

Analysis of elite football players serving in leagues from the perspective of squad-league networks: A case study of FIFA world cups from 1950 to 2022

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ABSTRACT

This study introduces the "Squad-League Networks" (SLN) methodology to explore the globalization of elite football player mobility between national teams and domestic leagues from 1950 to 2022. By constructing longitudinal networks based on FIFA World Cup data, the research aims to uncover global trends and structural patterns in player movements, with a particular focus on recent decades. The dataset includes elite players who participated in each World Cup tournament, capturing their affiliations with both squads and leagues. The analysis reveals a growing trend of globalization, with player flows increasingly extending beyond traditional North-South routes to more diverse and multidirectional pathways. Notably, a Matthew effect emerges: leagues with higher initial attractiveness continue to draw more elite players, leading to concentrated mobility and reinforcing existing hierarchies. These findings highlight the dynamic and uneven nature of global football labour markets. The study offers new insights for sports managers and policymakers, suggesting that understanding these mobility patterns can help strengthen the competitiveness of domestic leagues and guide policy responses to the challenges and opportunities posed by globalization in football. By integrating network analysis with historical data, the SLN approach provides a novel lens for examining long-term transformations in elite player distribution worldwide.

Keywords: Sport history, Squad-league networks, FIFA World Cup, Social network analysis, Globalization in sports, Elite football player mobility.

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INTRODUCTION

"Everything I know about morality and the obligations of man, I owe it to football," as the French writer Albert Camus eloquently stated in the 1950s. From the highlands of South America to the industrial zones of Germany, from the urban landscapes of London to the rural fields of China, football stands as a universal symbol bridging cultures across the globe. This global reach is also mirrored in academic research, where football has become a subject of inquiry in diverse fields such as medicine, psychology, economics, history, and sociology. Despite its varied disciplinary applications, football provides a unique and expansive 'playing field' for interdisciplinary exploration. Recent advancements in technology have further amplified opportunities for such cross-disciplinary collaborations, allowing for more sophisticated methods of analysis, particularly in the context of social network analysis (SNA), which has increasingly been used to explore the dynamics of football beyond traditional performance metrics.

Social network analysis has its roots in the studies of social structures and functionalism conducted by the classical sociologist Emile Durkheim (1858-1917). Simply put, it involves representing social entities as nodes and their connections as edges. These actors could be individuals, organizations, or even groups of individuals. The connections between them reflect various forms of interaction, often representing real-world relationships (Wasserman and Faust, 1994), such as scholars forming collaborative networks through co-authorship of research papers. This framework has made the corresponding analytical approach prominent in social sciences and popular in fields like economics, public health, and information science. The advancement of social networks within computer science, particularly in relation to artificial intelligence, has enabled the structuring and visualization of highly complex networks, such as those found in social media platforms using recommendation algorithms to analyze user interactions (Pramanik et al., 2019; Zhang et al., 2019).

In sports science, SNA was originally introduced by Passos et al. (2011) and Grund (2012), with the application of directed networks to describe player interactions in team sports, considering players as nodes and passes as relationships that connected them. Clemente and colleagues have employed the Social Network Analysis (SNA) method for several years to team sports match analysis, particularly focusing on passing networks. They have explored various aspects, including heterogeneity and centrality, at both, the overall team level and the level of individual nodes (Clemente et al., 2014). In the book chapter "*variables characterizing performance and performance indicators in team sports*", Araújo (2017) lists a large number of relevant literature in this topic. To advance the applications of SNA in match analysis, studies considered different regions of the pitch as nodes and the passes occurring between regions as the edges connecting them. Some studies have even tried to take both players and pitch areas into consideration, combining the two kinds of networks together in order to provide more accurate performance analysis (Buldú et al., 2018). Lames (2023) critically comments on passing networks, arguing that its exclusion of incomplete passes and specific game contexts fails to accurately reflect the complexity of football matches.

Although the application of social network analysis in performance analysis is currently largely limited to the aforementioned passing network studies, an increasing number of studies are applying network analysis methods to the fields of sports economics, sociology, and management. For instance, in a more basic application, individuals in the sports world are treated as nodes. Parnell et al. (2019) used social network theory as a framework to offer some insightful ideas regarding the role of sports directors in the England region, outlining potential research agendas related to social network theory and its associated concepts such as embeddedness, structural holes, and the strength of weak ties. Furthermore, Parnell et al. (2021) conducted semi-structured interviews with 25 sports directors of English football clubs, analyzing qualitative

data thematically through the lens of social network analysis. They pointed out that excessive reliance on closed networks may hinder the flow of information and innovation, ultimately restricting the potential performance of organizations. In addition, clubs have also been treated as nodes, and player transfers between clubs as edges, to construct global football labor market networks that describe the roles of economic agents in the transfer market (Bond et al., 2018, 2019; Liu et al., 2016). Velema (2020) not only employed social network analysis to investigate how teams in the UEFA Champions League facilitate a global transfer network encompassing 82 countries and 1,700 professional clubs, but also went further by categorizing clubs into five distinct brokerage roles: coordinator brokers, cosmopolitan brokers, gatekeepers, representative brokers, and liaison brokers. This framework was used to explore the recruitment strategies of teams at various levels across Europe and to gain deeper insights into the workings of the global transfer market. Motivated by this, we aim to explore whether network analysis methods can provide deeper insights into the global mobility of football players.

As we entered the 1990s, particularly after the enactment of the Bosman ruling in 1995, the global football labour market experienced a substantial increase in the international mobility of players, with Europe establishing itself as the central hub attracting top-tier talent from around the world. In 1998, Maguire and Stead published a seminal study examining the immigration patterns within EU and UEFA-affiliated nations. Giulianotti and Robertson's 2009 book *Globalization and Football* presented an extensive analysis of how football, as the world's most popular sport, has been influenced by a multitude of complex global forces in recent decades. Their research covers the historical, cultural, and economic dimensions of this transformation. At the same time, a growing body of studies has zoomed in on specific national and regional contexts to provide a deeper understanding of these dynamics. For instance, English clubs' recruitment of players from Commonwealth countries has been extensively studied (McGovern, 2002; Lanfranchi & Taylor, 2001), while the 1998 World Cup finalists have been used to explore global migration patterns within the sport (Maguire & Pearton, 2000). Furthermore, attention has also been drawn to non-mainstream football nations, as evidenced by Yanli Li and Sebata's 2023 investigation into the trends of Ugandan professional football migration from 1964 to 2022.

Despite the diversity in these studies, they converge on an important observation: the process of globalization in football does not represent a simple or linear strengthening of links between national clubs. Instead, it reveals a more intricate landscape where clubs, regions, and countries, with varying levels of resources, occupy distinct positions within a global football network. Simultaneously, the concepts of "*localization*" and "*internationalization*" are often simultaneously at play within individual teams.

From a regional perspective, it is generally accepted that European clubs have been at the forefront of driving the internationalization of football labour markets. The wealthiest leagues in Europe, supported by dominant clubs, investment entities, scouts, and agents, have built a globalized value chain, directing talent from peripheral leagues in the Global South (e.g., Latin America and Africa) to the established top leagues in Europe (Darby, 2007; Darby, 2011; Poli, 2010; Poli & Besson, 2010). European clubs, positioned at the apex of this speculative global value chain, secure talent at relatively low costs, only to subsequently resell them for higher transfer fees, thereby maximizing profits in the football labour market (Poli, 2006, 2010).

However, from the club's perspective, elite European football teams have not adopted a purely globalist recruitment strategy but instead tend to follow a more decentralized labour market approach. Velema et al. (2018) identified four primary factors that constrain the global recruitment strategies of clubs. First, policy restrictions: aside from UEFA and national football federations, many countries have enacted regulations that limit the influx of foreign players (Niemann et al., 2014). Second, the influence of professional social networks:

much like in other industries, football professionals—players, coaches, and agents—form informal networks, and it is often easier for individuals within the same nationality to establish stronger ties, allowing recruitment resources and information to flow more easily (Carter, 2013; Elliott and Gusterud, 2018). Third, many clubs lack the financial resources to establish a truly global scouting infrastructure, limiting their ability to gather comprehensive player data (Di Minin et al., 2013). Lastly, the integration of players from diverse countries, cultures, and languages poses significant challenges. Overly “internationalized” squads can struggle with cohesion, as the highly coordinated play required in football makes it difficult for teams to perform at optimal levels when players are not fully integrated (Agergaard and Ryba, 2014; Maderer et al., 2014). These dynamics create a tension in top clubs’ recruitment strategies: to either attract the best global talents or to prioritize local players, ideally from their own youth academies.

From a micro-level perspective, the dynamics affecting player migration and career choices mirror those of the club-level. Political, economic, and cultural factors all play a role in shaping players’ decisions. Many studies have explored this phenomenon, conceptualizing it as the influence of cultural and linguistic affinities, which are often remnants of colonial legacies that impact players’ choices (Magee and Sugden, 2002; Maguire and Stead, 1998; Maguire, 1999; Maguire and Pearton, 2000).

The aforementioned globalization studies reveal an intriguing phenomenon closely related to the Matthew Effect. In the process of football globalization, the movement of resources and players follows a “*the rich get richer*” trend. Top European leagues, with their stronger economic base, visibility, and competitiveness, attract a large number of top global players. These leagues not only acquire potential players at relatively low costs but also generate substantial profits through the transfer market, further consolidating their dominant position. Meanwhile, players from smaller leagues and developing countries face more mobility restrictions, and the flow of resources is primarily directed toward these top leagues, exacerbating the imbalance in the market. As the Matthew Effect suggests, the most attractive leagues and clubs continually expand their advantages, attracting more players and creating a vicious cycle, which further intensifies the asymmetric distribution of wealth and resources globally.

However, these studies often rely on simple historical data (such as player flow numbers) and employ relatively basic methodologies. Although some research has applied network analysis, most have treated clubs or national teams as homogeneous entities within the network, lacking methodological innovation. As a result, the conclusions of these studies are generally limited to revealing the globalization trends of specific regions or the “*North-South migration*” phenomenon. Furthermore, an important issue to consider is after player mobility formed a network, and how the existing network structure, in turn, influences players’ movement decisions.

Building on the understanding of global dynamics in football discussed earlier, our aim is to construct a framework to describe the mobility of players within top-tier global teams, known as the Squad-League Network (SLN). We seek to develop a network tool grounded in social network analysis theory, yet tailored to better fit the realities of the football world. By utilizing various network metrics, we aim to conduct a more objective, “*network-driven*” analysis from a systemic perspective. We begin by examining player rosters eligible for participation in international top-tier tournaments and explore their involvement in various national leagues. Player evaluation is generally a complex issue, but when facing major sporting events, e.g. international championships, relevant organizations (national federations) and coaching experts (national coaches) make selections based on various criteria such as physical condition, technical skills, teamwork, and injury status. Although these decisions may have limitations and occasionally spark controversies, they are particularly suitable for investigating player dynamics over extended periods and across various

tournaments. In exploring association football, considering honor rankings and international participation levels, the FIFA World Cup tournaments are primarily chosen as the subject of study.

The objectives of this study are twofold. Firstly, to explore methods for constructing Squad-League Networks (SLN), which involves defining nodes and relationships within the network. This includes making social network analysis (SNA) more straightforward and applicable for describing and analyzing the current state of player mobility. We aim to analyze indicators describing SLN networks, whether derived from SNA methods or not, to verify their ability to represent real-world scenarios and align with the public's understanding of the football world. Secondly, we aim to utilize the SLN methodology to construct networks for past male FIFA World Cup tournaments. From both the overall network and individual node perspectives, we will analyze relevant indicators to describe changes in the involvement of top football players in various national leagues within the free market.

METHODS

Squad-league networks

The graph theory-based social network analysis method is well-suited for studying elite football players' mobility due to its straightforward definitions of nodes and edges. In Squad-League-Networks (SLNs), the nodes are defined as the participating squads in an international event plus the leagues hosting the clubs that engage the players from these squads. The edges are given by the weighted connection between the squads and the leagues, i.e. how many players from a specific squad play in a specific league (see Figure 1).

Traditionally, in SNA nodes represent static entities with fixed relationships, such as players in passing networks where relationships are bidirectional and can occur vertically or horizontally. However, the SLNs introduced in this study assign context-specific meanings to nodes and edges. In SLNs, the above definitions of nodes and edges make them represent specific flows of players between national teams and leagues. A relationship from node A to B means that players from nation A's squad play in the league of nation B, whereas a relationship from node B to A means that the league of nation B hosts players from the squad of nation A. This distinction highlights the direction-specific characteristics of edges in SLNs. Self-loop relationships connecting squad A to league A represent players from a nation's national team playing in their domestic league. Accordingly, we can more intuitively observe player mobility and quantify the attractiveness of various national leagues using traditional social network analysis metrics.

Figure 1 illustrates the construction process of the squad-league network using the 1974 World Cup as an example. After data collection, the data underwent manual processing to build a relationship matrix where rows represent national teams and columns represent leagues from various nations. The 1974 World Cup featured 16 teams ranging from Argentina to Zaire, the maximum squad size for each team was 22 players, which may or may not (in rare cases) be fully exploited by the teams. However, players from these 16 national teams were not solely affiliated with their respective national leagues; they also played in leagues from other participating or even from non-participating federations such as England, Belgium, and France. For instance, Argentina had 16 players in their national league, one in the Brazilian league, one in the French league, three in the Spanish league, and one in the Portuguese league.

If the squad-league relationship matrix includes leagues associated with non-participating nations and the number of players from one of these leagues exceeds half of the national teams' player limit, then that league remains as a network node. Non-participating nations where the number of league players is less than half

Sample

From 1950 to 2022, a total of 19 FIFA World Cup tournaments held since the Second World War were selected as the study sample. Prior to World Cup competitions, the participating federations have to meet a deadline until which they have to officially announce their squad of participating players. After this, players in the squad may only be replaced when they suffer an injury. These squad lists are published and can be retrieved from many public websites. The data for this study were uniformly collected from the player lists of every FIFA World Cup tournament analyzed, which were retrieved from Wikipedia (https://en.wikipedia.org/wiki/Category:FIFA_World_Cup_squads).

Data analysis

This study used manual methods to collect data from Wikipedia, and used R for subsequent matrix and network processing. Ucinet is a software tool specifically designed for social network analysis, capable of calculating various SNA parameters (Borgatti et al., 2002, 2013; Hanneman and Riddle, 2011). In this study, it was used to compute centrality and centralization for SLNs of past FIFA World Cups. ChiPlot is an online network visualization tool utilized for the visualization aspect of this research (ChiPlot, n.d.).

RESULTS

General overview

The FIFA World Cup was first held after World War II in 1950, with only 13 teams taking part due to the withdrawal of India, Scotland and Turkey. The number of participating teams (SLN nodes) in each event rose from 16 in 1954 to 32 since 1998. The maximum squad size did so as well from 22 in the early events to 26 in Qatar 2022 thus raising the number of participating players from 278 in 1950 to 831 in 2022. Table 1 gives an overview of the events since 1950 including the number of teams, the maximum squad size and the number of participants.

Note that the number of participating players is not always the product of the number of teams and the maximum squad size as in some events teams did not exhaust the maximum squad size and took part in the event with fewer players. For example, Morocco took part in Mexico 1968 with a squad of only 19 of 22 and Iran in Qatar 2022 with 25 instead of 26 possible players.

Matrix representation of SLNs

Figure 2 illustrates the distribution of teams and their players' leagues in the 2022 Qatar World Cup, forming a stark contrast with Figure 1, which shows the 1974 World Cup. This clearly reflects the changes in the process of football globalization. In 1974, almost all national team players stayed in their domestic leagues. Only the Brazilian and German league and the leagues of the non-participating countries France, Spain and Mexico hosted 3 or more national players from abroad. However, the 2022 chart (Figure 2) shows a much wider and more diverse distribution of players across leagues. The English league stands out for attracting international players, with 157 players from other national teams. Furthermore, the French and German leagues also attracted a large number of foreign players, with 88 and 86 international players, respectively, along with Spain and Italy, which did not qualify for this World Cup. These so-called "top five" leagues stand out in their attractiveness. In addition, player mobility across leagues globally has increased significantly, including emerging leagues as well as traditionally attractive leagues with specific reservoirs of international players. Examples for emerging leagues are Qatar (QAT) and Saudi Arabia (KSA), which have begun attracting international players, with 7 and 6 foreign players, respectively, but with 100 %Homes. Traditionally attractive leagues are for example Belgium (19 external internationals, many from Africa, only 19 %Homes) and Portugal (12 external internationals, many from America and Africa, only 27 %Homes). The differences

between the network matrices in Figure 1 and 2 illustrate a clear change in football globalization between 1974 and 2022 with the underlying trends being captured by the SLN parameters in the next section.

Table 2. Host countries, champions, maximum squad size, number of teams and total number of players participating in the FIFA World Cups from 1950 to 2022.

Year	Host country	Champion	Number of teams	Max squad size	Participants
1950	Brazil	Uruguay	13	22	278
1954	Switzerland	Germany	16	22	350
1958	Sweden	Brazil	16	22	352
1962	Chile	Brazil	16	22	352
1966	England	England	16	22	352
1970	Mexico	Brazil	16	22	349
1974	Germany	Germany	16	22	352
1978	Argentina	Argentina	16	22	352
1982	Spain	Italy	24	22	526
1986	Mexico	Argentina	24	22	528
1990	Italy	Germany	24	22	528
1994	United States	Brazil	24	22	528
1998	France	France	32	22	704
2002	Japan/South Korea	Brazil	32	23	735
2006	Germany	Italy	32	23	736
2010	South Africa	Spain	32	23	735
2014	Brazil	Germany	32	23	735
2018	Russia	France	32	23	736
2022	Qatar	Argentina	32	26	831

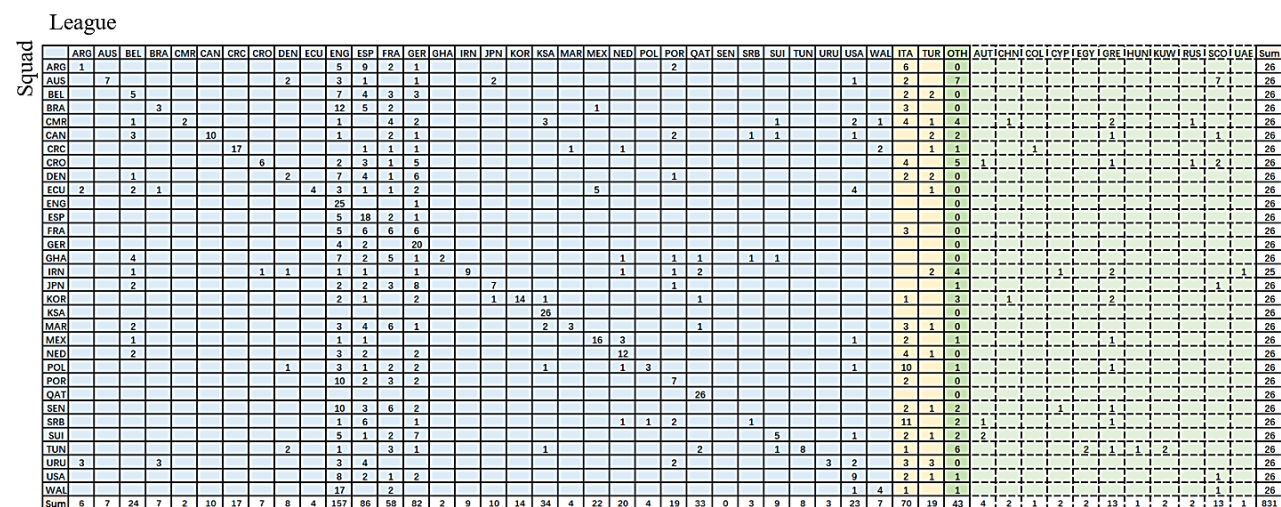


Figure 2. Squad-league network matrix of the 2022 Qatar World Cup.

SLN parameters

The trend of players remaining in their home leagues (%Home) shows two distinct phases (see Figure 3). Until 1970, the rate of self-loops was almost 100%, indicating that nearly all players played in their home nation's leagues, with only very few "*legionnaires*" playing abroad. For example, in 1950 George Robledo from Chile was the only one of the 279 players playing abroad for Newcastle United in England. Italy was attractive for four foreign players in 1962 (Horst Szymaniak from Germany, Luis Suárez from Spain, Anton

Allemann from Switzerland and Gerry Hitchens from England), thus, together with two players from Switzerland playing in France, accounting for all the players playing abroad.

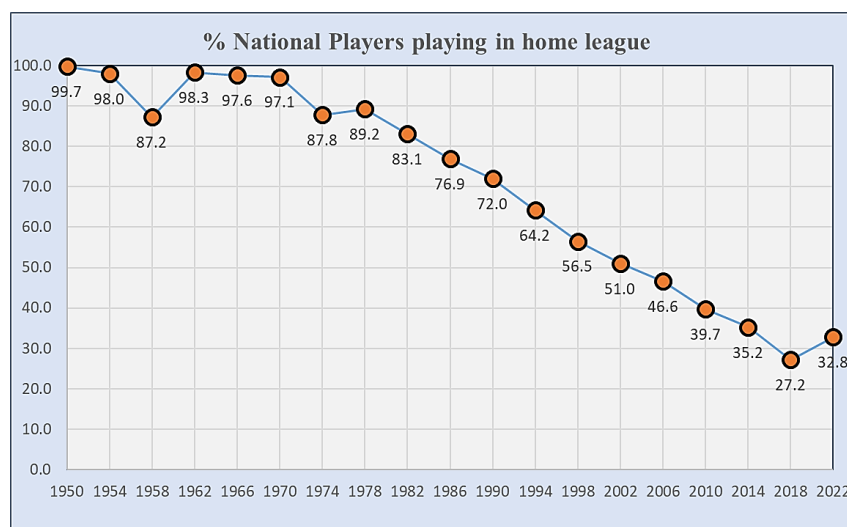


Figure 3. The proportion of players playing in their home leagues (%Home) in FIFA World Cups from 1950 to 2022.

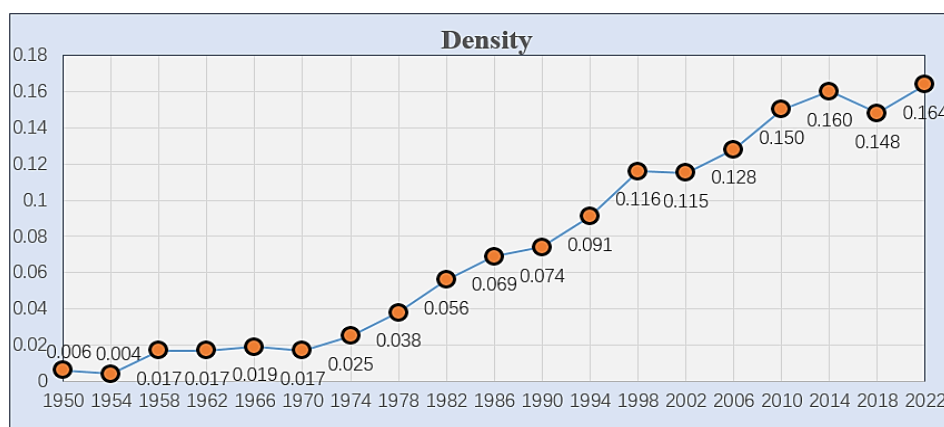


Figure 4. Density of squad-league networks in FIFA World Cups from 1950 to 2022.

The 1958 tournament in Sweden (%Home = 87.2%) is only on first glance an exception, because the three football federations of Scotland, Northern Ireland, and Wales all three qualified (for the first and only time in history) together for this tournament, with all players – except for one - playing for clubs in England (who did not qualify in 1958). Thus, although many of these players were not playing in the league of their home federation, they still played in their home nation (the UK).

The second phase starts in 1974 and extends until 2018 or 2022, showing a continuous decline in self-loops with a remarkably stable negative slope. Over 12 championships, the rate steadily decreased from nearly 100% in 1970 to less than 30% in 2018. By the 2002 World Cup, the percentage of players in their home leagues had dropped to 51.0% from 99.7% in 1950, with nearly half of the athletes choosing to play in foreign leagues. In the 2018 Russia World Cup, this percentage decreased to its minimum of 27.2%. The recent

increase of %Home in the 2022 Qatar World Cup to 32.8% may be due to the Corona pandemic that maybe hindered international transfers of players. This development indicates clearly when and to which extent the globalization of the football player market took place.

The parameter “*density*” of social networks stands for the overall degree of connectedness within the network, giving the percentage of existing connections between squads and leagues relative to all possible connections. Figure 4 shows a steadily increasing trend in this metric over time. There was little player “*traffic*” between nations in the 1950 and 1954 World Cups, a slight increase during the 1958-1970 World Cups, and a clear and steady rise since 1974. By definition, this metrics is in a way complementary to the parameter %Home displayed in Figure 3, although some minor differences occur, such as no relative minimum in 1958, and a tendency of the trend for density to level off in recent years.

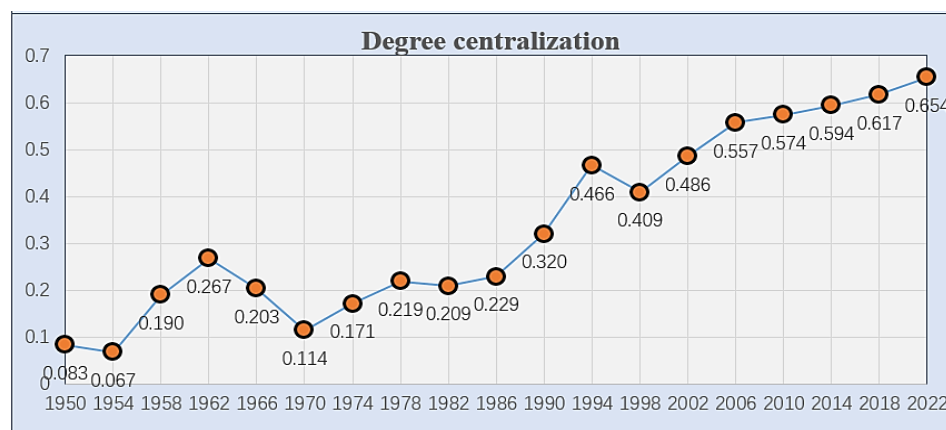


Figure 5. Degree centralization in squad-league networks in FIFA World Cups from 1950 to 2022.

Degree centralization (Figure 5) measures the distribution of weights, i.e. exchanged players, among the nodes of a network. A higher value indicates a greater disparity in the exchange patterns of different nations within the SNL network. Although the changes in degree centralization are highly variable, the overall trend is relatively clear, rising from an initial value of 0.083 to the peak of 0.654 in the 2022 Qatar FIFA World Cup. Although showing similar results, degree centralization grasps slightly different aspects of the player exchange compared to %Home and density. Whereas the latter ones are global indicators for the whole network, degree centralization characterizes the variations in the single node's characteristics. So, it reacts for example more sensitive to the initial small changes with only few players to play abroad, and the levelling off in the end indicates that we have more and more similar patterns of the nodes. This may be seen as a sign that in more and more countries a substantial part of the national player play in many countries abroad. Notwithstanding this, we still find in 2022 teams with very different characteristics, e.g. Qatar and Saudi-Arabia with all 26 players playing at home in contrast to Senegal with no player and Argentina and Serbia with only one player playing in the their domestic league. This means that there is still room left for an increase of degree centralization in the future until all players may be randomly hired by any of the leagues.

A more intuitive comparison between the different FIFA World Cup events is shown in Figure 6. In each Sankey diagram, the left side represents the different nations, while the right side represents the nations' domestic leagues. The thickness of the connections quantifies the intensity of the connections, i.e. the number of players exchanged. A highlighting result in Figure 5 is that in 1950, only one player from the Chilean national team went to the English league. In 1974, although most players still chose to play in their

home leagues, there was a notable increase in player mobility. The French and English leagues demonstrated significant appeal, and even leagues from nations not participating in the World Cup managed to attract players from other teams. Since 1998, the FIFA World Cup has had 32 quotas for the competition. Up to the FIFA World Cup in 2022, it seems that the attractiveness of foreign domestic leagues has only grown to top players, especially the ones from England, Spain, Italy, Germany and France. Italy, although not participating in the most recent FIFA World Cup, has shown to have an appealing domestic league to high level football players.

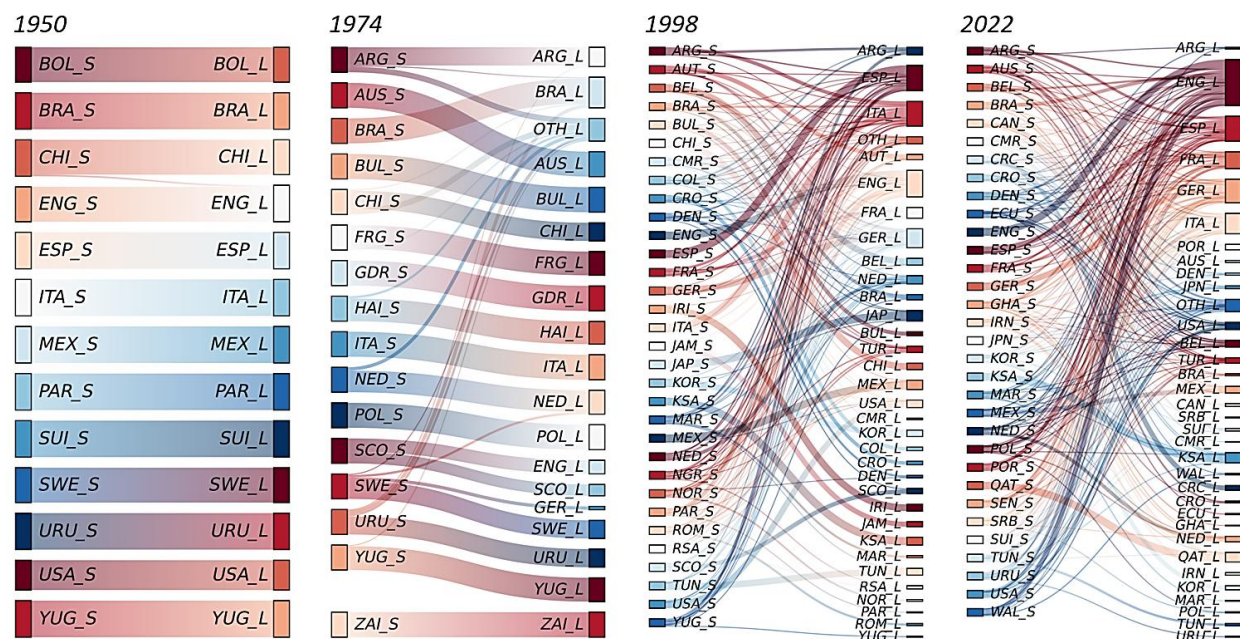


Figure 6. Sankey diagrams illustrating the distribution of players from national teams playing for various leagues of the 1950, 1974, 1998, and 2022 FIFA World Cups (AAA_S = Squad of Nation A; BBB_L = League in nation/federation B).

National developments

Since 1950, a total of 83 nations have participated in the FIFA World Cup. The map in Figure 7 shows the participation history of the NN nations that have competed in six or more World Cups. We had a closer look on the nations from the five major leagues and two consistently strong South American teams. Brazil has participated in 19 World Cups, Germany in 18, Argentina, England, and Italy in 16 each, Spain in 15, and France in 13.

Self-loops represent the number of players playing in their home leagues, measuring the league's attractiveness to its national players. As seen in the right side of Figure 7, while each nation has shown some fluctuations over time, since entering the 21st century, these seven nations can be divided into two categories. The first category includes four European nations: England, Italy, Germany, and Spain, with England (and Italy, but no data for the 2018 and 2022) showing a constantly very high home player retention. For Germany and Spain we recently see a rather stable rate of around 70% of self-loops with Germany already starting this development rather early around 1990 with an intermediate trend reversion (2010: 100% self-loops).

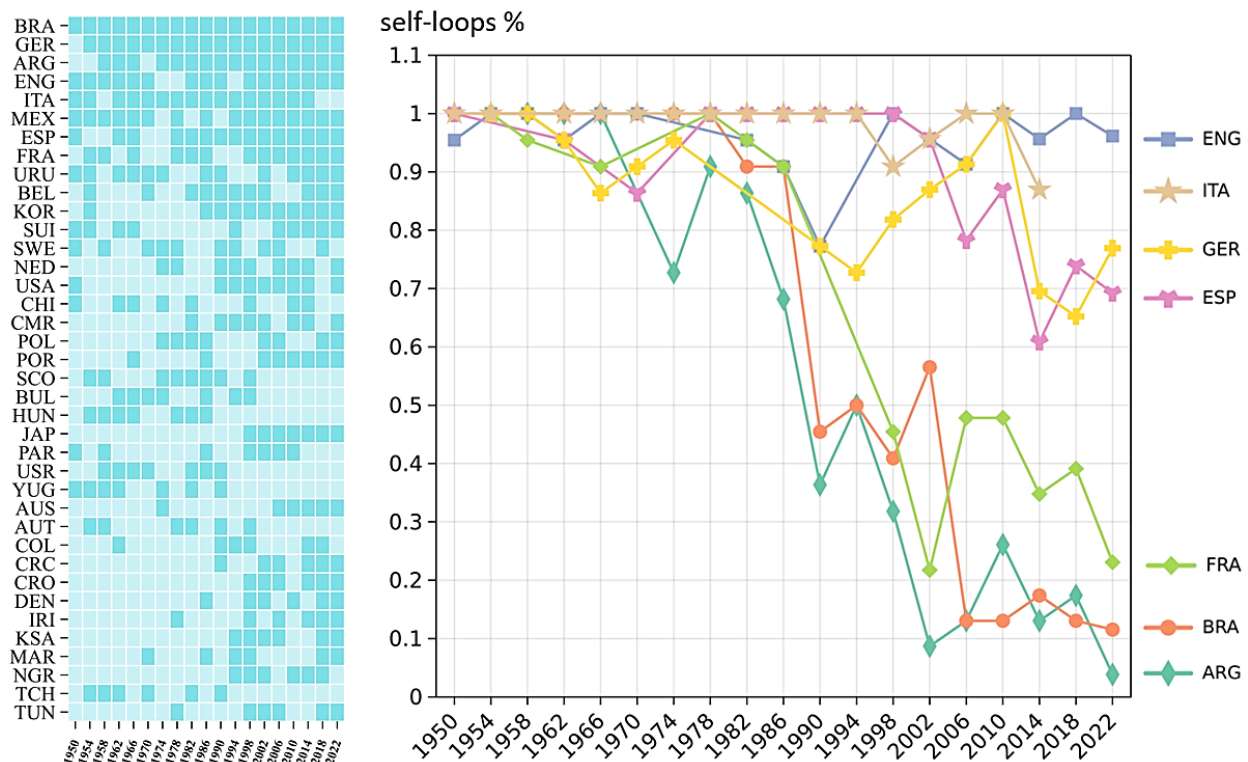


Figure 7. Left: Historical participation status of nations that have participated in more than 6 World Cups from 1950 to 2022 (dark blue - participation, light blue - absence). Right: The self-loops% of participating teams in previous Squad-league networks from 1950 to 2022 for the Brazil, Germany, Argentina, England, Italy, Spain and France.

The second category includes Argentina and Brazil from South America and France from Europe. These nations have shown a significant outflow of elite players who are eligible for the national team, especially the two South American nations. This development started at different times in the 1980/90ies: The first time %Self-Loops dropped below 70% was in 1986 for Argentina, in 1990 for Brazil and in 1998 – after two missed tournaments – for France. In the most recent 2022 World Cup, Argentina had only one player from its home league (Brazil: 3), the others were almost exclusively under contract in one of the “big five” leagues. Considering the reputation and geographical factors of the leagues, France is undoubtedly the “outlier” in Europe. While maintaining a high level of competitiveness in the whole world, these French players almost exclusively play in the other four major leagues.

Analyzing out-degree centrality and in-degree centrality helps explore a league's attractiveness to both home and foreign players. Figure 8 shows the situation for participating nations in the last four World Cups from 2010 to 2022, revealing a slow, divergent trend in the attractiveness of various national leagues. England stands out, with very few English players choosing to play in foreign leagues, while maintaining a strong appeal to players from other national teams, which noticeably increased among players in the 2022 World Cup. The German and Spanish leagues have shown similar patterns in recent years. Although their appeal to foreign players is not as high as England's, they still maintain a significant level of attractiveness. Italy had similar attractiveness to Germany and Spain in 2010 and 2014, but since its national team did not qualify for the last two World Cups, data can only indicate its high appeal to foreign players, but its attractiveness to domestic players cannot be discussed. Consistent with the discussion on self-loops, the French league, while

similar to Germany in attracting foreign players, is less appealing to its own national players. Leagues in South America, Asia, and non-traditional strong European teams have limited appeal to foreign players, with many top home players opting for stronger leagues. This trend has shown a slow concentration in recent years. It is worth mentioning that the SLN network also includes nations whose national teams did not participate in the World Cup but had many World Cup players joining their leagues. For clarity, we should focus on nations with an out-degree centrality value of 0 in relation to the World Cup, as this indicates that these nations' leagues did not have players participating in that specific World Cup. Notably, the Qatari and Saudi leagues' 'no in, no out' status in the 2022 World Cup is attributed to their football policies, which emphasize retaining home players within their leagues for training and collaboration with national team teammates. To avoid confusion, it is important to note that squads with 100% self-loops and an out-degree of 0 should be considered separately, as they reflect a different context compared to the emerging leagues narrative.

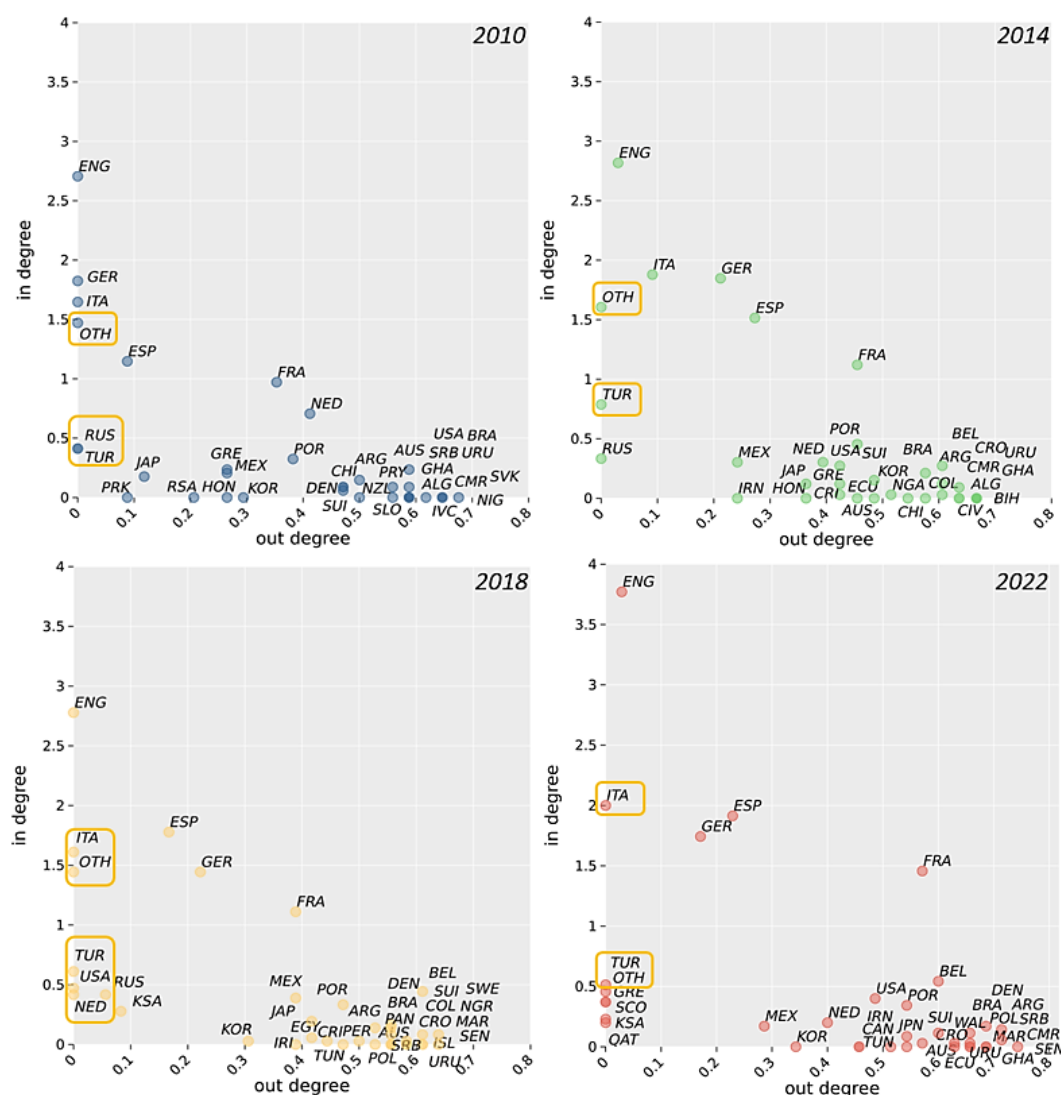


Figure 8. Out-degree centrality and in-degree centrality of participating nations in Squad-league networks in 2010, 2014, 2018 and 2022 FIFA World Cup (The points marked in the yellow box represent nations that did not participate in the World Cup but attracted players from other participating teams, resulting in an outdegree value of 0).

DISCUSSION

The primary aim of this study is to describe the organization and mobility of top-level football players within global domestic leagues using an adapted Social Network Analysis (SNA) framework. SNA is particularly useful in uncovering underlying patterns of player movement and the structure of interactions between teams and leagues. By applying SNA, we can quantitatively assess the flow of players and identify central hubs (e.g., prominent leagues) within a global football network, offering insights that traditional methods might overlook. We establish the Squad-League Networks (SLN) methodology to achieve this, focusing on elite players' participation in FIFA World Cups since World War II. This study explores their mobility across various national leagues globally and conducts a longitudinal analysis of Squad-League Networks from past World Cups to investigate the globalization process of elite football player mobility. Specifically, we aim to identify how key network metrics, such as density and centrality, shed light on the evolving dynamics of player migration and the concentration of talent within certain leagues and countries.

As a paradigm in sociological research, the simplicity and richness of content in the social network analysis (SNA) method allow it to be applied in various scenarios. Since its introduction to sports science, it has been extensively used in the analysis of performance in team sports competitions. Many indicators have also been enriched with perspectives from sports fields. However, it would be regrettable if its application were limited to on-field analysis alone. We aim to extend its application to some off-field scenarios.

As previously mentioned, in some studies related to sports sociology and sports economics, researchers have adopted the mindset of social network analysis, linking clubs, leagues, and nations through player transfer behaviors (Velema, 2020). However, the application of this basic network analysis usually involves only one type of node, referred to as a one-mode network in network analysis. Its innovation lies in the application of the method rather than making improvements to the method itself, which could be more suitable for sports science. This study innovatively connects two dissimilar nodes, national squads, and national leagues, by expanding the meaning of connections between nodes. At the outset of construction, it collapses the bipartite nature of the network itself into a one-mode network, making it easier to understand and calculate. Furthermore, this adjustment allows us to model the interconnections between national teams and leagues, and through this lens, we can assess the movement and attraction of players across nations, ultimately measuring the "*environmental attractiveness*" of football in each country.

Although there are some specific properties of the selection process, the squads representing a nation in a World Championship can be considered a selection of the best available players, as these teams generally feature the top-performing athletes in the country. The selections may be seen as a stratified sample according to playing positions, with a proportional representation of goalkeepers, defenders, midfielders, and forwards, ensuring the best players from each position are included. Other factors, such as the need to form a cohesive team or "*socio-psychological*" variables (e.g., players' willingness to represent their country), are often less emphasized or assumed to influence teams in a similar manner across all squads. In sum, the countries' interest in fielding their strongest possible team aligns with selecting the best players in each position, thus creating a sample stratified by role.

In the utilization of indicators, we not only employ classic metrics like density, degree centrality, and graph centralization commonly used in network analysis, but also focus on using intuitively understandable metrics to measure both the overall network and individual nodes, including %Home and self-loops. Given that Squad-League Networks inherently contain more nuanced information, these seemingly simple metrics can

effectively capture and differentiate key dynamics. The study's metrics successfully illustrate the evolving dynamics and shifting patterns of participation in the FIFA World Cup over time.

Starting with 13 teams in its inaugural year of 1950, the number of participating teams expanded to 32 by 1998, while the percentage of players remaining in their home leagues exhibited a significant decline over decades. This trend highlights a growing preference among players for international leagues. As global football grew more interconnected, network density, which illustrates interactions between national teams and their leagues, steadily increased. Degree centralization, reflecting the disparity in nations' importance, showed notable fluctuations in early World Cups but became more stable and predictable with the development of enhanced global connections and player mobility in the 21st century.

Moreover, in terms of network visualization, the Squad-League Networks method exhibit more intuitive results, as evident from the significant global trend of elite football player globalization in the comparative Sankey diagram in the results section. Describing different national football environments using in-degree and out-degree centrality metrics also provides a straightforward depiction of the attractiveness of different national leagues, with the results broadly aligning with our understanding of the football world. This validation of Squad-League Networks reinforces its potential as a powerful tool for examining the dynamics of player migration and league competition. In summary, the Squad-League Networks method has been validated and can be effectively applied to research in sports sociology, historical development, and other topics. The measurement indicators used in this study also demonstrate good interpretability.

In addition to introducing the novel concept of Squad-League Networks, this study also empirically portrays the choices of elite players from top national teams regarding leagues from 1950 to the present. The analysis of the overall development of Squad-League Networks reveals that with the evolution of the football world, especially over the past three decades since the 1990s, the globalization trend of elite players' engagements in leagues has become increasingly apparent, leading to the growing complexity of the entire network. Previous studies on player transfers mostly focused on movements between northern and southern regions, assuming that global player migration primarily occurs between other southern hemisphere nations and Europe, such as African or Latin American players moving to Europe (Darby, 2007, 2011; Littlewood, 2011; Poli and Besson, 2011). This study acknowledges the globalization trend towards Europe among elite players called up by national teams, but it does not assert its complete dominance. When analyzing the movement of players from all participating teams in past tournaments, we believe that such migration behavior is greatly influenced by time and relevant policies. For example, in 1998, Asian nations like Japan, South Korea, Iran, and Saudi Arabia, with relatively short histories of World Cup participation, tended to retain their players in domestic leagues. This trend is also evident in Qatar in 2022.

To explore Squad-League Networks in European nations hosting the top five leagues and the "*North-South migration*" of academic concern, this study conducted detailed analyses of the seven representative nations, including Germany, England, Italy, Spain, and France representing the top five leagues, as well as Brazil and Argentina representing South American football. We agree with other researchers' assessments of the North-South migration and the high attractiveness of European leagues, but this situation cannot be generalized. For instance, in European leagues, the attraction of the French league to domestic national team players is more close to Brazil. However, because Squad-League Networks involve players who can be called up by national teams, the choices of Argentine and Brazilian players cannot simply indicate a decrease in the attractiveness of their domestic leagues. It can also be explained by the fact that their strong skills attract offers from European leagues. Nations like England, which have an absolute appeal to domestic elite athletes while also attracting a large number of foreign elite players, indicate that although they may not demonstrate

absolute dominance in tournaments like the World Cup, their overall football environment and development have effectively dominated the football world.

Another interesting finding of this study is the hidden trend of individual node concentration under the globalization trend, akin to the Matthew effect, which refers to the phenomenon where "*the rich get richer and the poor get poorer*." The continuous decrease in %Home and significant increase in degree centralization indicators of Squad-League Networks over the years indicate a proliferation of connections between nodes, but these connections are more concentrated in specific pathways. This trend is also evident in the visualization of player inflow and outflow in Figure 8, where the UK has consistently maintained a leading position with low outflow and high inflow, with little variation over successive World Cups. From 1998 to 2022, most nations with low inflow and high outflow have exhibited a more pronounced trend towards homogenization. Particularly interesting is Italy, which, despite remaining a formidable force in world football, has been absent from the last two World Cup tournaments. Even so, Italy still had the second-highest proportion of foreign players in our Squad-League Networks constructed for the 2022 World Cup, trailing only behind the England. Moreover, these foreign players did not originate from specific national teams but from numerous nations eligible to participate in the World Cup. This characteristic of league attractiveness not only aligns with the implications of the Matthew effect but also validates the assertion made in the introduction section of this study that the network structure not only provides opportunities for actors within the network but also influences the decisions of these actors in turn.

This study also has some limitations. Firstly, in order to have a unified measure of elite athletes, we selected national teams and their players who participated in the final rounds of the World Cup for research. However, these qualifications for participation are determined by the qualifiers, and the number of slots allocated to different regions (continents) in each tournament may vary, introducing some randomness and bias. The squads of World Championships do not necessarily represent the strongest teams in the world, as the quota for European and South American nations prevents some strong nations from participation. Nevertheless, one may see the participants as a sample of the strongest nations in the world, stratified by continents.

Secondly, to better construct networks that reflect real-world conditions, when a nation does not qualify for the final rounds of the World Cup but its league still attracts players from other nations eligible to participate, such as Italy in the 2018 and 2022 World Cups, this league is included in the network calculation. However, in such cases, the number of participants from their national team is zero, making metrics like out-degree centrality inappropriate for indicating the migration of their national team players to other leagues. Only in-degree centrality is considered to measure the attractiveness of their league to players from other national teams.

An interesting hypothesis related to player mobility is the impact of the "*Bosman*" case. The Bosman ruling, which prohibited the imposition of quotas on foreign players from EU states in EU leagues, might have led to increased player "*traffic*" within European leagues. While our study did not find clear empirical evidence supporting this hypothesis, likely due to the global nature of our sample which includes teams from all over the world, it is worth noting that this phenomenon would specifically affect only EU teams. However, our Squad-League Networks (SLN) methodology could be employed to test this hypothesis in future research, offering a valuable avenue for further exploration.

The empirical findings of the study inspire follow-up questions relating to sports economics and sports history. The key question is: Why are the big five, the five leagues in England, Germany, Spain, France and Italy, so attractive for the best players from all over the world?

Financial reasons alone cannot be the decisive factor. If this were the case, the leagues from Saudi Arabia and Qatar would attract even more top players. So it cannot be the prospect of maximum income alone that attracts the world's best players to the top five European leagues.

The mobility of the world's best players is determined by the attractiveness of the leagues as well as the prospect of earning money. And here Europe has a competitive advantage, which consists of two factors: Firstly, European football has a governance structure that balances economy and cultural values created by football (Allen and Garcia, 2007; Niemann, Garcia and Grant, 2012). This can be shown by looking on the flagship of European football, the champions league.

The champions league, organized by UEFA, is an economic success because it is regarded as a kind of unofficial world championship for club teams. For the world's best players, the champions league title is the most important title a club player can win. However, the champions league is more than just a commercial spin-off of UEFA. It also has non-economic cultural roots: it picks up on a development that has been evident since the 1950s to construct Europe through genuine sporting competition formats. In this respect, the champions league benefits from the Europeanization of football.

Secondly, the European top leagues are dominated by soccer clubs that possess a good that cannot be bought: Tradition. Traditional clubs such as Real Madrid or Liverpool FC have a symbolic power that is a decisive advantage in attracting the best players of the world. When they move to Real Madrid, they become part of a chain of tradition at Europe's most successful club, which owes its global visibility to its success in European competitions (Pyta and Havemann, 2015).

CONCLUSION

This study introduces the innovative Squad-League Networks (SLN) methodology within social network analysis (SNA) to offer a deeper understanding of elite football player mobility. By analyzing national team players in FIFA World Cups from 1950 to the present, it reveals complex interactions between national teams and domestic leagues, extending beyond traditional migration models to highlight a clear trend of globalization in player movement. Notably, this trend moves beyond North-South migration, with major European leagues showing a 'Matthew effect' where the most attractive leagues draw more elite players, shaped by both economic and structural factors.

The use of network metrics such as density and centrality helps explore mobility patterns, but these measures are interpreted within a broader theoretical context, providing insights into how global football networks evolve over time. This approach not only enhances our understanding of globalization in football but also paves the way for future research on the impact of governance structures, migration policies, and cultural values on player mobility.

In conclusion, the SLN methodology represents a significant contribution to sports sociology by offering a new framework to examine the historical and social dimensions of football player mobility and the evolving dynamics of global sports networks.

AUTHOR CONTRIBUTIONS

C.Y. Yang conceptualized the study, conducted data processing and analysis, and wrote the manuscript. R. Ma assisted in data collection and preparation. J. Exel contributed to the conceptual framework and provided

methodological guidance. W. Pyta reviewed and edited the manuscript. M. Lames initiated the research idea, contributed to data acquisition, and participated in reviewing and editing the manuscript.

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