the nuances of a multicultural individual within the global context in which STEM talents are embedded. A graduate of the São Paulo State University (USP), his field is animal sciences. He was working for a large company in the Brazilian industry but left to pursue his Ph.D. in the U.S. and has not returned to Brazil since. A decisive factor for his decision to remain abroad was the perception that a Ph.D. is much more valued in the U.S. than it would be in Brazil. He also spent time in Scotland working for a multinational company before returning once again to the U.S.

Fernando (E10) expresses great satisfaction in exploring new cultures while advancing his career. He is another Brazilian STEM migrant who entered a doctoral program in the U.S. and later transitioned to working in the American animal nutrition industry. He comments that in his field, industry positions offer better salaries than academic ones. He is highly satisfied with his current role and maintains frequent interactions with teams in Brazil, regularly engaging in technical discussions, sometimes in person, and other times via teleconferences. At the end of his interview for this study, Fernando proudly showcased his collection of keychains representing all the countries he has visited through his work: 95 countries. *"I measure my success by this... There's no price tag."* (Fernando, E10).

Another compelling journey is that of Wellington (E16), Ph.D. in Physiology and Nutrition of Monogastrics. He completed both his Master's and Ph.D. in Brazil and subsequently worked in the industry at a large Brazilian food company, where he built a successful career and eventually reached management positions. In 2015, he was hired by a major American company in the same sector, and at the time of the interview, he was serving

as Global Director of Nutrition Programs: *"Basically, my role is to be a scientist within a private company"* (Wellington, E16). He also acts as a co-advisor at public institutions in Brazil and financially supports several doctoral theses in the country as a form of collaboration, given his interest in the data being generated. His decision to migrate was due to *"a combination of personal, political, and work-related conditions"* (Wellington, E16).

Wellington (E16) was married and had a child when he migrated to the U.S. He felt it was the right moment to make the move, considering his age, his son's age, the political and economic situation in Brazil, and some of his frustrations with the performance of science in the country. In addition, he had long nurtured the desire to have an international experience and to boost his career. At the time of the interview, he was extremely satisfied with his current professional status and believed he could contribute significantly to Brazil, as he holds considerable influence in his field and is able to navigate both academic and industry environments in both the U.S. and Brazil.

Joel (E22) holds a Ph.D. in Physiology and Nutrition of Monogastrics, with all his academic degrees obtained in Brazil at a federal university. During his Ph.D. in Brazil, he spent a doctoral internship at an American university. He would have liked to complete his entire doctorate abroad, but due to a health issue in his family, he was unable to do so. During his doctoral internship, he noticed several aspects that caught his attention, such as the faster pace of research, greater access to resources, and lower levels of bureaucracy compared to his university in Brazil.

Joel's (E22) definitive migration occurred when he moved to the U.S. to undertake a postdoctoral fellowship. At the time of the interview, he was conducting his postdoc in one of the top three swine nutrition research groups in the world. Even while living in the U.S., he co-hosts a podcast with another Brazilian professional, producing technical content in Portuguese that is accessed by other Brazilians. Through conferences and professional interactions in the U.S., he has expanded his network with both American and Brazilian colleagues. He noted that his financial life is more stable in the U.S. and, as of the interview, had no plans to return to Brazil.

Martina (E23) holds a Ph.D. in Cardiology and Cardiovascular Sciences and works as an Assistant Professor at an American university. She is another Brazilian STEM worker who came to the U.S. for a postdoc and ended up staying abroad. Her initial plan was to return to Brazil, but for personal reasons, she remained in the U.S. What initially attracted her to migrate was the opportunity to work in the lab of a professor who had been an inspiration to

her in her field. She would have the chance to work closely with someone she greatly admired.

She completed her specialization at the second-best hospital in the U.S. and acknowledges the importance of having been inserted into a highly qualified network in her field, which allowed her to meet influential and prominent figures who significantly contributed to her international career. In addition, she is the co-founder of a non-governmental organization that promotes the formation of networks among Brazilians abroad, aiming to create opportunities for mutual support and exchange among Brazilian migrants.

Graziela (E29) holds a Ph.D. in Biochemistry and Molecular Biology and currently works as a Postdoctoral Researcher. She completed all her academic background at Brazilian public universities. During her Ph.D., she spent one year as a visiting doctoral scholar in the U.S., where she was highly productive and was informed by the department that they would like her to return for a postdoctoral position. After completing her doctorate in Brazil, she returned to the U.S. and is now conducting postdoctoral research in the field of genetics at Harvard University.

In the U.S., she is part of the leadership of a group called PUB (an acronym for Brazilian researchers and university students), which organizes events and connects Brazilian scientists and artists, with a focus on scientific dissemination and multidisciplinarity. She has an extensive network of Brazilian scientists abroad and also maintains ties with the Brazilian scientific community. In her words, *"there isn't a single day I don't assist a Brazilian who is in Brazil and needs something, or is asking for help... or wants to exchange ideas about something..."* She notes that she is able to transfer knowledge to Brazil, but in an organic way, and she would like to be able to do this in a more structured manner.

Antonella (E30) is a Computer Engineer. At the time of the interview, she was pursuing her Master's degree at Harvard and was also a member of the university's Innovation Lab. She completed her engineering training in Brazil, and her area of specialization is artificial intelligence. She is an entrepreneur and owns her own AI consulting startup, with most of her clients being Brazilian. Her family also owns a business, and she maintains strong professional ties with Brazil.

She describes herself as passionate about knowledge and is pursuing that through her international experience, while also having the opportunity to be close to highly influential mentors in her field: *"when you go to lunch, and you end up sitting at the same table as the guy who invented Java, right?"* While she receives valuable contributions from her professors to help grow her business, she is also increasingly contacted by professionals and companies

in Brazil interested in her expertise in artificial intelligence, especially through her social media channels. Additionally, she was featured in a series of reports by one of Brazil's major television networks as one of the Brazilian minds excelling abroad in the field of artificial intelligence.

Arthur (E40) is an industrial engineer who graduated from a federal university in Brazil. He experienced rapid career advancement working in multinational corporations in Brazil, which provided him with substantial expertise. However, he expressed to his last employer, a global automotive giant, that he preferred to pursue international experiences over rapid vertical advancement.

Subsequently, he was transferred to an American division of the company, following an invitation from a global director he had met during a visit to Brazil. Arthur (E40) accepted the challenge and joined a new team in the U.S. At the time of the interview, he had recently left this position, as his girlfriend also resides in the U.S., albeit in a different state. Consequently, he prioritized being closer to her, relocated to California, and ultimately departed from the company. He explains that he is currently on a sabbatical in the U.S., expanding his professional network and looking for new opportunities in the country.

The professional trajectories and career choices of STEM migrants often intersect with their personal and family life paths. The decision to migrate frequently involves both convergences and divergences within the family. Married life and family were frequently mentioned in the interviews as decisive factors in the choice to emigrate, postpone migration, or return - or not - to Brazil.

Wellington (E16) moved to the U.S. with his entire family and carefully considered his son's age before accepting the relocation, setting a clear limit for this decision. Giovana (E20) met her American husband while completing her doctoral internship program in the U.S. She returned to Brazil to complete her Ph.D. and fulfill all academic commitments. Later, she went back to the U.S. to reunite with him and continue her academic career there. Amália (E5) had her daughter in the U.S. together with her Brazilian husband (also a STEM worker) and believes she will not return to Brazil - not even upon retirement - so she can live close to her daughter in the U.S. Martina (E23) married in the U.S. to a husband of another nationality, and this, along with her professional life, is another reason why she does not wish to return to Brazil.

Marriage and relationships are relevant factors in the migration process of Brazilian STEM workers to the U.S. The decision to migrate involves family conversations, often between spouses, who must align their personal and professional goals, career plans, and the

well-being of their children. On the one hand, there is a pursuit of better living conditions. On the other, the emotional weight of being distant from family and friends who remain in Brazil is significant. Another recurring issue is that many times one member of a couple migrates for a specific professional opportunity, and the other simply accompanies them. In such cases, couples arrive in the U.S. with a job offer for one partner, while the other must wait some time to establish themselves professionally. This is the case for Amália (E5) and Bernardo (E9), as well as for Heitor (E4) and Heloísa (E7).

Amália (E5), who migrated to the U.S. due to a job opportunity offered to her husband, explains that her career had to take a few steps back before it could begin progressing again:

> *"Again, I feel that I am behind in my career. I am at the stage of my career at 34, which I think is more normal for 27-year-olds, you know? So, you are delaying your entire career, because even though I came with an MBA, with a bachelor's degree, in order to be considered for the positions I wanted, which was research in technology, I had to do a master's degree here, even though I already had the knowledge. So I think that is the biggest disadvantage. It is the delay, in quotes. I feel that, with rare exceptions, almost every immigrant is on a timeline that is behind the average worker in that area."* (Amália, E5).

Missing family and friends from Brazil is a factor that consistently accompanies the migratory experience of Brazilian STEM workers in the U.S. Since the decision to migrate, for most of them, was driven by professional and career-related opportunities, family and personal matters must be reconciled with this choice. Over time, this becomes a type of emotional pain that migrants must learn to live with, though it can be eased by more frequent visits to Brazil and by communication technologies. Some interviewees shared that they would not have liked to leave Brazil but felt compelled to do so due to career opportunities, as is the case of Giovana (E20) and Cecília (E27), among others.

Another aspect identified in the empirical evidence is that many Brazilian STEM migrants move to the U.S. without a clearly established long-term plan. Since their entry point is often a temporary professional opportunity, such as a postdoc, Ph.D. program, or an unstable job, and because U.S. visa processes are quite complex, migrants' outlooks tend to shift over time. As Brazilian STEM migrants encounter new challenges and opportunities in their journey in the U.S., they adjust their plans accordingly. Initially, they may not know whether they will be able to stay in the U.S. long term, but over time, they adapt their lives as

their careers evolve. This is the case of Manuela (E35), Brenda (E39), Artur (E40), and Verônica (E41).

Table 6 presents some selected excerpts that illustrate the influence of personal and family factors in the migratory experience of Brazilian STEM professionals.

Table 6 – Influence of personal and family factors on the migration experience.

Source in interviews	Report (Empirical evidence)
Fernando (E10)	*"For those who are Latin, in the Brazilian case, we still have this strong connection with family and friends."*
Fernando (E10)	*"Most of them [Americans] have no friends and no friends at the job they are at the moment. And sometimes when they change jobs, that friendship also kind of disappears... They don't have that strong connection, they are a little colder."*
Fernanda (E19)	*"We like the friends we made and that doesn't mean we won't come back, but that's not what we think. We don't have a plan for 10 years from now. We think about staying here [in the US], but it was something that developed organically. We didn't come with many plans and we saw how we adapted."*
Fernanda (E19)	*"I have a 2 and a half year old boy, so every night I'm having dinner with him, every night I'm putting him to bed, and that's been better for me than I imagined it would be in Brazil, considering some of the people I know in Brazil. I don't know if my job would be like that in Brazil, you know?"*
Giovana (E20)	*"The factor that really weighed the most was [my American husband]. It was the fact that we wanted to be together and because there were many more opportunities for me to go to the U.S. than for him to go to Brazil, right? It was always my dream to work in forensic science, I tried for a long time in Brazil and I couldn't do it either. So even if [my husband] didn't exist, I probably wouldn't work in forensic science in Brazil."*
Joel (E22)	*"My advisor wanted to... And I really wanted to go abroad for a PhD because I saw several friends doing PhDs here in the United States and being very successful, and learning a lot. But I had a health problem in the family, which made me very reluctant to leave, and so I told my advisor: I'm going to stay for my PhD, but I want a sandwich period."*
Martina (E23)	*"An opportunity arose to apply for a research grant, which was specifically for Brazilians, to spend some time here in the United States. And then, with this research grant, I ended up coming to do my postdoctorate and, in fact, my intention was to return to Brazil, but then life happens and I ended up deciding to stay in the United States for family reasons."*
Pietro (E24)	*"Because my entire family is in Brazil. So that ends up taking me to Brazil, right? That's my personal interest. I like to go because I like to come back, be with my family and bring knowledge, but from a professional point of view, I think that if you have the knowledge, you can take it to Brazil, right?"*
Iago (E25)	*"In 2021 [year of migration], I was before 40. I have a 5-year-old daughter. At the time, she was 5 years old when they made me the offer [...] And I understood that although I was in a very interesting moment within the bank, with possibilities for professional growth [...] I understood that at that moment I needed to value the balance between personal life and professional life more".*

Iago (E25)	*"If I wanted to, eventually, if I wanted to return to Brazil after spending 10 years in the United States, I would still be returning at an age that would be a little more difficult, but I would still be able to find a new job. I would be close to 50, right? In an executive position, and my daughter would have had 10 years of exposure to a second language that would give her, without a shadow of a doubt, the possibility of adopting the second language as a native speaker, right? So, I thought it was an interesting combination and it made a lot of sense for us."*
Iago (E25)	*"It's something personal, right? Because I barely saw my daughter, and today I see my daughter grow up and play with her. My relationship, my marriage has improved significantly because of all this, so I think you'll find other pleasures and other activities other than just the professional side, right? [...] It's the personal aspect, continuing the way it is, it also helps me to continue, right?"*
Adriana (E26)	*"My migration was not a scientific migration, not a planned one. It wasn't because, in reality, it was my husband who was transferred and my husband is a geoscientist , [...] so he was transferred from the Rio office to here. And I was doing my doctorate, I still had a year of research ahead of me, but I had my 3-year-old son with me and I really didn't think much about it. We were in a process there, in 2017, we were taking money out of our own pockets to keep students in the laboratory. Many projects were continued, but without funding, so it was something that I didn't think much about. I said, look, there's no prospect here as a researcher at [the Brazilian institution]."*
Adriana (E26)	*"Husband is being transferred, son needs his father. I need my husband, I want to keep my family together, so I'm going. And then I ended up coming as a spouse, you know?"*
Cecília (E27)	*"I'm a bit of a strange case, because I never had any intention of coming to the United States. It was never my dream to do a doctorate or come live in the United States. I had graduated from college and what happened was that I met my boyfriend at the time and he was moving to the United States and he was also Brazilian. And I ended up coming because of that, so that was, let's say, the biggest motivating factor."*
Tainá (E28)	*"When I decided to come, I decided to prioritize my relationship, so I focused on vacancies that were here, right? At universities in New York, which has a lot of universities, right? So that's a good thing [...] In academia, in Brazil, but given the 3 or 4 negatives that I received, I combined it with the fact that my husband had moved here and decided to look for opportunities here [in New York]."*

Source: Developed by the author.

These factors also seem to shape the outlook of STEM migrants, as they become accustomed to adopting a more flexible vision of the future, acknowledging the uncertainties of their migratory condition and the fact that their needs and decisions may change over time. Working conditions, visa status, and even unforeseen personal or family circumstances may require them to change their lives once again, as mentioned by Fernanda (E19): *"You might start working and hate it. You can't adapt to the climate, you miss your family, or someone*

gets sick, and then you have to go back." Accounts like this demonstrate how migratory experiences are fluid and subject to personal variables that can change everything.

Finally, certain personal values and opinions also influence the migration of STEM workers: quality of life, (de)valuation of the currency, and the political context emerge as some of these values. Professionals such as Graziela (E29) and Davi (E36) emphasize how much they value quality of life, safety, and well-being as key pillars in their decision to migrate and to remain abroad. Meanwhile, Heitor (E4) and Bernardo (E9) comment on how they perceive a greater purchasing power with the U.S. dollar compared to what they had in Brazil with the *Real*. Lastly, Heloísa (E7) and Wellington (E16) mention that Brazil's sharply polarized political context also influenced their pursuit of opportunities abroad.

Table 7 presents some excerpts illustrating these personal values.

Table 7 – Personal values and opinions that influence migration of STEM workers.

Source in interviews	Report (Empirical evidence)
Heitor (E4)	*"But these things contribute, then, to the search for a new job and the political issue. And also the perspective of a professional future in Brazil [...] The issue of retirement, start doing some calculations. You see that the math won't add up. And the issue of the value of your money."*
Heitor (E4)	*"For me, it's a very clear calculation, right? In a little while, how many days do I have to work to buy a computer? How many days does my work cost me a good vacation, right? This relationship abroad, in Brazil, in Europe. It, the money is worth more, right? So, in a little while, even if I spend more, I know that the cost of living is higher, but one thing is having 5% of my salary left here, that's worth much more than having 40% of my salary left in Brazil, so that was also a factor, right? A financial factor of quality of life that I had."*
Heitor (E4)	*"This decision [to migrate] together with [wife]... I'm married, we, all decisions end up going through both of us. We concluded that it would be good for both of us."*
Heloísa (E7)	*"I think there are a lot of people who must have left Brazil at the time of [the former Brazilian president], just as there were a lot of people who left now with [another former Brazilian president]."*
Breno (E8)	*"... But being able to pay for a quality school, being able to provide security, having quality healthcare, if I think about the purchasing power I had in Brazil, to be able to provide for my family, for my daughter, for my wife."*
Bernardo (E9)	*"The big question I think ends up always being the bigger picture, you know? Which is the question of security and the question of the value of things."*
Pablo (E13)	*"We can pay the bills, we can have quality of life, because I say that our money is worth it here, so that is a very good thing, and it won me over a lot."*
Wellington (E16)	*"I say that it was a situation [the decision to migrate] of personal, political and working conditions combination".*
Wellington (E16)	*"Guys, because my wife and I talked a lot, we had a family dream and my son was approaching 10 and I knew I wanted to put a limit on that. I didn't personally want to move past 40, so I put a time*

	limit on it."
Wellington (E16)	*"As a politician, I knew, because I was in a big company, that the following year would be a disaster. I kept that in mind and understood that the US was experiencing a shortage of professionals in my area. It was something that I really researched, understood, saw that it was a reality and thought: this is the opportunity."*
Graziela (E29)	*"Some factors made me migrate [...] One would be the quality of life, right? The search for a better quality of life abroad."*
Davi (E36)	*"I think what makes me less likely to return to Brazil is the issue of security. Compared to the city where I live, I think that is just a very strong point here. I feel very safe going out without any problems, like, I have never suffered anything, no robberies, nothing [...] I was born there, I grew up there, but I don't feel as safe as I do here and that is something that is a very strong factor for me".*

Source: Developed by the author.

In the next section, findings about adaptation and identity of Brazilian migrant STEM workers in U.S. will be explored.

4.2.1 Adaptation and identity

Two relevant characteristics for the success of STEM migrants in the host country are flexibility and cultural adaptation. Many interviewees demonstrate the traits of so-called multicultural individuals (as proposed by Szymanski et al., 2021), as they develop the ability to understand and embrace cultural conditions different from those of their country of origin. As Miguel (E1) points out, the immigrant is often someone *"more open to understanding others,"* a quality not always found in individuals who have never had to radically shift their life perspectives as migrants do.

For many interviewees (Heitor, E4; Amália, E5; Fernanda, E19; Samuel, E33), adaptation and integration into the host country occur intuitively. However, there are also some conscious choices made along the way that significantly influence this process. First, adapting to and accepting local formal and social norms is essential. This pragmatic approach allows STEM migrants to minimize acceptance barriers or interpersonal conflicts, particularly at the beginning of their new lives. When a migrant has had a previous international experience, it tends to make the adaptation process less abrupt, as reported by Miguel (E1), Fernando (E10), and Antonella (E30).

Nevertheless, multiculturalism does not mean abandoning one's cultural roots. On the contrary, it involves reconciling different cultural backgrounds acquired throughout life and using them effectively. Although many strive to emulate local practices, such as the clear

separation of professional and personal life (a strong feature of the American work environment), they also preserve elements of their cultural identity. For instance, improvisation and high adaptability at work are important and recognized strengths among Brazilians (as noted by Amália, E5; Vinicius, E17; Graziela, E29), and familiarity with Latin languages and cultures gives Brazilian STEM workers certain advantages when working with those countries. The ability to navigate across different cultural frameworks is a factor that makes STEM migrants particularly valuable in global work environments.

Table 8 presents some empirical findings supporting these observations.

Table 8 – Multicultural individuals: flexibility and cultural adaptation.

Source in interviews	Report (Empirical evidence)
Miguel (E1)	*"These are cultural experiences, right? That Americans don't necessarily have... It's that idea that others adapt to me and that's it. And when you're an immigrant, I think you have this thing... You're much more flexible in the sense that you can understand others differently. I think in a much more open way, I imagine."*
Miguel (E1)	*"I did an exchange program in Germany, so that was my first shock of this question of, well, is it bad? It is bad! You deal with it and live your life being rejected when you have to be..."*
Melissa (E2)	*"And then, if the person has generally had experience with other Brazilians, I generally see it as positive in the sense that, like, the person says, wow, I like to work, they are motivated... Like, jack of all trades now."*
Heitor (E4)	*"And the American, he completely separates everything. He won't talk to you about personal issues or any issue that might generate a little more controversy. He sees it as completely separate from work and he sees his coworkers as coworkers."*
Heitor (E4)	*"Don't expose yourself too much. In Brazil, we have this thing where, if something funny happens, someone makes a joke. Here you have to be very careful, because people might like it or they might think you're clueless. So I've been taking care to actually be quieter, more silent, and for me, it's difficult, because I'm a person who talks a lot."*
Heloísa (E7)	*"So I think I'm good with people, I'm good at dealing with people from different backgrounds and so on. I think I can apply this characteristic of mine as a teacher to life here, so to speak."*
Heloísa (E7)	*"I like the United States and I think I learned that the United States, that a lot of the stereotypes that I had, a lot of the things that I had, the prejudices that I had, that the United States, I kind of, I don't know, I kind of destroyed them, because I discovered that the United States is not just what I thought it was my whole life."*
Breno (E8)	*"Here it's either 8 or 80, there's no middle ground... It's very rigid, so bringing a little bit of Brazilian knowledge... into the business... Man, this is an exchange that really enriches the business. And that's what we're trying to do here today, right?"*
Bernardo (E9)	*"The relationship with the rest of the teams and people, everything was very good, I think because it is a very multicultural issue, right?"*
Fernando (E10)	*"You will be learning a lot about a different culture. You are exposed to knowing, experiencing their culture. If you earn*

	reasonably well here, it is the place for you."
Renata (E11)	*"Looking at it this way, looking at myself, first of all it's an absolutely enriching experience, right? Both knowing how to speak a new language fluently, having the experience of living in a new culture. It gives you much greater interpersonal skills than if I hadn't come here or hadn't had this opportunity."*
Pablo (E13)	*"In our laboratory, where we have different nationalities together, the staff ends up being more receptive to everyone, so I started to integrate a lot and because I am Brazilian, especially from Minas Gerais, I have this way, it is easier to get close to people and try to communicate."*
Pablo (E13)	*"I think this made things easier, so I always took some time away from my work to have a coffee and I tried to talk to other students to get involved and during the weekends I tried to go out to places to meet other people so I could be a little more cohesive, immersed in the culture, both in the park, in the social area and in the work area."*
Clarice (E14)	*"Yes, yes, because Brazil was considered one of the worst countries to import from due to the bureaucracy, right? So, only we, being Brazilian, understand this bureaucracy and can work with it, you know?"*
Carla (E15)	*"Yes, I think we have a broader background, from different cultures, because it's usually not the first time someone has come here, right? So we have the ability to adapt more easily and everything."*
Carla (E15)	*"Yes, we live in a completely different culture in some ways... So I think I had to change my mind, I had to accept that the culture is different from Brazil, that certain things are different..."*
Fernanda (E19)	*"I would police myself to try to imitate what other people did, how they did it, for example, how did people complement each other? How did people interact, like, at lunchtime, you know, everyone goes to lunch together, right? How did people talk during work hours, I would pay more attention."*
Joel (E22)	*"I see a lot of people here, Brazilians here in the United States, who can't disconnect from Brazil, in terms of feeling, you know, too much... You know that thing about the soccer player who missed the beans from Brazil, you know? Dude , there are beans in the market here too, it's not that, it's something else. Beans are just a synonym for what you want to say. So I think it's a little bit of that."*
Joel (E22)	*"... It's about understanding and... Not criticizing the guys' culture, it's about being interested, you know? Why do guys eat at 6 pm? Look, how interesting, why do guys do that? You being interested, getting involved, it's kind of like turning the key yourself, and stopping wanting to compare it to your way and thinking that your way, your culture is right and the rest is wrong. That's an important point."*
Joel (E22)	*"I did a little bit of homework, trying to understand Kansas a little bit more... What are the people of Kansas like, compared to the rest of the people in the other states? I really like maps, so... I wanted to know a lot, like what the city is like and why is there a river here? What was it like in the past?"*
Iago (E25)	*"I think that first we add different perspectives of a reality that has come together. And even though I work for the development of Latin America, I have many relationships with American people in fact... I interact a lot with people who don't necessarily come from the same background, so for us this adds an interesting component, which is the component of diversity, of realities, of experiences..."*

Cecília (E27)	*"I see, for example, an advantage, the diversity thing. We are used to dealing with different people, dealing with different cultures, so we adapt very well. Some companies are able to recognize this, but not everyone has this mentality, you know? But the truth is that we don't have much difficulty adapting. We are used to it."*
Tainá (E28)	*"One thing I really like is dealing with the training students and new generations of scientists, which is something he gives me complete freedom to conduct in the way I think is best. But in general... They really like Brazilians, they really like the dynamic we have in our work, right?"*
Davi (E36)	*"I can bring a different point of view to the company, or a different one from the culture that they are used to with Americans. Another vision too, maybe because I went through this whole process, starting in Brazil, with this infrastructure, I might value the equipment, everything more. I know how much effort it takes to be able to come and do an analysis, because I might not be able to do it in Brazil. [...] I think that this ability to perhaps communicate with other people from other cultures is also easier as an immigrant."*

Source: Developed by the author.

Adapting to communication styles and social interaction is one of the most significant challenges faced by Brazilian STEM migrants in the U.S. The necessary transition from a more expansive and informal Brazilian style to a more reserved and pragmatic environment requires substantial adjustment. For example, Heitor (E4) reports that in Brazil it is common for humor and informal conversations to be part of the work environment. However, he realized that in the U.S. he would need to be more cautious and careful when telling jokes or expressing opinions, as there was a risk of being misunderstood. Like him, many STEM migrants adopt a more observant stance until they better understand the social codes of their new context.

The same applies to Fernanda (E19), who carefully observed how her American colleagues interacted in everyday situations, such as during lunch or in work meetings, to adjust her behavior to the social expectations of her new workplace. This was a conscious initial effort to avoid discomfort and to integrate more smoothly. Despite these efforts, in general, Brazilian STEM migrants still carry a distinctive mark when it comes to communication, as they are typically very open to establishing new interpersonal relationships.

Many interviewees, such as Vinicius (E17), argue that Brazilian STEM migrants possess a unique ability to solve problems creatively and to work with limited resources, which becomes a valued trait by American employers. He explains that because many Brazilian STEM workers are used to working in resource-constrained environments, they tend to develop a more hands-on and solution-oriented approach to challenges, something he does

not always observe in American professionals, who are more accustomed to environments with abundant resources and infrastructure.

Identity redefinition is a central issue in the behavior of STEM migrants in the host country. Interviewees demonstrate an ability to intelligently combine elements of Brazilian culture with those of American culture, to optimize their integration process abroad. However, there is a fine line between strategically maintaining positive aspects of Brazilian culture and resisting acceptance of American culture. Joel (E22) explains that STEM migrants who fail to show interest and effort in engaging with a new culture may lose prestige among their American peers. Thus, a genuine effort to integrate and understand the local culture is essential, accepting differences while reinforcing one's multicultural identity.

In the next section, findings related to brain drain phenomenon in Brazil will be explored.

4.3 BRAIN DRAIN

According to part of the interviews, the migration of Brazilian STEM workers to the U.S. has the potential to generate a progressive disconnection between migrant workers and their professional networks in their home country. Some respondents mentioned that their connections with former colleagues, professors, and partners who remained in Brazil gradually weakened over time after they left the country. This discontinuity is partly attributed to physical absence and the focus on new demands and professional commitments in the international environment.

This disconnection from professional networks in Brazil directly affects the possibilities for partnerships and collaborations between migrant STEM professionals and their peers in Brazil, limiting the creation of synergies that could benefit the country. Moreover, this dynamic suggests a systemic difficulty in Brazil in fostering an integrated environment for knowledge exchange between its skilled emigrants and local professionals. Additionally, there is an apparent absence of Brazilian mechanisms to encourage the maintenance of global professional networks, leading to missed opportunities to leverage the contributions of its talents abroad, even remotely.

Table 9 presents some accounts that illustrate the difficulties some interviewees face in maintaining professional networks in Brazil after migrating to the U.S.

Table 9 – Disconnection of STEM workers from their professional network in their home country.

Source	Report (empirical evidence)
Miguel (E1)	*"So, I imagine that the network in Brazil... I still have people's phone numbers, but I don't keep in touch with them. No, I don't talk to them that often, no [...] I 'm really bad at keeping up active communication, so I think it's less because I moved to another country and more because I'm not there on a day-to-day basis (in my previous job)."*
Melissa (E2)	*"I don't have much contact with people from Brazil, so, one point I would say would be to talk about forming a collaboration in the sense, like, now let's do a collaborative project, and let's go, really collaborate, send a student here and make this transfer... There's no such part, so it's more unilateral in that sense."*
Heitor (E4)	*"Yes, it gets weaker over time, with each passing day, right? We are moving away from there and settling more here (in the U.S.)"*
Heitor (E4)	*"I feel a very strong barrier because my friends who still work in Brazil, I don't see them envisioning, for example, coming here. So, I don't see much connection with the people who are here, who live the reality here. They don't intend to return to Brazil either."*
Amália (E5)	*"I can hardly see myself activating people I worked with at company "Y" [...] I think they are a good professional contact, but, other than that, unless they are friends [...] But then it is friendship and not networking, but I don't see myself activating that contact."*
Beatriz (E6)	*"It's not very strong, just some veterinary professors that I had more contact with during my undergraduate studies. But apart from that, I think maybe because I didn't work in Brazil, I moved here right after I graduated."*
Breno (E8)	*"Man, a few people, but yes, there are some people there that I worked directly with..."*
Pablo (E13)	*"I consider that I have professional friends and research friends there (in Brazil) because my research, as it is outside the scope of what I was doing, and as I do not have any collaboration with Brazil now here, so I no longer have professional contact with anyone. I only have friends and acquaintances who are in the areas, doing their postgraduate studies, working in the same way that I am here, but no professional contact."*
Glauco (E31)	*"I believe that the Brazilian network you maintain when you come here depends a lot on the network you had before you left. So, that's my point of view. I know people who have maintained their network with Brazil, who will even strengthen these ties precisely because they have the endorsement there. There's something there saying that you're at an American university [...] This is in the United States, and this also generates interest from Brazil in continuing to network with you."*
Glauco (E31)	*"I never had many connections before leaving Brazil [...] I feel that it depends much more on the connections you had before, so my wife, she continues to have incredible connections, because she has always been a person who had connections, she simply enhanced that, reinforced it".*
Davi (E36)	*"No, I don't know [professionals in Brazil]. I know very few people who are in chemistry in Brazil. I know my undergraduate professors better, but other than that, I don't keep in touch with the professors at other universities."*

Source: Developed by the author.

The loss of human capital in Brazil is intensified by the high qualifications of STEM migrants. Most interviewees completed their education in Brazil, many of them at federal universities supported by public resources. Furthermore, the quality of Brazilian education is highly praised by many respondents. For example, Wellington (E16) recalls what an American professor once told him: *"You have a very high selection threshold in Brazil, and when I take someone from there, I am already getting the best of the best."* However, this excellent education ends up benefiting foreign markets. The departure of these highly qualified professionals further reduces the already scarce workforce in these fields in Brazil.

In this scenario, Brazil exacerbates its deficiencies in strategic sectors essential for a country's development in the 21st century, such as science, technology, and innovation. With the outflow of talent and the reported difficulties in maintaining an international connection with their home country, this situation represents a concrete obstacle to Brazil's economic and scientific advancement.

Table 10 presents the interviewees' perceptions about the education and qualifications of Brazilian STEM workers in the U.S., highlighting the extent of the intellectual loss that Brazil experiences due to the migration of these professionals.

Table 10 – Perceptions about education and qualifications of Brazilian STEM workers.

Source	Report (empirical evidence)
Heitor (E4)	*"I even like to tell people in Brazil that the knowledge of Brazilian workers is at a very good level. People, sometimes we have the feeling that in Brazil we are dumber, we don't know and so on... I think that Brazilian professionals are very good, they know a lot..."*
Heitor (E4)	*"Even in academia, I consider that my higher education in Brazil was very similar to that here in the United States, with less structure"*
Martina (E23)	*"In fact, my education in Brazil was largely led by women. I had very strong female role models and I had female advisors, teachers, and researchers, many very strong women in my life. So it never crossed my mind that there was anything I couldn't do, because as a woman I never had a problem with that."*
Brenda (E39)	*"I think this is the advantage because I think that here, as I said, a little of our education in Brazil prepares us for everything, so I think we are very resilient, in the sense of being able to think outside the box, because in Brazil, precisely because we don't have this financial support or even this resource, the infrastructure, we are forced to".*

Source: Developed by the author.

Most interviewees express a desire to contribute to Brazil. However, some respondents highlight that despite their willingness to help, the absence of structured mechanisms to

facilitate this contribution hinders a more significant impact. In her interview, Beatriz (E6) stated: *"... I feel bad for not being in Brazil, you know? I feel like I'm not helping my country, you know?"* Similarly, Amália (E5) commented: *"I would love to do something for Brazilians... but I don't really know how that would work, what the mechanism would be..."* These accounts suggest a certain misalignment between the potential of Brazilian STEM migrants to collaborate and the lack of strategies and policies in Brazil to integrate and leverage this knowledge.

Many interactions between STEM migrants and Brazil occur reactively or spontaneously, such as when colleagues or institutions reach out requesting support. However, many interviewees lament the absence of more structured partnership initiatives. Additionally, professionals often encounter institutional and practical barriers that make it difficult to contribute to Brazil in a more consistent manner. Two key conditions stand out in this regard. First, most interviewees are not yet in a position of autonomy within their work environment to have decision-making power to establish collaboration or institutional partnerships with Brazilian organizations. The accounts of Glauco (E31) support this observation:

> *"I wish I had that power or that potential, that ability to develop collaborations or bring that knowledge back to Brazil. Unfortunately, I'm in the position of being a researcher who is associated with another researcher... I don't have the autonomy to do that in any official way. What you can do is in your free time, through science communication or informal collaborations"* (Glauco, E31).

Second, there are significant differences in working conditions between Brazil and the United States, particularly in fields that require substantial resources and equipment. Consequently, interviewees in certain areas see an additional challenge in collaborating with Brazil, as differences in infrastructure, resources, and funding make exchanges between American and Brazilian teams more difficult. To better illustrate this, the following statements from Pablo (13) stand out:

> *"I'm kind of unsure how a research project with Brazil would actually work, because yes, it would be somewhat difficult from the standpoint of, I mean, replicating some of the experiments we do here. We have so much ease here — sometimes the work functions almost like a facility. I know Brazil doesn't have the same infrastructure, so I think doing it would be a bit more complicated, right?"* (Pablo, E13).

Therefore, the set of situations outlined so far ultimately restricts the collaborative potential of STEM migrant workers with their home country. Although there is a willingness to contribute to Brazil, the barriers faced discourage some interviewees from achieving this goal, limiting this potential despite the interest and openness expressed by STEM migrants.

When asked about a possible return to Brazil, most interviewees indicate that this is a remote possibility. The reasons vary, encompassing aspects related to professional fulfillment, institutional factors, family considerations, economic conditions, and quality of life. Many point out that, even with a solid academic background and international experience, Brazil does not offer opportunities that align with their skills and knowledge. A striking example is that of Verônica (E41), a Ph.D. in Biomedicine, who states:

> *"Yeah, I didn't want to, like, go back to being a lab technician, because I had already worked as a lab technician in 2019, when there was no doctoral fellowship [...] It was a technician year, but, like, come on, I have a Ph.D., so [...] going back to being a technician again, although, if that were the only option, fine, but then this opportunity [to migrate] came up. So we decided to give it a shot"* (Verônica, E41).

From a professional standpoint, the primary barrier to returning can be summarized as the fact that STEM migrant professionals do not see in Brazil the conditions necessary to fully perform the work for which they were trained. Three main reasons are most frequently cited for this: first, particularly in highly technical fields such as Biomedicine, Animal Science, Chemistry, and others, a significant number of professionals graduate each year in Brazil, yet the Brazilian job market does not absorb all of them. Many mention that public service examinations are the only employment opportunities available, but these exams are infrequent and offer very few positions.

Second, for many fields that rely on experiments, equipment, and laboratories, Brazil presents an institutional landscape burdened with bureaucracy, which creates obstacles for research and projects, delaying and complicating the achievement of significant results. This reality is entirely different in the United States, which offers a more agile institutional environment with fewer bureaucratic hurdles.

Finally, the disparity in resources and investment in science, technology, and innovation between the U.S. and Brazil is substantial. As a result, once STEM migrant workers gain access to greater resources, they tend not to consider returning to Brazil, as they

not only achieve higher salaries but also have the opportunity to practice their professions with higher quality and feel that their contributions have a greater impact.

Regarding the decision to return to Brazil or not, personal and family considerations play a dual role: they can either weigh in favor of returning or reinforce the decision to remain abroad. In other words, family-related factors could motivate some STEM migrants to return to Brazil, although none of the interviewees in this study had done so by the time data collection was completed. On the other hand, migrants who either brought their families with them or started families in the U.S. report that even upon retirement, returning to Brazil would be a difficult decision. This is because their children will have grown up in the American environment, will likely pursue their education and careers there, and will build their lives abroad.

Consequently, it would be challenging for parents to return and be separated from their children. This observation is reinforced by Bernardo (E9) in the following excerpt from his interview:

> *"People say, I had exactly the same plan [to return to Brazil after retirement], but my son is here, I'm still here today. So there's this whole perspective. Your son will be an adult, you won't want to go back [...] Then you'll have your daughter's children, even a grandchild here. You'll want to stay away?"* (Bernardo, E9).

When conducting interviews with Brazilian STEM migrants, a significant difference between Brazil and the United States becomes evident: the relationship between academia and industry. While in Brazil, many highly qualified professionals with doctoral degrees see their opportunities limited almost exclusively to academia, in the U.S., they expand their horizons with access to high-quality job opportunities in the industry. This dynamic further exacerbates Brazil's loss of human capital in the fields of science, technology, and innovation, as Brazilian industry appears to be failing to absorb the knowledge and skills of highly qualified professionals, who instead contribute to international industries.

Many interviewees mention that in the U.S., the relationship between academia and industry is more prosperous and integrated, whereas in Brazil, it is more fragmented and challenging. According to the interviewees, there is a disconnect between Brazilian academia and industry that reduces opportunities for scientists to apply their knowledge in practical projects, which in turn limits the development of innovative solutions in the country.

Overall, some interviewees express the need for an ecosystem that connects scientists, academia, and industry, ensuring that the knowledge generated by scientific research is increasingly applied in Brazilian companies. In table 11, selected excerpts from the interviews reflect these concerns.

Table 11 – Perceptions about relationship between academia and industry.

Source	Report (empirical evidence)
Renata (E11)	*"Now I'm in the industry, it's a slightly different dynamic, especially because we have a team of Brazilians in Brazil, right? This company, because it's a multinational company, so the projects are happening there, but on their initiative."*
Renata (E11)	*"Since there is a lot of partnership between industry and universities, a lot of things are obviously paid for, right? The university will work for you. I think that in Brazil this connection is still very weak. It is difficult to see an industry opening doors like this for a university and getting them to help."*
Renata (E11)	*"So I think that the forces are not very united in Brazil, so the University alone has to fight hard to find out what is happening in the industry."*
Carla (E15)	*"... and I also think about the future perspective, because here I see myself going both to academia and to industry. With many, many more options."*
Wellington (E16)	*"There is something called a link between industry and academia. Unfortunately, in Brazil, this gap has been lost."*
Vinícius (E17)	*"Yes, I would work in academia, but I also see the industry sector in the United States as a very good opportunity, financially speaking..."*
Manuela (E35)	*"Because here it is very common for you to do your doctorate and then you are already in the industry, doing it together, it is the industry with the university, with the hospital... Anyway, in Brazil it is very separate, right? It is at the university or it is in the industry, so it is one thing or the other."*
Brenda (E39)	*"It's a range of options that are offered here, because here you can have... You can finish your post-doctorate, and you can go to an industry and get a job with a good salary, a good career plan and being valued, having good benefits, right?"*

Source: Developed by the author.

The phenomenon of brain drain creates an asymmetry in knowledge transfer between Brazil and the United States. The accounts of the interviewees indicate that there is a strong force driving Brazilian STEM workers to emigrate, leading Brazil to export highly qualified talent along with their knowledge and skills. However, the reverse movement in the flow of knowledge is more challenging, faces more barriers, and can be more costly to materialize in practice.

As observed in some testimonies, many STEM workers recognize that their intellectual contributions and resulting innovations are being incorporated in the U.S., yet there are no structured mechanisms to encourage collaboration with Brazil. Interviewees

mention that there are no clear ways to maintain active collaborations, whether due to a lack of autonomy, time, or funding, or because of bureaucratic barriers in both countries, making Brazilian science less integrated into a global innovation network.

The asymmetry in knowledge transfer not only harms Brazil in terms of innovation and competitiveness but also causes a certain discomfort among STEM migrant workers themselves. Many express a strong desire to contribute to Brazil but often struggle to find the appropriate channels to do so. Some migrants experience frustration upon realizing that, despite their willingness to collaborate, the barriers limit a more active contribution to the development of science, technology, and innovation in their home country.

For example, Beatriz (E6) shares her feelings regarding this frustration:

> *"But I feel bad about not being in Brazil, you know? Not helping my country, you know? I think about that sometimes, but what I'm doing here... I don't think I would have the same opportunities in Brazil"* Beatriz (E6).

Thus, it is undeniable that the departure of these highly qualified STEM workers weakens research groups, university faculty, and the skilled workforce available for specific industrial activities in Brazil. This, in turn, reduces the country's capacity for innovation. Based on data analysis, it can be inferred that the emigration of STEM workers has the potential to impact the training of new generations of these professionals in Brazil. The reduction in the number of qualified mentors in the country limits the development of new professionals, particularly in terms of the quality of their education.

In the next section, findings about brain circulation will be explored.

4.4 BRAIN CIRCULATION

The phenomenon of brain circulation represents a critical dimension in the context of global knowledge and technology transfer. Theoretically, brain circulation facilitates a bidirectional flow of knowledge, skills and innovation that can enhance the scientific and technological landscapes of both home and host countries. However, for its effective occurrence, some conditions are necessary (BACCHI, 2016). In this section will be showed some empirical evidence about brain circulation perspective regarding the case of Brazilian migrant STEM workers in U.S.

The interviews conducted provided a rich array of information on how the phenomenon of brain circulation occurs in its various forms and through different channels. Knowledge transfer often happens in a decentralized manner, even through unconventional means, such as a *YouTube* channel, a digital platform used to disseminate technical and scientific information from abroad to Brazil. This is the case of Elaine (E3), who created an educational channel to share content related to her field, including topics on forage management and technology that she applies in the U.S., providing valuable information to her Brazilian peers: *"I started making videos in Portuguese because I noticed this need"* (Elaine, E3). Through her videos, she shares with Brazilian professionals the best techniques and procedures she practices in her field in the U.S.

This type of initiative reflects a contemporary model of brain circulation, in which knowledge flows do not rely exclusively on physical mobility but are driven by global connectivity and the strategic use of digital media.

In science, collaboration between STEM migrant workers and Brazilian institutions occurs, for instance, through mentoring and direct support for students and researchers in Brazil. Some migrants continue to serve as co-advisors for master's and doctoral students at Brazilian universities, helping to structure scientific projects in partnerships across the country. These interactions ensure that the knowledge and expertise acquired internationally are shared with Brazilian researchers, contributing to local scientific development and strengthening the internationalization of national research.

The network formed by Brazilian STEM professionals who migrated to the U.S. plays a crucial role in facilitating talent mobility and strengthening brain circulation. Although this issue can be controversial, since encouraging the mobility of Brazilian talent might increase brain drain, it also has a knowledge circulation aspect, as many Brazilian STEM workers choose to spend a period abroad and later return to Brazil. In other words, supporting this mobility can bring benefits to the home country.

Many interviewees demonstrate an active commitment to helping other Brazilians who wish to study or work abroad. This support takes the form of recommendations, sharing opportunities, and even guidance on American bureaucratic and documentation procedures. This type of initiative, reported by several interviewees, demonstrates that many STEM migrants become true mobility agents, facilitating access for fellow Brazilians to global knowledge networks and professional development opportunities. Regarding the role of STEM migrant workers as mobility agents while abroad, supporting other Brazilians in

gaining international professional or educational experiences, some reports can be highlighted:

> *"We have a strong emphasis on trying to bring Brazilians. It's about creating resources to break down barriers, to bring Brazilians, to have experiences here. Because we depended a lot on that, right? On having people here who gave us opportunities, so I think that's one of the factors that over time, if I were here, I understood that I could perhaps generate more resources and even help the development of researchers"* (Elaine, E3).

> *"I do for others what I would like them to do for me, you know?"* (Wellington, E16).

Another important point is the maintenance of a Brazilian professional network by some of the interviewees, even after their move to the United States. Sustaining this network, despite occasional challenges, enables a flow of knowledge that also returns to Brazil. Once again, technological tools play a fundamental role in this process. The ties formed through these networks persist through continuous channels of information exchange and professional support. *WhatsApp* groups, for instance, can be used for this purpose. Heitor (E4) comments in his interview: *"I still have this network of contacts, and I talk to them almost every day."* In this way, these networks not only assist migrants but also contribute to knowledge exchange and the internationalization of Brazil's STEM activities.

As discussed so far, the knowledge acquired by STEM migrants in the U.S. can be transferred to Brazil in various ways. Many interviewees maintain some type of connection with Brazil, sharing experiences, work methodologies, and technologies that can be applied in different strategic sectors of the country. Several of these professionals act as bridges between Brazilian and American companies and universities, facilitating a bidirectional flow of knowledge and creating new opportunities for business and collaboration.

The presence of STEM migrant workers in high-level global networks suggests that knowledge circulates fluidly and in a decentralized manner, crossing borders and being shared through platforms such as conferences, collaborative projects, webinars, and international business partnerships. For example, the interviewee Renata (E11) mentions that the American industry operates within an interconnected logic, which allowed her to quickly establish a professional network with strong opportunities in this regard. Similarly, the interviewee Carla (E15) highlights how the strong academic structure in the U.S. facilitates access to preexisting networks, enabling a STEM migrant worker to connect with leading figures in their field.

The interviews suggest that although these global knowledge flows predominantly move toward the Global North, there are instances in which Brazil, as a country from the Global South, also benefits from this exchange. Through various mechanisms, Brazilian STEM workers abroad end up contributing, directly or indirectly, to the circulation of knowledge in Brazil. For example, the interviewee Wellington (E16) states: *"That's what I say, it might actually be more help than when I was in Brazil"*.

Thus, the participation of these highly skilled migrants in the global landscape not only strengthens their own careers and individual trajectories but also, by maintaining certain ties with Brazil, allows them to bring their home country closer to these high-level global networks. In the next section, the mechanisms used for Brazilian migrant STEM workers for knowledge flows in direction to Brazil will be presented.

4.4.1 Mechanisms for knowledge flows

As discussed in the theoretical framework, this study considers some mechanisms through which knowledge flows between countries can occur, thereby operationalizing the phenomenon of brain circulation through the actions and activities of skilled migrants. The data collection confirmed the existence of these anticipated mechanisms, particularly shedding light on how and under what conditions they take place. In the following pages, these findings will be further explored.

4.4.1.1 Global networks

Brazilian migrant STEM workers in the U.S. become embedded in highly qualified global networks within their respective fields, where they interact directly with researchers, managers, executives, and professionals who hold significant influence in their areas. This privileged access to global networks allows Brazilian STEM migrants to expand their academic and professional horizons, integrating into globally relevant projects and working with internationally renowned institutions, either directly or indirectly.

Beyond the individual benefits of integrating into global networks, many STEM migrants also serve as instruments for connecting other Brazilians to these international networks. For example, Elaine (E3) highlighted that she observes a continuous effort to seek talent from Brazil for opportunities abroad, such as doctoral research internships or postdoctoral fellowships. Similarly, Carla (E15) reported that she connected her principal

investigator (PI) in the U.S. with her former Ph.D. advisor in Brazil, creating a bridge for scientific collaboration between the two countries.

The presence of Brazilian STEM migrants in the U.S. not only expands their own connections with highly qualified global networks but also creates access channels for other Brazilians. This enables professionals who remain in Brazil to connect with researchers, professionals, and prestigious international institutions. The interviewees' accounts suggest that STEM migrants can act as facilitators, opening "gaps" in highly qualified global networks so that Brazil can increasingly establish its presence in these spaces.

Table 12 presents interview excerpts that support this observation.

Table 12 – STEM migrants as facilitators for Brazilian entry into global networks.

Source	Report (empirical evidence)
Beatriz (E6)	*"I have a friend, she studied with me, but she continues at the academy, she is a teacher [...] And she is really cool, what she does, she tries to have a lot of contacts in Brazil, she brings students from Brazil to work with her".*
Breno (E8)	*"Not only here in the United States, taking some key employees and giving them the opportunity to visit other factories, visit other businesses, meet other people..."*
Renata (E11)	*"I also knew people from [company name] in Brazil, so the people from Brazil kind of helped me connect with people who worked here in the United States."*
Renata (E11)	*"These Brazilian people that I know, they work in companies here [in the U.S.], so they have their American network as well, so I think that really helps, in the sense that you have this Brazilian network of people who are very good technically."*
Pablo (E13)	*"I received a proposal, I received an email from a researcher [Brazilian in the US] who was looking for a post-doctorate and then I spoke to her and then she invited me to come here and work with her."*
Giovana (E20)	*"The fact that I went to conferences and congresses [in the U.S.], that helped a lot. I went to a lot of conferences, so I ended up meeting a lot of people like that."*
Tainá (E28)	*"For example, here in my lab, [...] a girl who was already here in New York, right? But because of these networks and these exchanges, we ended up getting in touch and she came to do an internship here in my lab, so it's a way of promoting these opportunities to other Brazilians."*
Verônica (E41)	*"I was also, how can I say, lucky, because the head of [name of institution] was Brazilian and my English was terrible, so I was still able to present [the project] in Portuguese and he was very interested in what I was doing."*

Source: Developed by the author.

The interviews reveal that STEM migrant workers have significantly expanded their networks over time after emigrating to the United States, often beginning with the job or academic program that served as their entry point into the country and gradually evolving into

broader connections. When asked about their networks, most interviewees report that in the U.S. they are closer to globally recognized professionals in STEM fields. This occurs not only due to the presence of American professionals but also because of talents from other countries who are drawn to the U.S. and benefit from closer proximity in the country's institutional environment.

The relevance of global networks in the exchange of knowledge extends beyond individual benefits; they also serve to facilitate the flow of knowledge and create academic and professional opportunities for other Brazilians. For example, Melissa (E2) mentions that she has used the networks she established in the U.S. to help many Brazilian Ph.D. students and researchers secure study opportunities at American institutions. This demonstrates that the expansion of global networks by STEM migrants strengthens their professional trajectories and, beyond that, indirectly increases international opportunities for other Brazilians, bringing them closer to these global networks and fostering more connections between Brazil and the United States in STEM fields.

In this regard, academic and professional conferences and events were frequently mentioned in interviews with STEM migrants. These events provide an ideal environment for the exchange of ideas, the formation of new collaborations, and the creation or strengthening of professional connections, generating opportunities for networking and knowledge mobility. Melissa (E2) also commented that she has witnessed fellow researchers forming new research groups at conferences in a quick and spontaneous manner. Similarly, Joel (E22) highlights how introducing himself and approaching other STEM workers at conferences is essential for gaining access to and expanding qualified global networks, as well as being positively regarded by fellow professionals. Naturally, being affiliated with an American institution facilitates access to these events, both due to geographic proximity and the availability of funding for participation. These factors contribute to the formation and expansion of professional networks.

Table 13 presents some evidence about Brazilian migrant STEM workers and their connection to global networks in the U.S. context.

Table 13 – STEM migrants and global networks.

Source	***Report (Empirical evidence)***
Renata (E11)	*"I would say my networking expanded exponentially after I entered the industry."*
Carla (E15)	*"He has a lot of connections, so I end up benefiting from his connections, right? The difference here is that my advisor has connections with very important people, right?*

Marcelo (E18)	*"I would say that I met, despite having been here for a short time, I went to conferences, university, it gave me the opportunity to go to Congress, to meet a lot of people, including the position I have here, I was recommended by a university professor here."*
Fernanda (E19)	*"And today, here in the U.S., I feel like I know all the people who are doing the same work as me and all the industry support as well."*
Fernanda (E19)	*"Anyway, everyone comes to conferences that take place here, right? Not everyone goes to Brazil, so the visibility in the United States makes them more recognized."*

Source: Developed by the author.

Conferences and academic events also facilitate informal interactions that can have lasting effects on the career trajectories of STEM workers. Amália (E5), for instance, reported that her participation in conferences in her field of UX Research Design led to interactions with influential professionals, allowing her to establish important connections for herself and other Brazilian professionals. She managed to connect two Brazilians – one who was looking for a job and another who had a job opportunity to offer. She met the first one at a conference in the U.S., where he explained that he was seeking employment. The second one, she learned through *Linkedin*, had a position available in Brazil. Thus, she was able to connect the two, creating a new job opportunity for a qualified professional in Brazil. Thus, Amália's presence in the U.S. facilitated access for other Brazilians to highly qualified global networks.

The next mechanism for knowledge flows is about ethnic ties and personal connections and will be explored below.

4.4.1.2 Ethnic ties and personal connections

The mechanisms of knowledge flows related to STEM activities do not occur solely through formal institutional channels but also through informal networks based on ethnic ties and personal connections. In the case of Brazilian STEM migrants in the U.S., these ties play an essential role in knowledge exchange, idea dissemination, and the creation of job opportunities, both for migrants in the international market and for professionals who remain in Brazil.

The interviews reveal that these connections are activated in different ways, whether through direct relationships or through intermediaries who share common contacts. The collected evidence highlights how Brazilian STEM workers frequently rely on their compatriots to access study and job opportunities in the U.S. Conversely, those already established in the U.S. become active agents in this process, giving back to their Brazilian

peers the same kind of support they once received at the beginning of their professional and academic journeys.

A significant number of interviewees report that, despite physical distance, they have maintained their network of contacts in Brazil and that this network is often activated for various reasons, in both directions. The ties maintained by migrants and their Brazilian peers become valuable channels for the exchange of expertise and knowledge between the two countries. Some of the mechanisms mentioned include job and study recommendations for international opportunities, informal mentorships, and scientific collaborations. Thus, ethnic ties and personal connections serve as powerful instruments for knowledge flows and the construction of bridges between STEM communities of Brazil and the United States.

In table 14, selected excerpts from interviews illustrate these arguments.

Table 14 – The strength of ethnic ties and personal connections.

Source in interviews	Report (empirical evidence)
Renata (E11)	*"Yes, and I think it also has a lot to do with the desire of the Brazilians there, right? It's not just me transmitting it, but their curiosity in asking me, and that's why they are usually students who want to have this experience too. So, these people usually come to me and ask questions, right?"*
Renata (E11)	*"Yes, I still have a lot of connections with people in the industry in Brazil, where I worked, so this is a constant exchange of knowledge. I have very close friends who work in the food safety area and I always exchange ideas with them. I even get information from them too, right? It's important to have this exchange."*
Carla (E15)	*"Whenever I give a talk about what I do and everything else, my intention is to be able to show people, those people who are in college, that there are opportunities all over the world and that it is possible to dream, although it is not so easy, but it is possible to dream a little, so that if we start organizing ourselves early, it is possible to achieve certain goals that we never imagined existed."*
Wellington (E16)	*"[The Brazilian colleague] is a great friend. My whole life, I may not see him for, I don't know, 5 years, but if he calls me now saying he needs me, I'll help him, you know? Just like me, I think he'll help me."*
Wellington (E16)	*"I get this... Wellington, what are you seeing in the United States about this? Can you help me? What is the Chinese market like today? If I don't know, I know how to find reliable sources there. This is a help, this is a help, you know?"*
Wellington (E16)	*"So, [...] I have no desire to return to Brazil today. What I want is to continue helping Brazil in this way, which I described [...] I will never turn my back, neither on my friends nor on companies. And I will always, I will be an agent trying to distribute what I learn, whether in China, because it is useful for Brazil."*
Fernanda (E19)	*"And the fact that everyone helps each other is really cool too, you know? The [Brazilian colleague] recommends us, we accept them because we want to help, you know? Everyone, because someone helped us when we were coming here, I remember calling people, asking how it is, what do you do. Do you like it,*

	don't you like it? It was hard to adapt and everyone is super helpful. And we ended up creating 11 networks of Brazilians doing the same thing in the United States, which is really cool, because I don't know if all cultures are like this, but in Brazil it certainly is. So, when we go to Congress, you know, all the Brazilians meet up. That's, you know, cool, so I'm still keeping in touch with my roots."
Fernanda (E19)	*"I don't know if it's true for all cultures, but it's amazing how Brazilians here, even without knowing each other, you know? Being Brazilian in the United States, working in this area, there's a great affinity, you know? You end up meeting a lot of people, becoming friends with them, because you know that everyone has been through this."*
Joel (E22)	*"I think so, and I like that. I'm super open, man. Anyone who invites me from Brazil: do you want to speak to our student study group? I'm in, it doesn't matter. Come on, I feel this debt. I kind of, in quotes, create this debt in my head to want to help, to maybe help someone."*
Joel (E22)	*"But people are looking for me, more people are looking for me [...] But I always, I think the podcast still helps a lot, so I end up including scenarios from here, comparing them with scenarios from Brazil to help people see these dualities. But yes, more people are looking for me, yes."*
Joel (E22)	*"Wow, the guy is really busy, he won't be able to help... Dude, send me a message, I'll explain, I'll help you, I want to help in this sense and I like being able to help. I feel like my birthplace is Brazil. And I have this intention. Whether the person wants it or not, that's up to the person, but I feel that I can, yes."*
Joel (E22)	*"Because I've needed a lot of help. I've had a lot of references here in the United States when I lived in Brazil. Now I want to send, I want to be that reference to help people, right?"*
Pietro (E24)	*"I think it also has a bit of personality, right? Yes, there are people who don't like to give presentations, for example, who prefer to sit in Excel doing calculations. But I'm a bit of both, so I think I benefit from this ease I have in transmitting technical knowledge."*
Cecília (E27)	*"So there's a great desire to be able to give back, you know? Everything the country has done for me and also the United States for having done, right? For having paid for my studies. And also for having believed in me, so I feel like I have to give back a lot of things."*
Iago (E25)	*"Because I think that again, you giving back a little bit to the communities where I came from, where I am from, I think being here with you [giving the interview] is an example of that."*
Iago (E25)	*"So, it's about participating in a volunteer mentoring project for young people or professionals who are looking to relocate. Yes, I do it [...] It's precisely to understand what the challenges of the local market are and see how I can contribute."*
Tainá (E28)	*"It's like this, to get rid of the underdog syndrome that we have and to encourage other Brazilians to come here, right? [...] So that people become increasingly aware of the quality of Brazilians, so that's why I think we do this work here, which is like an ant."*
Tainá (E28)	*"In addition, we also end up helping those who are in Brazil and who have the idea of applying, to understand what a reference letter is, how to write it? For the researcher and so on. So I think all of this ends up being a link, right? For those who are in Brazil to have this opportunity, right?"*
Manuela (E35)	*"Yes, I still keep in touch with the people I worked with in Brazil, doing science. And then, as I also said, I worked part-time in this*

	job, remotely in Brazil, which also greatly expanded my network of people. So, I also know that if I went back to Brazil, I would have these contacts [...] So, even with people who are still in Brazil, I only have contact now, [...] because I'm here. I would hardly have any if I were in Brazil."
Lívia (E37)	*"At the moment, I have a Brazilian master's student and I will receive a doctoral internship student, she is arriving next month."*
Lívia (E37)	*"So, it has already happened, through the Brazilian network, that I took the head of the department to Brazil and we started conversations between universities there. And here we are, and it establishes a bit of a connection, yes."*
Lívia (E37)	*"Training Brazilian students. So this doctoral internship student that I'm going to host... That's exactly the idea. She's going to have the experience here and come back with that knowledge. But we're also planning to offer a course, so the courses that I teach here, a short course, right? Three days for the industry. We're organizing to offer this course in Brazil, you know? Universities there in Brazil, in Portuguese, so that's the idea, to expand knowledge."*

Source: Developed by the author.

Brazilian STEM migrants in the U.S. report that they frequently receive inquiries from colleagues in Brazil seeking assistance in securing positions in the international job market or admission to American educational institutions. The interviewees indicate that they generally try to find ways to help their Brazilian colleagues. Sometimes, this support results in the emigration of another Brazilian to the U.S., while in other cases, it simply provides an opportunity for an international experience, allowing individuals to gain exposure abroad and then return to Brazil.

An interesting finding from the interviews is the presence of a strong sense of reciprocity among STEM migrants. As they establish themselves professionally in the U.S., they begin to support initiatives that help other Brazilians enter their respective industries. There is evidence of a certain cycle of reciprocity, a mechanism through which those who have already faced the challenges of adaptation are willing to ease the path for newcomers or for those who remain in their home country.

For interviewees, this type of ethnic support network does not exist to serve individual interests but rather stems from a collective sense of contributing to professionals from their country of origin, enabling them to achieve greater success and access increasingly significant opportunities in their fields. The sense of reciprocity among migrants plays a crucial role in sustaining knowledge flows and fostering partnership opportunities between Brazil and the U.S. This dynamic supports the argument that talent migration is not merely a one-way outflow of human capital but a complex process that can generate positive impacts for those who remain in the home country.

According to the interviewees, sharing a common cultural identity and language makes it easier to establish relationships with other Brazilians in similar immigrant situations in the U.S. As a result, they develop informal networks for exchanging information about their professional fields, American bureaucratic procedures related to migration, and career opportunities and challenges. These informal networks gradually structure themselves and leverage technology, such as virtual groups in instant messaging apps and social media platforms, to facilitate communication and cooperation among migrants.

Thus, many interviewees report that their entry into professional opportunities and projects in science, technology, and innovation in the U.S. was facilitated through connections with other Brazilians. These personal connections often became activated in ways that contributed to their integration into the global market. Furthermore, these connections also function in the opposite direction, from Brazil to the U.S., as Brazilian STEM professionals reach out to their counterparts in the U.S. to receive professional contributions from them.

Another element identified in the interviews is the desire to contribute to Brazil in some way. Most of the interviewed STEM migrants express a willingness to give back to Brazil, even though they are sometimes unsure of how to do so. Some, even accompanied by a sense of guilt, maintain an emotional connection and a strong desire to reciprocate to their home country, which remains present in their lives despite the physical distance.

As strategies to mitigate the impact of their departure from Brazil, some decide to share their knowledge through virtual or in-person lectures in Brazil, participation in master's and doctoral defense committees, informal mentorships, or publications about their work, not only through academic channels but also via alternative knowledge dissemination platforms such as podcasts and YouTube videos. In this way, even though they may not intend to return to Brazil, STEM migrants leverage their privileged global position to share knowledge and ideas with Brazilian professionals. This demonstrates that their connection to their home country remains despite the distance and manifests in many ways, creating a driving force that enables STEM migrants to contribute to Brazil in some form. The table below compiles evidence related to these findings.

Table 15 – Desire to contribute to Brazil.

Source in interviews	Report (empirical evidence)
Iago (E25)	*"I definitely feel like I'm giving back to the market I came from, right? And sharing a bit of my knowledge, a different perspective. Not that I'm right, on the contrary, or that I think I know everything, even less. But I can add different knowledge to the mix, right? The local experience here in the United States, my*

	regional experience from working abroad, and now with the needs of different countries in the region. So I bring other knowledge to people's reality, which sometimes people are too focused on their day-to-day lives, right? Without seeing a bit of the bigger picture, so it's this perspective that I think I add and I feel happy to continue adding."
Tainá (E28)	*"So yes, I like the idea of contributing to Brazil."*
Graziela (E29)	*"I think it would have to be in this sense of structuring, right? In terms of real demands that are needed and that I can contribute to. And I don't know, something like that, if there was a website, a bank where people would say, look, I'm interested, I need people who do this type of analysis, people who want to discuss this type of subject, and then I could access that. Look, this makes sense to me, this has to do with what I already work on today, I have experience in this. I can come and help."*
Antonella (E30)	*"I think that artificial intelligence has the ability to change the world and I want it to change the world for the better. That's why I like working in the consulting field so much, and even more so if it can change the world, being able to change Brazil is already good enough. So I like to select startups that I see have a great mission, right?"*
Glauco (E31)	*"For me, this is a way of trying to help other researchers, of contributing to Brazilian science, of contributing to other ways of developing science, fostering science."*
Jade (E32)	*"Yes, I like the idea. In fact, I've been thinking about it all the time and how I could somehow contribute, you know? It's about establishing collaborations with Brazilian laboratories and everything. Yes, I still have a lot of contact with the people I used to do research together in Brazil, so I think that's a possibility, but what I told you is the truth, that the only thing that's needed for this to happen is money. So, it would be some source of funding that would be willing to finance this collaborative research, right? I know that exists. FAPESP [São Paulo Research Foundation] does this a lot, right?"*
Cecília (E27)	*"So, I don't have that feeling, like, I know that some people have a grudge against their country sometimes, like, my country is crap, I want to leave and I don't. I don't have that mentality. I really like Brazil. I think that Brazil has a lot of opportunities for me too, it was more a question of, at that moment, it was the best decision I could make."*
Catarina (E34)	*"When I came to Kansas, I had a dream of establishing, let's say, a path where I could have Brazilian students come to do internships, for example, a summer internship in the United States. It's something that I ended up not being able to make viable, right? But I wanted to do it."*

Source: Developed by the author.

The next mechanism for knowledge flows is related to scientific and innovative collaboration practices, and will be explored in the next subsection.

4.4.1.3 Scientific and innovative collaboration practices

The interviews conducted highlight the importance of collaborative practices in science and innovation between Brazilian STEM migrants in the U.S. and professionals and institutions in Brazil. The data reveal how STEM migrants can serve as a bridge between the two countries, facilitating the transfer of knowledge and innovative ideas while also contributing to the internationalization of Brazil's scientific environment.

These interactions occur through various mechanisms, such as structured institutional partnerships, collaborations in research and technological development projects, academic exchange programs, participation in master's and doctoral defense committees, and remote teaching initiatives. They shape the pathways through which knowledge flows between the U.S. and Brazil. These mechanisms are highly dependent on personal initiatives, which means that many of these contributions occur sporadically or without systematic coordination. Therefore, it is essential to gain a deeper understanding of how these mechanisms function and what triggers their activation.

One key element in the mechanism of scientific and innovative collaboration practices is structured scientific collaborations and institutional programs. Such collaborations are more commonly found among scientists. For instance, interviewee Pablo (E13) emphasizes that participating in master's and doctoral defense committees in Brazil allows Brazilian scientists abroad to contribute critical evaluations and transfer updated ideas to researchers in training in Brazil. Similarly, Fernando (E10) collaborates on research projects with the Federal University of Pernambuco, participating in research protocols in the field of animal nutrition. Other examples include scientific exchange programs, both initiated by Brazilian institutions such as Foundation for the Coordination of Improvement of Higher Education Personnel (CAPES) and National Council for Scientific and Technological Development (CNPq) and supported by American educational institutions that offer funding for such initiatives.

For example, the renewal of the agreement between the São Paulo Research Foundation (FAPESP) and the U.S. National Institutes of Health (NIH) represents an important milestone in consolidating international cooperation in biomedical and behavioral health research in Brazil. Initially signed in 2014, the agreement seeks to encourage joint projects between researchers from the State of São Paulo and U.S. institutions, and in this new phase, it aims to expand its scope and strengthen existing collaborations. With over 200 initiatives underway, particularly in infectious diseases, the NIH recognizes Brazil as a strategic partner (FAPESP, 2024).

In this case, Brazil's prominent role is also evident in the presence of 83 Brazilian scientists working in NIH research centers and in the fact that, among middle-income countries, Brazil leads in the number of scientific publications co-authored with the American agency. Furthermore, approximately 40% of scientific papers by researchers from São Paulo have international co-authors, with 23% of those collaborations involving authors from the U.S., demonstrating the intensity of academic interactions between the two countries. The renewed agreement thus contributes to strengthening institutional ties and to enhancing the value of Brazilian scientific talent in global contexts (FAPESP, 2024).

Personal connections play a fundamental role in knowledge flows between STEM migrants in the U.S. and their peers in Brazil. The interviews demonstrate that many of these exchanges occur informally, initiated through personal connections that are part of the migrants' academic and life trajectories. Often, these knowledge flows take place with Brazilian institutions where the migrants previously studied or worked before leaving Brazil. As a result, they maintain connections and ties with professors and former colleagues who remained in the country.

One example is the case of Wellington (E16), who holds a prominent position in the Brazilian scientific community despite living and working in the U.S. His reputation and personal connections allow him to act as a facilitator of discussions between academic and corporate actors. In his field, he is frequently invited to give lectures and participate in debates for Brazilian audiences, bringing his international experience to specialists in Brazil and fostering an environment of intellectual exchange.

Individual knowledge transfer initiatives are an impressive mechanism for knowledge and idea exchange in STEM fields between countries. Many Brazilian STEM migrants voluntarily engage in educational and scientific activities involving their home country, even when these actions are not formally structured or encouraged by institutions. The case of interviewee Elaine (E3) illustrates this type of individual initiative. She created an educational *YouTube* channel to disseminate technical knowledge in the field of forage science, making it accessible to Brazilian professionals. This independent initiative has the potential to generate new connections and interactions with other Brazilians in her field.

Another important mechanism is collaboration in research and technological development projects between STEM migrants and institutions in Brazil. Some interviewees continue to participate in projects with Brazilian universities and research centers. However, this type of collaboration is also possible in industry, as illustrated by the case of Bernardo (E9), who participated in a facial recognition technology project in which Brazilian teams

needed to develop specific expertise to implement an innovative solution. The project was conducted within a multinational company, and both countries (Brazil and the U.S.) benefited - while the company achieved its project goals, the Brazilian teams acquired new skills through the experience.

There are still unexplored opportunities in the international collaborations discussed here. Melissa (E2) points out that bioinformatics is an area particularly suited for transnational collaboration, allowing scientists established abroad to share methodologies, data, and analytical resources with colleagues in Brazil, expanding opportunities for learning and joint innovation. She highlights that data analysis can be conducted collaboratively and remotely, without the need for physical relocation of the involved parties, thereby facilitating cross-border collaboration.

> *"In the area of Biomedicine, in general, Bioinformatics has been very important, you know? Sometimes with the sample itself, it's really expensive, but this would be a really cool area of collaboration, because, for example, analysis itself is all computer-based and you don't necessarily need a fantastic computer to do it. You need someone who knows how to run it, and often the programs are free. I do cell sequencing analysis like this [...] So it's an easy resource to transfer, there's a lot of data to use. So it's something that, with collaboration, would work out really well."* Melissa (E2).

Table 16 selects evidence from the interviews that illustrates scientific and innovative collaboration practices as a mechanism for knowledge flows across borders.

Table 16 – Scientific and innovative collaboration practices.

Source in interviews	Report (empirical evidence)
Elaine (E3)	*"Last year I applied as part of a collaborative project [...] of the CNPq universal project."*
Amália (E5)	*"Wow, without a doubt, I can transfer this knowledge, because, after all, research knowledge, unlike law, which depends on the country's legal structure and so on, is highly adaptable. So much so that I helped a friend of mine to do a research project for a fintech company in Brazil. Using the knowledge I have here."*
Wellington (E16)	*"I was also a supervisor in Brazil and today I continue to act as a co-supervisor in public institutions in Brazil, [...] There are always one or two students and projects that we do with supervision and I also provide funding, that is, I support the thesis as a collaboration as well [...] We help and are also helped because the data is interesting. I give a lecture, I am invited to some event [...] I have already been invited to events there in Brazil. I am always remembered, which for me is good."*
Vinicius (E17)	*"I recently participated in a master's degree defense, and I was looking at the methodology and the way I did it in the United*

	States was first formaldehyde, then alcohol. And in Brazil they were doing exactly the opposite. It was one of the things I questioned, I explained their side. Oh, we hadn't thought of that. Is that how you do it there? We'll try to do it that way next time."
Vinicius (E17)	*"There are many experiments conducted in Brazil, and the data we discuss here are from experiments conducted in Brazil, by Brazilian students. And, there will even be a Congress in our area, [...] One of the experiments I will present was conducted by a student in Brazil, but who was unable to come to present it."*
Marcelo (E18)	*"So, I have also participated in master's and doctorate panels in Brazil, undergraduate, master's, doctorate... When I was a professor, I had taught classes remotely during Covid-19 and at other universities, for example, the University of Mato Grosso, they invited me to teach classes online, so I taught classes after I came here".*
Bento (E21)	*"I am in the process of establishing a collaboration with a research group in Brazil. I am, let's say, representing the part of our company that is in relationship with this group."*
Martina (E23)	*"I'm starting out like this. I've always wanted to, I've been interested in getting involved with the Federal University of Rio Grande do Sul, in different ways. And it's something that's always been on my radar, and now that I'm in this position as a professor, I decide what I do with my time and so on... I started a project with my best friend from Brazil, who is also a medical researcher. And she was also invited to be part of the doctoral committee of a student from the postgraduate program in medicine in cardiology. It's in an area that has to do with the things I do too, and I was very happy with the invitation. I hope to contribute to the intellectual discussion, right? And I hope this is just the beginning of many opportunities to interact with my institution, [...] in Brazil."*
Pietro (E24)	*"In two months we will have a seminar with clients from Brazil, from offshore, where I will go with my boss and he will give a talk. And the talk will basically be, how do you do this type of repair in the United States? Because in Brazil it is still very much not well regarded. People do not have technical confidence that it is a viable solution, right? So, a big part of it is to bring this type of information. There is a different way of doing a type of repair that can be safer and just as efficient, right? The guy goes up on the Petrobras platform, does the inspection, sees that there are these deficient areas, sends the report to me and I make a project for each type of repair, right?"*
Adriana (E26)	*"I was the first to produce written material in four languages about Covid-19 for scientific dissemination, you know? About how to prevent it, what it was, and how to prevent it. I was the first in the world and it was published here, then it was published through the consulate here and it left Brazil."*
Adriana (E26)	*"So I spoke to several audiences and at the end I was also providing training for community agents, who were indigenous people, who only spoke their tribe's language via radio. I spoke from here to a colleague of mine, you know? From public health in Manaus. He would pass it on via radio to the tribes and there they would provide training for the others. So it was a very crazy thing and without a set schedule, right?"*
Adriana (E26)	*"In my group, in my original group, we continue to work on the issue of neglected diseases. The issue of dengue fever and Chagas disease, these two continue to be addressed within Fiocruz. And for Alto Solimões, we are working on the issue of epidemiology as a whole, but in reality, we work on epidemiology without borders, so it is a question of thinking about health in a way that is*

	accessible to everyone."
Tainá (E28)	*"Yes, yes, me again, because of scientific dissemination, I have scientific extension projects that are approved by the State University of Goiás with a collaborating professor, who is, in fact, we have funding from CNPq, from CAPES, right?"*
Tainá (E28)	*"More recently, we also created a collective of female scientists in a network. And it also has the goal of requesting funding from the federal government to promote scientific outreach work that aims to increase gender equality within universities. And so, in this project, there are universities from various parts of Brazil, so we have collaboration, right? With professors from universities in the south, midwest, north and northeast. So I can maintain an active relationship, in addition to my former advisor, who is at USP, with whom we published the last article this year. So even after more than four years since I left the laboratory, I still maintain these relationships with Brazil."*
Tainá (E28)	*"Officially, I have this scientific extension project, which is linked to the State University of Goiás, right? So this is the project we have and it is linked to the Brasil platform, which has an ethics committee. We have the collective of women scientists, which for now is a collaborative group. We submitted our first project asking for funding from CNPq, but we haven't received a response yet."*
Tainá (E28)	*"I have the science with coffee. It's actually a company, right? I have a CNPJ for it in Brazil and it aims to work on scientific dissemination and education. So I've already offered some online courses, in addition to producing content, which I do on social media, mainly on Instagram. Of course, I see that by monitoring metrics and such, content produced on certain topics is used as teaching materials, right? So, several teachers sometimes send me: look at your video, it's there in the classes, there's your material. How do I reference that, then? So yes, social media ends up being a very important source for people, who go looking for information, knowledge."*
Catarina (E34)	*"Yes, I have several students and former students who are now professionals in Brazil. They still consult me today about things, about professional decisions, when they are about to change jobs or are in doubt or when they have an idea for a project or even when they want to resume a project that I did, but that I am no longer working on, to get a sample, to know if they can use my data. So, there is still a lot of exchange with Brazil, I believe."*
Catarina (E34)	*"Yes, as I tell you, as I guide students, right, the knowledge I acquire here can be applied. I have colleagues to whom I sent the sample, because I work in certain specific areas. I still work on publications with my colleagues there, right? [in Brazil] Of things I was doing before, but of things that have evolved, and so I have some knowledge that can contribute in this specific area, right?"*
Rodrigo (E38)	*"So I saw this part of the research in Brazil and I always thought, wow, when I became a professor, I had this desire to establish this bridge with Brazil, in a way, to interact with Brazil, which has a lot of good things in Brazil that we can take advantage of. And I think that Brazil can also take advantage of some of the good scientific things, right? That are also developed here, in that spirit of collectivity, right? So you combine two good things, you can do something even better, right? [...] So, I always had this desire, and I think that if I weren't Brazilian, I don't think I would have had the same success in establishing these collaborations."*

Source: Developed by the author.

The next mechanism for knowledge flows is related to diaspora communities and will be explored in the next subsection.

4.4.1.4 Diaspora communities

The set of interviews conducted demonstrates that cultural affinity and the shared experience of international migration serve as motivators for forming connections among Brazilian STEM migrant professionals in the U.S. There is a certain ethnic proximity that fosters an environment conducive to the exchange of information, mutual recommendations and referrals, as well as opportunities in research and innovation, ultimately aiming to enhance the professional competitiveness of migrants in their host country.

The connections established among Brazilian STEM migrants in the U.S. contribute to the circulation of knowledge at the international level. These diaspora communities, whether formally or informally structured, can enable this knowledge to extend beyond the host country and back to the migrants' country of origin. Here, a collective force is observed, and it has the potential to influence individual actions.

The interviewees' accounts reveal a sense of shared identity that naturally fosters affinity among STEM migrants, facilitating the exchange of information related to their professional fields. Beyond that, some accounts even suggest relationships that transcend the professional sphere, as many interviewees mention that most of their close friends in the U.S. are fellow Brazilians. For instance, Fernanda (E19) highlights: *"Being a Brazilian in the United States, working in this field, creates a strong sense of affinity, you know? You end up meeting a lot of people."* Similarly, Heitor (E4) notes his difficulty in forming friendships with Americans due to their more reserved nature and the tendency to separate work from personal life.

Diaspora communities exhibit a tendency to seek connections with other Brazilians, which influences how knowledge circulates within the migrant community. These communities function as a support network, where the primary bond between their members is their shared nationality and cultural background. In table 17, the interviewees' accounts are explored regarding the role of diaspora communities in this transnational dynamic.

Table 17 – The role of diaspora communities among Brazilian STEM migrants.

Source in interviews	Report (empirical evidence)
Beatriz (E6)	*"I think I know a lot of Brazilians who are here in the United States [...] We are scientists who are coming from Brazil to work here because there are more opportunities. And I also think that when you are... It's easier to make friends with Brazilians, right?"*
Heloísa (E7)	*"... Or Brazilians who live in the United States, the companies I work with are usually Brazilian too. So my professional contact is still very Brazilian, let's say."*
Carla (E15)	*"I've already managed to do this with some friends, mainly a network of Brazilian friends, which I think also helps us feel more... It's just that we have a certain community here at the university, right? So, it helps a little."*
Martina (E23)	*"In fact, I helped found it. I am the co-founder of a non-governmental organization, which we call science, the Brasil Foundation, we called it the Ciber Foundation. And in fact, it all started because there was a group of Brazilians who met every week to talk about their work at the home of one of these Brazilian women."*
Martina (E23)	*"When she started this group, of course, there were 8 or 10 people. And then the Science Without Borders wave came along, right after I arrived in Brazil, and soon the group had 20, 40, 60 people, and we organize these events for 60 people once a month. And it was really cool to work with this network, to connect Brazilians, and there were people who always saw a lot of value in that."*
Adriana (E26)	*"It's an association [PUB] that started in 2011, still in Boston, in 2013. More or less. We opened here in Houston, but I wasn't there yet, and it was an association that helped me a lot, you know? But they don't work with the issue of brain drain, but rather with diaspora, you know? So, yes. It's another concept. And it's very interesting, because there's the rescue of building bridges and giving back and so on."*
Adriana (E26)	*"I not only believe in it, but I also work towards it, right? My first step here was to really get involved with the work of PUB, because I saw that it was possible to keep these bridges between Brazil and the United States active and to pursue this, even though I was never able to benefit directly from this network, you know? But I put a lot of people in contact with others and made this happen. This gives me great pleasure."*
Tainá (E28)	*"For example, we have a partnership with the Brazilian consulate, because of a group we have here, which is called the pub, which is Brazilian Researchers and University Students. It's in several places, right? And then the consulate ends up creating this bridge that is contrary, right? By promoting fairs, which are about foreign trade and then talking about this relationship between Brazil and the United States, about the scientists who are here. About scientists who have startups and these startups, then within the universities, here and so on. So I think we end up being able to create the bridge, right? And back."*
Tainá (E28)	*"... Bringing together researchers and university students who are outside of Brazil with the aim of creating this networking, of making these international relations between Brazil and various countries work more fluidly, both for professionals and students, right? And the United States is the country with the most PUB."*
Tainá (E28)	*"So, here, for example, the PUB in New York is, we get partnerships with companies related to Bahia. Technology and biotechnology to sponsor specific events, so we have an annual event, which is at the UN, right? So a Brazilian diplomat, he*

	explains what the UN's work is throughout that year, that there is always another scientist working, right? With something that is related to human rights issues or the promotion of clean technology, right? And we do a guided tour at the UN. For this, we have sponsorship from these specific biotechnology companies."
Graziela (E29)	*"Yes, we end up being part of a very large network, like the Brazilian diaspora, right? In fact, tomorrow we have a meeting with the global network, which includes Switzerland, Germany, New Zealand, Japan, England, Italy, and a network from Canada."*
Graziela (E29)	*"So, the pub's work is, it turned 14 this year. And over the years I saw this need for many Brazilians here in Boston, in this research area, and they could help each other, precisely because we know that Americans don't help each other and that we have this collaborative characteristic. So we can help each other. And for us to help each other, we need to know each other, right? In the sense of not knowing each other as individuals, but knowing the work each one has done."*
Graziela (E29)	*"So it started with this idea of being a collaborative meeting point and also because, at that time, people were returning to Brazil. The vast majority of them were returning during the Science Without Borders period, and so on. People were returning to Brazil and they wanted to maintain the collaborations when they returned to Brazil. So, they wanted to increase their contact network when they returned, because one would return to São Paulo, another would return to the South, another would return to the Northeast. They wanted, in some way, to maintain this collaboration."*
Graziela (E29)	*"So [...] The model we run here in Boston is to have a monthly meeting with two people from the community presenting their projects, their work, their results, their lines of research, to other Brazilians. Today, there are PUBs all over the United States and also in Europe. And each PUB runs independently. Each one lets it happen in the way that makes the most sense for that community."*
Glauco (E31)	*"I am one of the coordinators of PUB in New York [...] the purpose of PUB New York is to create a network among researchers who are abroad. I don't see much of a transfer back. I don't see the path being made back there."*
Glauco (E31)	*"There is a diaspora of Brazilian researchers in New York, Washington, PUB Chicago, there are PUBs everywhere in France... It is that community of researchers. There, they try to coordinate themselves in a minimally coherent way among themselves and there, minimally adjusted, so that their experience is good and they can help people. Maybe this is an incentive to bring more Brazilians. Is it a way of saying, encouraging or helping in general or, on the contrary, are you encouraging more brain drain? I still don't know if this is good or bad, but I feel more about PUB as something that tries to organize, mediate and create a network among people who are already immigrants, and are there in that specific diaspora, you know?"*
Jade (E32)	*"I participate in PUB in Boston [...] I am part of the PUB team. These lectures are more for us to get to know the Brazilians who are here. And to do this networking, it is a really cool program that I started participating in a year ago and today I am part of the PUB Coordination. I think it is one of the ways I do a lot of networking too, apart from all the events that Harvard promotes, but it is a lot, a lot of networking."*

Source: Developed by the author.

Mentioned several times in the interviews, PUB (Brazilian Researchers and University Students) constitutes a diaspora community in practice. For example, PUB Boston is an organization dedicated to connecting Brazilian scientists, artists, innovators, students, and graduates in the Boston area. Through free monthly meetings, the group promotes the discussion and dissemination of multidisciplinary work, encouraging collaboration and knowledge exchange among participants (PUB Boston, 2025).

In addition to in-person meetings, PUB Boston maintains several online communication platforms, such as *Facebook* groups, *Slack*, and *Google Groups*, facilitating the exchange of information, collaboration opportunities, and support for the adaptation of new researchers in the region. One notable initiative is the "Swallow's Guide" (*Guia das Andorinhas*), a collaborative document created by community members to assist newcomers, especially students, in settling into life in Boston (PUB Boston, 2025).

Furthermore, the activities of PUB Boston highlight a strategy for strengthening transnational scientific connections through the voluntary engagement of the community. The existence of initiatives such as the "Swallow's Guide" illustrates how members themselves organize to facilitate the integration of new researchers, fostering a collaborative logic grounded in values of reciprocity and a commitment to scientific development. This dynamic expands Brazilian researchers' capacity to access resources, training opportunities, and highly qualified networks (PUB Boston, 2025).

One point of attention, however, deserves to be mentioned. The activities of a community such as this may primarily serve the needs of STEM migrants already living abroad, while the return of benefits to Brazil may be controversial. Migrant STEM workers like Adriana (E26), Tainá (E28) and Graziela (E29) argue that there are indeed benefits for Brazil, as the community's organization helps to create or maintain ties with scientists in Brazil, especially those who have returned from international experiences. On the other hand, Glauco (E31) notes that organized initiatives like PUB could, in theory, contribute to increasing brain drain in Brazil, since they support and provide resources for qualified Brazilian migrants abroad.

The next section will discuss the research findings, as well as their theoretical and practical implications and main contributions.

5 DISCUSSIONS AND IMPLICATIONS

The general aim proposed for this study was to investigate how the personal and professional journeys of migrant STEM workers influence brain drain and brain circulation. At this section, we analyze findings, highlighting contribution to the reviewed studies in human capital mobility, relations between migration, science and innovation, as well as brain drain and brain circulation phenomena. Beyond contributions to extant theory, new elements emerge inductively and suggested the need for new analytical categories to explain the phenomenon herein focused. This study contributes to shedding light on discussions about these phenomena, particularly from the perspective of migrants' professional journeys and effects on their country of origin.

5.1 HUMAN CAPITAL MOBILITY

On the perspective of human capital mobility, the case of Brazilian STEM workers' migration to the U.S. reveal complex and multifaceted pathways, which combine professional, personal, structural, and contextual factors. The analysis reveals two primary vectors of entry into the U.S. labor market: academia and industry, which are often intertwined throughout the careers of migrants. Universities frequently serve as an initial entry point, either through Ph.D. or postdoctoral programs, while industry may emerge as a destination following academic experience, or even as the initial path, often offering the appeal of higher remuneration.

Interpersonal relationships and family topics also emerge as central elements in the migration process, working both as drivers of migrants' permanence abroad. The decision to migrate is frequently made jointly with spouses or family members, requiring the renegotiation of professional and personal roles and directly affecting the pace and direction of one's career. These aspects challenge exclusively economic readings of skilled migration and highlight the need to incorporate relational and personal dimensions into the understanding of human capital in global contexts. Such dimensions could broaden the scope of studies by Aboites and Díaz (2018) and Faggian et al. (2018), since personal and family factors carry significant weight in the trajectories of STEM migrants.

A fundamental dimension of Brazilian STEM workers is their ability to integrate different cultural repertoires without quit their own identity. For instance, the value placed on improvisation and adaptability, traits commonly found in Brazilian experience, becomes a

competitive advantage in the international market, especially in fields where creative problem-solving is essential. In this sense, multiculturalism becomes a tool or skill that contributes to a more effective insertion into the global labor market. Brazilian STEM migrant workers demonstrate their ability to leverage this cultural adaptability as a professional asset, aligning with the ideas of Szymanski et al. (2021).

Traditionally, human capital theory emphasizes investment in education and skills to increase individual productivity and, consequently, earnings (Becker, 1962; Schultz 1961). However, the journeys of Brazilian STEM migrants in the U.S. reveal that such investments are also responses to national contexts marked by scarcity, instability, and lack of recognition. In this way, human capital becomes an adaptive response to structural devaluation, indicating that the broader structural context must be considered.

Another theoretical advancement offered by this study is the incorporation of subjective and personal factors in the mobilization of human capital. Decisions to migrate, remain, or return to one's home country involve considerations such as quality of life, emotional stability, family well-being, and alignment with cultural values – all of which deeply influence how human capital is deployed and transformed. Thus, economic pragmatism in studies like Kerr (2016), is enriched by attention to the personal dimensions that shape individual decisions and trajectories.

The first assumption of this research was: *the migration of human capital, characterized by skilled professionals, is associated with the performance and productivity of organizations, regions, and nations. The movement of such professionals, across different modalities, influences the knowledge flow among the involved organizations, countries, and regions.*

The findings of this study are aligned with the first assumption, confirming that the migration of skilled human capital influences the performance and knowledge dynamics of both host and home countries. The professional trajectories of Brazilian STEM migrants in the U.S. illustrate how the relocation of high-level expertise contributes to the innovation capacity and global competitiveness of receiving institutions and regions. Migrants often integrate into elite academic and industrial environments, where their skills, multicultural adaptability, and problem-solving capacities enhance organizational performance and scientific output.

Simultaneously, the research confirms that knowledge flows generated by these migrants can extend beyond national borders. STEM migrants contribute to Brazilian science and innovation ecosystems through different mechanisms, thus acting as transnational bridges

between institutions, despite some institutional barriers and difficulties. Anyway, the empirical evidence substantiates the assumption that the mobility of human capital reshapes the knowledge landscape and performance potential of organizations and countries involved, affirming its central role in global knowledge economies.

5.2 RELATIONS BETWEEN MIGRATION, INNOVATION, BRAIN DRAIN AND BRAIN CIRCULATION

Findings at this study demonstrate that brain drain and brain circulation coexist in practice. They are not a "zero or one" occurrence, where only one exists while the other does not. On the contrary, they coexist, and elements of both phenomena can be observed within the experiences of the same migrant STEM worker. Previous studies have treated brain drain and brain circulation as separate phenomena (LE, 2008), assuming that a given relationship between countries would result in only one of them, with scholars merely determining which of the two possibilities occurs.

This research demonstrates that in fact, as they coexist, both phenomena simultaneously generate impacts and implications for the migrants' country of origin, requiring home countries to develop strategies to address each impact. For instance, talent retention policies and the promotion of science and innovation may reduce brain drain over time, but they will not bring back those who have already migrated. Conversely, to maximize the effects of brain circulation, different policies must be designed and implemented, which will be discussed further in this section.

Similarly, Brazilian STEM migrants working in the U.S. shift between both ends of the spectrum. While their departure from Brazil undeniably reduces their capacity to contribute to the country and results in a loss of human capital (DOCQUIER; RAPOPORT, 2012), and while their local networks in Brazil naturally weaken over time, they also identify various ways in which they contribute to Brazil through their STEM expertise, using different channels - also confirming what is suggested in the literature on brain circulation (SAXENIAN, 2005, 2012).

Regarding brain drain phenomenon, this research offers significant insights into the Brazil-U.S. case. Geographically, the physical distance between STEM migrants in the U.S. and Brazil is clear, but how distant is Brazil from its STEM migrants in terms of science and innovation? This study elucidates these details through the professional and personal trajectories of STEM workers.

Based on interviewees' experiences, there is a gradual disconnection from professional networks in Brazil compared to the period when they were still living in their home country. However, the degree of this disconnection is higher among professionals working in industry, multinational corporations, or technology firms. In contrast, those working in academia experience a lower degree of disconnection from Brazilian networks. This suggests that the academic sector has been more successful in leveraging the benefits of STEM migrants. This nuance of brain drain and brain circulation is rarely discussed in studies such as Kerr (2016) or Czinkota et al. (2021).

The concept of brain drain is reinforced by the narratives of Brazilian STEM workers who have migrated to the United States in search of better opportunities. This aligns with the theoretical insights provided by Vega-Muñoz et al. (2021), who emphasize the human capital losses incurred by countries like Brazil. The interviewees' motivations for migrating – especially the working conditions, better career opportunities, and higher salaries, leading to an improved standard of living – are symptomatic of the push factors identified by Miranda-Martel et al. (2017), highlighting factors that drives talent from emerging to developed economies.

STEM fields that require more infrastructure, investment in equipment, and resources are those that seem to exert the most pressure on Brazilian professionals to emigrate. Many highly skilled workers report being unable to fully practice their professions in Brazil, often relying on scholarships or scarce public sector positions with extremely high competition. Consequently, seeking more favorable markets for professional fulfillment becomes the alternative. In this sense, the research confirms that the U.S. presents an attractive environment that encourages the retention of qualified STEM migrants.

Regarding brain drain, the findings highlight an essential issue that should play a more prominent role in discussions on this phenomenon: the relationship between academia and industry. This relationship deserves more attention because it can both push STEM workers away from their home country and attract them to a host country. In the case of Brazil and the U.S., this is precisely what happens. According to STEM workers' accounts, the weak relationship between academia and industry in Brazil reduces their career prospects. Conversely, the stronger relationship in the U.S. aids in retaining STEM migrant workers in the country.

In another perspective, the notion of brain circulation suggests a more optimistic view, where migration leads to mutual benefits for both the origin and the host countries through the exchange of knowledge and skills. This phenomenon aligns with Saxenian's (2005)

description of brain circulation, which posits that the mobility of skilled individuals and their extensive international networks can benefit the regions they leave. Of course, this process is not without challenges, which will be addressed in this section.

By the findings, it is possible to conduct a critical discussion on brain circulation and its implications for STEM migrants' trajectories and their country of origin. A significant portion of interviewees maintained activities that connected both their home and host countries in STEM-related fields. These practices can be interpreted as a form of resistance to brain drain, as they require additional effort and often involve "swimming against the tide" to be successful. This proactive effort by STEM migrants is another aspect that was only captured through the research method employed in this study.

There are various ways in which Brazilian STEM migrants transfer knowledge between their activities in the U.S. and Brazil, including scientific collaborations, participation in dissertation and thesis committees, co-authorship of academic papers, participation in research seminars and conferences (both in-person and virtual), researcher exchange programs, the creation of *YouTube* channels and Podcasts, and global team meetings for knowledge exchange, among others. Moreover, this study places particular emphasis on the mechanisms by which these actions occur, revealing valuable insights.

The findings indicate that, despite its difficulties, while academia enables a more bidirectional knowledge flow at a global scale, the industrial sector presents additional challenges. Interaction between the host and home countries depends on many factors, including the STEM worker's level of autonomy, the scarcity of collaborative projects with the home country, and the influence of global companies' economic interests, which hinder brain circulation effects in this sector. This suggests that brain circulation does not occur uniformly across different STEM sectors and is highly dependent on the organizational and institutional contexts in which migrants are embedded.

Thus, informal knowledge-sharing initiatives across borders - facilitated by digital and technological tools - gain prominence, revealing new forms of brain circulation that transcend traditional models centered on physical mobility. The concept of brain circulation must be expanded to encompass a more dynamic global context, where individuals, ideas, and institutions are increasingly interconnected. STEM migrant workers do not only move physically between countries, they also integrate into a global flow of knowledge, becoming essential actors in this continuous exchange of ideas, innovations and expertise. Through their international trajectories, they connect with highly qualified networks, collaborating with researchers, institutions, and companies abroad. This dynamic contributes to a global

ecosystem in which science and innovation are driven by transnational interactions and collaborations.

Another key point this research uncovers, made possible by the adopted method, is the influence of personal traits and individual characteristics on the degree of connection a STEM worker maintains with their home country. The interviews revealed that more reserved individuals were already so in Brazil and will be the same anywhere in the world. Consequently, they are less likely to actively engage in knowledge exchange networks or international collaborations unless required professionally or if their personal profile supports it. It is essential to consider this individual aspect to avoid treating all migrants the same way. This research demonstrates that individual contributions of migrants within the same field to their home country are not uniform - an aspect rarely discussed in the literature on this topic.

The second assumption of this research was: *the influence of skilled migrants on innovation is especially pronounced in certain economic sectors, notably those within STEM fields. Thus, the behaviors and contributions of STEM workers become pivotal areas of interest in innovation studies.*

The data reveal that Brazilian STEM migrants actively contribute to knowledge production, science and innovation advancement. STEM workers demonstrate to be key agents in the diffusion of knowledge and innovation within and across national boundaries.

Moreover, the research highlights that the influence of STEM migrants on innovation is not uniformly distributed across sectors. The academic sector appears more conducive to brain circulation, offering more frequent and structured opportunities for bilateral knowledge exchange. In contrast, STEM migrants working in industry encounter greater limitations in engaging with Brazilian institutions. Despite some barriers, STEM migrants contribute to innovation by applying technical expertise, an excellent academic background and adding new skills. Therefore, the study affirms that the contributions of STEM workers are indeed pivotal in innovation studies.

The third assumption of this research was: *the mobility of highly qualified professionals does not inherently result in a straightforward loss or gain of knowledge for the countries of origin and destination. Knowledge flows facilitated by highly qualified professionals' connections can lead to interactive models wherein mobility benefits both the origin and destination territories.*

While the initial departure of STEM workers may lead to a reduction in local capacity and the weakening of professional networks in Brazil, many STEM migrants simultaneously cultivate channels of collaboration and knowledge sharing with their home country. Although

institutional weaknesses in Brazil limit the full realization of these knowledge flows, the persistence of migrants in maintaining connections, even in the absence of structured policies, illustrates the potential of mobility to create shared value. Therefore, this study affirms that the impact of skilled migration is not inherently a zero-sum outcome but a complex interplay of losses and gains shaped by relational dynamics and transnational engagement.

5.3 MECHANISMS FOR KNOWLEDGE FLOWS

In this study, ethnic ties and interpersonal connections, global networks, collaborative practices in science, technology, and innovation, and diaspora communities were identified as key knowledge flow mechanisms that enable brain circulation. While some important studies have examined these topics individually (BRESCHI et al., 2017; ELO, 2018; MIGUELEZ, TEMGOUA, 2020; HONIG, 2021; LAM; RUI, 2022), this study adopts a more integrative perspective, viewing them as interdependent mechanisms that collectively facilitate brain circulation. Therefore, reflecting on the implications of each is essential.

Regarding global networks, the findings demonstrate that the integration of Brazilian STEM professionals in the U.S. into highly qualified global networks serves as a key mechanism for knowledge flow in the phenomenon of brain circulation. Empirical evidence shows that STEM migrants become agents of interconnection between Brazil and internationally renowned professionals and institutions, effectively embodying the bridge role that migrants can play, as suggested by Elo et al (2018), Etemad (2018) and Ratten (2022).

The role of STEM migrants as strategic links between professionals and institutions in both countries indicates that brain circulation has strong relational elements, as connections established in the host country are frequently leveraged to open new opportunities for other Brazilians in the home country. This relational dimension of brain circulation remains underexplored in the literature, possibly due to the predominant use of pragmatic research methods, which, despite relying on robust datasets (for example, ABOITES; DÍAZ, 2018; MIGUELEZ; TEMGOUA, 2020; USECHE et al, 2020), fail to capture how relationships are established and maintained.

Another piece of evidence supporting this claim is that, among the 41 STEM migrants interviewed, despite many contributing to Brazil in some capacity, none were involved in patents – one of the key metrics traditionally used to measure innovation relationships between home and host countries, as seen in studies like Perri et al. (2017), Tanrikulu (2020) and Miguélez (2019). However, the empirical findings confirm that these relationships are far

more complex than patent-based assessments suggest. While such measures are valuable, they are insufficient for a complete understanding of skilled migration, brain drain, and brain circulation, corroborating the arguments of Breschi et al. (2020).

Evidence indicates that the participation of Brazilian STEM migrants in global networks is not homogeneous; it depends on the level of engagement of individual migrants. While some assume a strong commitment to facilitating opportunities for their fellow Brazilians, others do not necessarily prioritize maintaining connections with Brazil. This finding enhances the understanding of brain circulation as a phenomenon shaped by migrants' individual motivations, the institutional contexts of the countries involved, and the presence or absence of support structures for interactions between migrants and professionals in their home country.

One critical role that STEM migrants play is reducing barriers that typically hinder Brazilian participation in prestigious international academic and professional environments. The capacity to act as a facilitator varies according to the migrant's professional position abroad, access to resources, and available time to invest in maintaining relationships with Brazil.

One of the most significant benefits of STEM migrants as facilitators in global networks is the expansion of international opportunities for other Brazilians. Establishing connections with North American institutions and professionals enhances access to funding, scholarships, research projects, collaborations, and even job opportunities for Brazilians. This integration brings Brazil closer to highly qualified global networks, overcoming the country's geographic and institutional barriers and generating positive impacts on its science, technology, and innovation sectors.

Furthermore, research findings indicate that academic conferences and professional events play an essential role in integrating Brazilian STEM workers into global networks in their respective fields. The interaction between STEM migrants and other Brazilians at these events not only facilitates their insertion into global networks but also enhances their visibility within them. Those migrants who are already well integrated into these networks contribute by introducing their Brazilian peers, breaking entry barriers, and creating opportunities that would otherwise be much harder to access.

However, for countries like Brazil, there is a structural challenge in this regard: while STEM migrants often have substantial funding to attend conferences and events, many professionals in Brazil struggle to participate due to financial constraints and a lack of organizational or governmental incentives. These findings contribute to discussions on the

effectiveness of public and private funding for Brazilian STEM workers to attend international conferences and events. The evidence suggests that policies promoting Brazilian presence in international events remain crucial and that Brazil should establish conditions that do not rely predominantly on individual initiatives to maintain its presence in global STEM knowledge networks.

Regarding ethnic ties and personal connections, this research highlights that knowledge flows between Brazil and the U.S. do not occur solely through formal means but also via interpersonal and informal connections supported by ethnic ties. Thus, ethnic ties and interpersonal connections emerge as essential mechanisms within the brain circulation phenomenon. This section will explore key ideas revealed by empirical research.

In practice, ethnic ties and interpersonal connections extend beyond formal institutional relationships between STEM migrants in the U.S. and the STEM environment in Brazil. Just as these ties are observed within the migrant community in the host country - the U.S. - they are also evident in interactions between migrants, professionals and institutions in their home country, Brazil. Regarding interactions among STEM migrants in the host country, the evidence suggests that there is a strong pull that brings Brazilians together, likely anchored in ethnic and cultural proximity, supporting some ideas from Choudhurry and Kim (2017) and Honig (2021).

Once again, the relational aspect is crucial for this knowledge flow mechanism to function effectively. The activation of these interpersonal connections occurs either directly or through intermediaries with shared networks, and when established remotely, they rely on the powerful support of existing communication technologies. Therefore, even though many STEM migrants reported in the interviews that their professional networks in Brazil weakened after leaving the country, they still maintain certain connections that allow for some level of exchange or benefit for Brazil.

By operating in an informal and spontaneous manner, ethnic ties and interpersonal connections work as an unofficial mechanism for knowledge flows, as they often lack public policy support to facilitate them. However, this mechanism proves to be highly effective in the practical operationalization of brain circulation, expanding the ideas of Fackler et al. (2020), which is little explored in previous studies.

The presented results also highlight the sense of reciprocity expressed by Brazilian STEM migrants in the U.S. This insight demonstrates that skilled migration is not merely an individualistic phenomenon, where each migrant is solely focused on their personal interests. Instead, it can be a phenomenon involving social commitments, encompassing collective

interests within a specific STEM community. As STEM migrants establish themselves abroad, they begin to support new Brazilian migrants or professionals in Brazil, replicating the assistance they themselves received upon arriving in a foreign country. This perception aligns with studies such as D'Ambrosio et al. (2019).

The sharing of a common cultural identity is an important factor in ethnic ties and interpersonal connections. Cultural and linguistic affinity facilitates the creation of trust-based relationships and enables a greater exchange of information and knowledge about the professional and academic environment abroad. The results indicate that, in addition to this shared cultural identity, migrants also experience common migration-related challenges, which foster a sense of unity, as they recognize their struggles in one another. This applies to both long-term migrants in the U.S. and Brazilians engaged in temporary international mobility experiences. Once again, ethnic ties emerge as a significant factor.

The professional networking maintained by STEM migrants with professionals and institutions in Brazil facilitates partnerships, collaborations, and professional and academic opportunities. Thus, even if these professional ties with Brazil are weaker than when they lived there, they remain important channels for the flow of knowledge, resources, and expertise, contributing to Brazilian science, technology, and innovation. Consequently, Brazil could invest in strengthening these connections, as they are strategic for the country's positioning in the global knowledge economy.

Another key research finding, which contrasts with the brain drain phenomenon, is the strong desire among Brazilian STEM migrants to contribute to Brazil in some way. The majority express this intention, even if not all have found a way to do so yet. This presents an opportunity that Brazil, as the country of origin, could leverage to enhance interactions and exchanges with STEM workers abroad. Interviewees' accounts suggest that this desire is primarily driven by two emotions: (a) gratitude toward their home country and/or (b) guilt for having left. Once again, capturing such insights would only be possible through a study that places migrants' experiences at the center of the research.

Regarding scientific and innovative collaborative practices, research findings indicate that knowledge flows occur through both structured and informal channels. The interviews contain numerous accounts of STEM migrants participating in master's and doctoral defense committees in Brazil, engaging in Brazilian research projects, contributing to Brazilian research groups, and supporting academic exchange programs with students or scholars from Brazil. However, the results show a strong dependence on individual initiative to activate this brain circulation mechanism, highlighting gaps in the institutionalization of these practices.

Findings suggest that the effects of brain circulation tend to be more effective when there are clear public policies and incentives to foster professional interactions between STEM migrants abroad and professionals and institutions in Brazil, rather than relying so heavily on individual and spontaneous actions. While individual initiatives are important and beneficial, more structured policies and formal incentives could maximize their positive effects on the migrants' country of origin. This complements ideas previously discussed by Bongers et. al. (2022).

The interviews reveal that prior connections between STEM migrants and universities or colleagues in Brazil enable the existence of scientific and innovation collaborations, even sometimes in an informal manner. This can be seen as a form of resistance to brain drain, led by the individuals involved, talented professionals in these fields. Maintaining these ties creates knowledge flows that benefit the country of origin. However, a critical issue in this aspect is the dependence on individual initiative and willingness, especially when collaborations lack a strong formal framework. If the individuals involved lose interest or no longer have available time, the continuity of these collaborations becomes threatened.

To strengthen the positive impact of scientific and innovative collaborations in the brain circulation phenomenon, it would be essential to create institutional programs that formalize and encourage the participation of STEM migrants in knowledge diffusion initiatives with their home country. This would help systematize and sustain these interactions over time. Additionally, it would provide guidance for STEM migrants who express a desire to contribute to their home country but are unsure of how to do so - an issue mentioned several times in the interviews.

Regarding diaspora communities, although this mechanism of knowledge flow was less prominent in the empirical data, the study shed light on their dynamics and how they can contribute to brain circulation. The shared migration experience and cultural affinity facilitate the formation of diaspora communities. This study identifies a dual role for these communities: (a) they can support STEM workers who have already migrated to the host country and (b) assist STEM workers who remain in the home country.

According to empirical findings, one of their functions is to expand connections among STEM migrants in the host country. Although these migrants are already integrated into a broader global network, diaspora communities allow them to strengthen their ties with other Brazilians abroad. Indirectly, it has the potential to increase access for Brazilian professionals to global networks in their respective fields, as previously discussed in the global networks mechanism.

However, diaspora communities also need to be targeted by programs and policies aimed at leveraging them to generate benefits for the migrants' country of origin. The example of the PUB movement, which operates in many U.S. cities, illustrates this need well. According to interviewees involved in the movement, its actions primarily benefit Brazilians already in the U.S., serving as a support and integration network for migrants but not yet functioning as a strong link between them and Brazil. These results challenge the assumptions of studies like Baron and Aki (2019), demonstrating that merely having a diaspora community abroad does not necessarily translate into positive brain circulation effects, but these need to be actively stimulated to occur, as defended by Raczynski (2020).

Regarding all the mechanisms discussed, interviewees reported several barriers that hinder stronger brain circulation effects. Some are related to financial limitations within Brazilian institutions, which make it difficult to establish partnerships or formal cooperation. Others stem from asymmetries in resources and infrastructure between American and Brazilian institutions, which, according to interviewees, in some cases make collaboration impossible, as Brazilian institutions lack the capacity to keep up with activities performed within the U.S. system. Finally, the lack of time and autonomy among STEM migrants, especially those who are not in leadership positions within their American teams, further complicates interactions with Brazil.

5.4 INSIGHTS AND CONTRIBUTIONS

Findings suggest that STEM migrants need to be proactively called by their home country to contribute in some way to Brazil. The interviews indicate that the initial outreach should ideally come from the home country to the host country. Once this contact reaches a STEM migrant abroad, they are unlikely to refuse a professional or academic contribution. However, there is a lack of what could be called "bridge policies" between the home and host countries, which would facilitate connections between Brazilian STEM workers and their counterparts abroad, enabling knowledge exchange between them.

Empirical evidence suggests that the government of a country like Brazil should focus more on designing "bridge policies" and programs rather than solely on talent return policies. For STEM migrants based in economically advanced countries like the U.S., returning is highly unlikely due to differences in work and career conditions. Therefore, return policies centered only on isolated opportunities will not be effective. However, there is an

underutilized potential of human capital abroad that, with better institutional policies and programs, could significantly benefit Brazil.

Another relevant aspect is that vast majority of STEM migrants report having emigrated in search of better working conditions and career opportunities, which in some cases was even a necessity to practice their profession due to the lack of opportunities in Brazil. However, most interviewees do not express resentment toward Brazil; rather, they left as a professional and career-driven choice. Considering the reported difficulties in forming personal friendships abroad and the extent to which they miss their families in Brazil, this personal aspect could potentially bring them back to their home country. However, it would require significant structural and institutional improvements in Brazil to accommodate them professionally. This should be a continuous focus for improvement in Brazil.

Thus, this research offers several contributions. First, by deeply analyzing the career trajectories of STEM migrants, it reveals how micro-level influences shape macro-level outcomes, demonstrating that STEM talent, as individuals, are key actors in the phenomena of brain drain and brain circulation, which in turn impact entire countries. Second, beyond measuring frequency and intensity through quantitative methods, this study details how brain circulation actually occurs. The research contributes by identifying which mechanisms are more or less effective in facilitating knowledge flows between countries through STEM migrants. The study dissects which mechanisms drive global knowledge transfer through migrants and which have the greatest relevance and potential.

There is a gap in understanding how to actively promote brain circulation effects in the home country, with few studies addressing this issue. The key to answering this question lies in closely listening to the migrant talents and building the necessary bridges. Only they have the answers, as they are the primary actors; without them, brain circulation cannot occur. This study goes beyond simply debating whether brain circulation exists; it outlines concrete pathways to strengthen the bridges and connections between economically unequal countries through STEM talent (human capital), who produce knowledge and innovation on a global scale.

The following table synthesizes the key findings and insights of this research.

Table 18 – Summary of key findings and insights.

Category	Key findings and insights	Contribution to extend theory and literature
Human capital mobility	Personal and family factors shaping migration decisions. Multiculturalism of migrant STEM workers as a competitive advantage in the workplace. Personal and professional trajectories and their influence on human capital mobility.	The study incorporate relational and personal dimensions into the understanding of human capital in global contexts. Incorporation of subjective and personal factors in human capital mobility studies.
Brain drain	Gradual disconnection from professional networks in Brazil. Brain drain is more evident among STEM workers in industry, multinational corporations, or technology firms. Key motivations for migration: working conditions, better career opportunities and higher salaries, resulting in improved living standards and quality of life. Relationship between academia and industry as a differentiating factor (weak perceived relationship in Brazil and strong perceived relationship in the U.S.).	How micro-level influence and shape macro-level outcomes, regarding the role of STEM migrant workers and their country of origin (for brain drain and brain circulation effects).
Brain circulation and mechanisms for knowledge flows	Practical actions from STEM migrants: scientific collaborations, participation in dissertation and thesis committees, co-authorship of academic papers, participation in research seminars and conferences (both in-person and virtual), researcher exchange programs, *YouTube* channels and Podcasts for Brazilian audience, global team meetings for knowledge exchange, among others. Academia enables more bidirectional global knowledge flows than industry. STEM migrants become agents of interconnection between Brazil and internationally renowned professionals and institutions, effectively embodying the role of	Beyond measuring frequency and intensity, this study details how brain circulation actually occurs. The study dissects which mechanisms drive global knowledge flows through STEM migrants, and which have the greatest relevance and potential. Brain drain and brain circulation coexist in practice. They are not a "zero or one" occurrence, where only one exists while the other does not. On the contrary, they coexist, and elements of both phenomena can be observed within the experiences of the same migrant STEM

	a bridge. STEM migrants reduce barriers that typically hinder Brazilian participation in prestigious international environments. This integration brings Brazil closer to highly qualified global networks. Operating in an informal and spontaneous manner, ethnic ties and interpersonal connections function as an unofficial, yet important, mechanism for knowledge flows. There is a strong desire among Brazilian STEM migrants to contribute to Brazil. Scientific and innovative collaborative practices can occur through both structured and informal channels, but are highly dependent on individual initiative. Diaspora communities allow STEM migrants to strengthen their ties with other Brazilians abroad, although the intensity of their connection with the country of origin (Brazil) remains controversial. The government of an emerging country like Brazil should focus more on designing "bridge policies" and programs rather than relying solely on human capital return initiatives.	worker. A significant portion of brain circulation actions takes place in an organic and informal manner. More structured policies and platforms could enhance and help systematize these actions.

Source: Developed by the author.

The research successfully achieved its main objective of investigating how the personal and professional journeys of migrant STEM workers influence the phenomena of brain drain and brain circulation. Through an in-depth qualitative data analysis, the study revealed how individual migration trajectories are shaped by a complex interplay of structural, professional, relational, and personal factors. These trajectories explain the motivations behind migration decisions and illuminate the multifaceted ways in which knowledge and expertise are mobilized across borders.

Furthermore, the specific objectives of the research were addressed. First, the analysis of personal and professional journeys highlighted patterns of entry into the host country's labor market, often through academia or industry, as well as the role of family, cultural adaptability, and individual choices. Second, the effects of these trajectories on brain drain

were examined, showing the gradual disconnection from Brazilian networks and the institutional barriers that hinder collaboration. Third, the study demonstrated how these same trajectories facilitate brain circulation and knowledge flows through scientific collaborations, informal knowledge sharing, participation in global networks, and other mechanisms.

This study adopted a micro sociological perspective on human capital by focusing on individual choices and trajectories regarding mobility and examining how these personal trajectories collectively shape the macro-level phenomena of brain drain and brain circulation between countries. One of the central findings of this research is that in a country with weak institutionalization (such as Brazil), the phenomenon of brain circulation tends to occur through informal mechanisms, which should be more encouraged and institutionalized by the country.

In the next section, the conclusions of this study will be presented.

6 CONCLUSIONS, LIMITATIONS AND FUTURE STUDIES

6.1 CONCLUSIONS

This study analyzed the trajectories of Brazilian migrant STEM workers who migrated to the United States, and the influence of their personal and professional journeys in the brain drain and brain circulation phenomena. The findings reveal that these dynamics do not occur in a mutually exclusive manner, but, rather, coexist and often overlap at various points in the migrants' journeys. Understanding human capital as a dynamic resource, this research broadens the traditional scope by incorporating subjective, personal and relational dimensions into the analysis of skilled migration. By highlighting the interplay between individual experiences and global processes, this research broadens the understanding of the effects of human capital mobility on brain drain and brain circulation, providing empirical evidence that enriches theoretical debates on the subject.

Findings indicate that brain drain and brain circulation coexist in practice. While migration results in human capital and technical losses for Brazil, it simultaneously opens channels for international knowledge flows, through academic networks, scientific collaborations, personal connections or spontaneous knowledge-sharing initiatives. This dual character calls for moving beyond the traditional dichotomy of loss versus gain and demands public policies that acknowledge and stimulate knowledge circulation, even in the absence of physical return of migrants to their country of origin. Knowledge flows should be understood as socially embedded and relationally constructed phenomena, shaped by the willingness of migrants to give back and the readiness of the home country to receive and integrate these contributions. This perspective invites new ways of measuring and supporting transnational engagement.

By adopting a qualitative approach centered on the narratives of migrants themselves, this research uncovers aspects often overlooked by quantitative studies, such as emotional motivations, the sense of belonging, the desire to give back to the home country and the institutional barriers that hinder contributions. The study shows that brain circulation is not automatic but rather depends on individual engagement, institutional support and the existence of "bridge policies" connecting STEM workers abroad with networks and initiatives in Brazil. In this context, government initiatives focused solely on talent return are insufficient given the complexity and diversity of transnational connections maintained by migrants.

Furthermore, the research highlights the role of STEM migrant workers as bridges between Brazil and global networks, especially through informal and spontaneous initiatives that are often not captured by traditional innovation metrics, such as patents. This relational engagement underscores the importance of mechanisms like global networks, ethnic ties and collaborative practices in generating knowledge flows. However, the maintenance of these connections depends on the individual initiative of the migrants, revealing a gap in public policies aimed at institutionalizing brain circulation. The absence of "bridge policies" between Brazil and its STEM talent abroad limits the transformative potential of this human capital.

Institutionally, the study points to Brazil's weak capacity to engage with its STEM migrants abroad in a structured and strategic way. While some initiatives exist, the absence of coherent public policies aimed at fostering transnational knowledge exchange means that much of the brain circulation observed is dependent on personal initiative rather than systemic support. Universities appear to be better positioned than industry to maintain ties with Brazilian STEM workers abroad, yet these connections remain fragile and uneven.

The recognition of existing connections and the creation of structured channels for collaboration are promising pathways to transform brain drain into opportunities for national development. By placing the voices of the STEM migrants themselves at the center, this research sheds light on new ways to rethink Brazil's integration into the global knowledge economy.

In conclusion, this study offers theoretical contributions by incorporating relational and subjective factors into the analysis of human capital mobility, proposing a more integrated view of the mechanisms that enable cross-border knowledge flows. It also provides practical insights for the development of public policies that value and leverage Brazilian human capital abroad, not merely as a loss to be reversed but as a strategic asset to be mobilized. By positioning migrants as key actors in the phenomenon, the study reinforces the importance of actively listening to their perspectives in designing effective strategies, enabling Brazil to benefit from the global circulation of its talent in a structured and sustainable way.

6.2 PUBLIC POLICY AND SOCIAL IMPLICATIONS

This study offers relevant social and policy implications by revealing how the migration of Brazilian STEM workers to the U.S. affects their individual career trajectories and also the broader science and innovation landscape in Brazil. The findings indicate

significant barriers to effective brain circulation, including financial constraints, institutional asymmetries, lack of formal engagement mechanisms and limited time or autonomy on the part of STEM migrants. The evidence shows that brain drain and brain circulation are not mutually exclusive outcomes, rather, they coexist and manifest simultaneously. This nuanced understanding challenges binary perspectives on skilled migration and invites policymakers to move beyond simplistic return-oriented strategies. Instead, policies should focus on enabling ongoing, multidirectional engagement between migrant talent and their country of origin.

One key social implication concerns the latent willingness of many Brazilian STEM migrants to contribute to Brazil, despite having settled permanently abroad. The research demonstrates that this desire is often motivated by a sense of gratitude or responsibility, which can be mobilized through appropriate institutional mechanisms. Yet, in the absence of targeted policies or platforms, these intentions often remain unfulfilled. Therefore, governments and research institutions in Brazil should proactively create opportunities for engagement, such as virtual mentorship programs, remote participation in academic boards, collaborative research projects and diaspora engagement platforms, to channel this potential into concrete contributions across borders.

From a policy standpoint, the study underscores the need for what may be termed “bridge policies”, public initiatives specifically designed to connect STEM workers abroad with their peers, institutions and opportunities in Brazil. While current policy frameworks tend to emphasize talent repatriation, the findings suggest that such efforts may have limited effectiveness given the structural disparities between Brazil and host countries like the U.S. Most of the interviewees in this research have no intention of returning to Brazil. In contrast, bridge policies acknowledge the reality of permanent migration and focus on leveraging transnational knowledge flows, facilitating scientific collaborations, and integrating Brazil into global innovation networks.

Another relevant implication is the unequal capacity of different sectors – such as academia and industry – to engage with brain circulation. The data reveal that Brazilian academic institutions have been more successful in maintaining connections with STEM migrant workers, whereas the industrial sector remains largely disconnected. This suggests that sector-specific strategies are necessary. For instance, public policies could incentivize partnerships between Brazilian technology firms and Brazilian STEM workers abroad, promote international R&D cooperation and propose collaborative innovation platforms that transcend national borders.

Brazilian public policies have shown limited effectiveness in addressing the knowledge flows generated by Brazilian STEM migrants abroad. Despite the increasing presence of highly skilled Brazilians in global centers of science and innovation, there is an absence of structured governmental initiatives aimed at engaging this talent in collaborative efforts with institutions in Brazil. As the findings of this research suggest, many STEM migrants express a strong willingness to contribute to Brazil, yet their efforts often depend entirely on personal initiative due to the lack of institutional support, communication channels or platforms to connect with Brazilian academia and industry.

One of the key barriers to the effective realization of brain circulation in the Brazilian context lies in the country's weak institutional framework. Brazil has yet to develop robust policies that integrate its skilled migrants into national innovation systems. The absence of institutional mechanisms for collaboration contributes to the informal nature of most knowledge flows. As a result, Brazil remains dependent on individual initiative to activate and sustain international knowledge flows, rather than enabling such exchanges through policy design. Without institutional continuity, Brazil’s capacity to benefit from brain circulation remains severely constrained. In this context, strengthening institutional frameworks is a strategic action to harness the full potential of its globally dispersed human capital.

This research carries important social implications by shedding light on the lived experiences of Brazilian STEM migrants abroad. It highlights how migration decisions are not solely driven by economic or professional motivations but are also deeply intertwined with personal relationships, family dynamics and emotional well-being. These findings call for more holistic social understandings of the migration process, ones that account for the human, relational and affective dimensions involved. By doing so, the study contributes to a more comprehensive view of skilled migrants.

Furthermore, the study reveals the social costs of migration for both migrants and their countries of origin. STEM migrants face emotional challenges such as disconnection, guilt and the struggle to remain linked to their homeland, while Brazil experiences a weakening of professional ties and a loss of engagement from highly skilled citizens.

6.3 LIMITATIONS

This research presents limitations inherent to its methodological design. The choice of conducting in-depth interviews with Brazilian STEM workers who migrated to the U.S. enabled the exploration of subjective, personal and relational nuances of migratory

experience, but it is limited by the individual point of view. Additionally, regarding brain circulation actions, there is a notable difficulty in finding secondary data that demonstrate initiatives between Brazil and the U.S. in STEM fields involving Brazilian professionals on the American side. Since informal actions are rarely reported, those that are formalized tend to highlight the institutions involved rather than the individual professionals themselves.

The methodological choice of a single case study, focused on the migratory relationship between Brazil and U.S., imposes limitations on the comparative breadth of the results. While this approach allows for an in-depth analysis of the specific dynamics of this case, it does not account for other countries with different levels of development, talent attraction policies, or historical ties with Brazil, that could have distinct dynamics of brain drain and brain circulation. Therefore, although the findings offer valuable insights and contributions that should be applied in other similar contexts, their applicability to other migratory configurations should be approached with caution, what could be an appropriate question for future comparative studies. Comparative analyses with other national contexts or a multi-sited research strategy could enhance the generalizability and robustness of the findings, offering a broader understanding of how different environments affect skilled migration outcomes and knowledge flows.

Finally, while this research captures a wide range of experiences and mechanisms related to human capital mobility, it relies mainly on primary data reported by the migrants. Although this approach privileges the migrant perspective, an intentional and valuable choice, the time and resource constraints limited the inclusion of voices from institutions in Brazil, such as universities, research centers, or public agencies, which could have enriched the analysis of how the home country engages (or fails to engage) with its migrant STEM workers abroad.

6.4 FUTURE STUDIES

Future research on the international mobility of STEM workers can build upon the findings of this study by adopting comparative approaches. One of the possibilities is conducting comparative investigations across different migration flows of STEM workers, such as Brazil-Europe, Brazil-Canada or Brazil-Australia. Comparing destinations with distinct science and innovation policies can deepen the understanding of contextual effects on the phenomena of brain drain and brain circulation.

The present study has shown that experiences of brain circulation occur primarily through individual initiative. However, future research could explore in greater detail how institutional policies, international cooperation agreements and government programs influence these dynamics. In this regard, studies adopting an organizational approach could shed light on formal mechanisms that encourage international collaboration, thus complementing analyses focused on STEM migrant individuals.

Another promising avenue lies in examining the institutional and organizational strategies that successfully foster engagement with skilled migrants. Case studies of programs or initiatives – whether led by universities, research institutes, public agencies or diaspora organizations – could identify best practices and scalable models for enabling knowledge flows. Particular attention could be given to the design and impact of collaborative platforms or digital infrastructures that facilitate sustained interactions between STEM migrant workers and their home country. Such studies would contribute both to academic literature and to the formulation of evidence-based public policy.

Future research should also focus on understanding the barriers that currently inhibit the full potential of knowledge transfer across borders, including organizational and policy constraints. It could help in formulating strategies that maximize the positive impacts of skilled migration, through brain circulation.

Finally, another research agenda concerns the emerging forms of knowledge flows mediated by digital technologies. The present study has already identified initiatives such as Podcasts, *YouTube* channels and participation in online events as mechanisms of exchange between STEM migrants and Brazil. However, these phenomena remain incipient in literature and require further investigation. Analyzing how digital platforms and professional social networks (such as *LinkedIn*, and others) operate as facilitators of brain circulation could reveal new pathways for strengthening the ties between qualified talent abroad and science and innovation in developing countries.

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APPENDIX A – CASE STUDY PROTOCOL

First part: case study overview

General objective: To investigate how the personal and professional journeys of migrant STEM workers influence brain drain and brain circulation.

a) Specific objectives:

- To analyze migrant STEM workers' personal and professional journeys.
- To analyze personal and professional journeys of migrant STEM workers in brain drain's effects.
- To analyze personal and professional journeys of migrant STEM workers in brain circulation's effects.

b) Research problem: How do the personal and professional journeys of migrant STEM workers influence brain drain and brain circulation?

c) Main theoretical concepts covered: Human capital, skilled migration, innovation, brain drain, brain circulation.

d) Definition of the unit of analysis: the personal and professional journeys of Brazilian migrant STEM workers and their relationship to the effects of brain drain and brain circulation in Brazil.

e) Study funding body: CAPES, through a scholarship.

Second part: data collection plan

a) Definition of the case and methods of data collection:

- Brazilian professionals in the STEM areas who have migrated to the United States.

- Primary data: semi-structured interviews with Brazilian professionals in the STEM areas who have migrated to the United States.

- Secondary data: reports from governments and non-governmental organizations regarding migration, technical studies on skilled migration, reports, news, laws and regulations relating to skilled migration, scientific articles and books.

Third part: field operational procedures

a) Semi-structured interviews scheduled via *Linkedin*, email or *WhatsApp application*, observing confirmations from informants.
b) Sending an Informed Consent Form to interviewees via email.
c) *S*emi-structured interview guide on the *notebook*, use of the *Microsoft Teams platform* in the case of remote interviews.

Fourth part: case analysis plan

a) Thematic analysis:
   - This research uses *Thematic analysis* as a data analysis technique.
   - *Atlas.ti software used* to operationalize data analysis.

APPENDIX B – FREE AND INFORMED CONSENT FORM

Free and Informed Consent Form

You have been invited to participate in the research entitled: 'Knowledge flow across borders: the role of migrant STEM workers' personal and professional journeys'", conducted by Anderson da Cunha Jesus, PhD. Candidate in Administration at Universidade do Vale do Rio dos Sinos - UNISINOS, Porto Alegre/RS, under the supervision of Prof. Dr. Yeda Swirski de Souza and co-supervision of Prof. Dr. Ronaldo Couto Parente of Florida International University.

The general objective of this research is to investigate how personal and professional journeys of migrant STEM workers influence brain drain and brain circulation.

The research uses a qualitative case study methodological approach. Your participation is invited for an individual semi-structured interview in a virtual environment, via a videoconferencing platform, funded by UNISINOS and at no cost to the participant. The interview content will be recorded and subsequently transcribed, kept under the care of the researcher and used exclusively for research purposes, as a basis for a qualitative data analysis, without identifying individual sources, preserving names or information that could identify the interviewee. The research results will be disclosed on the UNISINOS website and may be published later.

The research does not present clinical or physical risks to the participant. However, the possibility of some questions causing emotional discomfort to the participant, as they relate to their trajectory as a migrant from one country to another, is considered a risk. In this regard, the participant has the freedom to interrupt or abandon the interview at any time or not to answer questions that they do not feel comfortable with, without the need for any justification.

This term must be saved by the participant in their electronic files. The participant can obtain information about the progress or results of the research by contacting the researcher's email."

APPENDIX C – SEMI-STRUCTURED INTERVIEW GUIDE

Block 1 - Identification data

1. Please provide your academic background, the organization you work for, your current position, and the length of time you have lived in the United States.

Block 2 - Migration background and integration process

2. What factors were decisive in your decision to migrate abroad?
3. What barriers or difficulties did you encounter in finding employment in your field in the U.S.?
4. Describe your professional trajectory from your arrival in the U.S. to the present moment.
5. What are the main advantages and disadvantages of being a qualified migrant in the U.S.?
6. Did you need to change anything in your professional performance to adapt to the needs of the American market or the company you work for?
7. Have you ever experienced any type of discrimination in the professional environment in the U.S.?
8. After securing your job, what strategies did you adopt to optimize your integration into the professional environment?
9. Is your current professional activity aligned with your education?

Block 3 - Evidence on brain drain or brain circulation

10. After your arrival, were you able to create a network of contacts / networking in the U.S.? How was this process?
11. Do you maintain a professional network of contacts / networking in Brazil, even at a distance?
12. If yes, do these two networks connect in any way? Do you play any role that contributes to this?
13. Between Brazil and the U.S., which network/networking that you participate in has people of greater influence in your area?
14. Are you able to transfer in any way knowledge/technology acquired from your experience abroad to Brazil? How?

15. Do you participate in any collaborative project or work that involves professionals in your field in Brazil? Can you talk about them?
16. Would you like to contribute more to Brazil in any way? What barriers do you face in relation to this? How to increase the chances of this contribution?
17. Do you intend to return to Brazil one day? At what point and why?