



Acionistas e propriedade comum no mercado de anticorpos monoclonais: uma análise de redes

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Resumo: A inovação na indústria farmacêutica tem sido um motor central das melhorias na saúde da população, gerando ganhos substanciais na expectativa e qualidade de vida, embora por meio de um modelo de desenvolvimento caracterizado por elevada intensidade em P&D, longos prazos e custos elevados, frequentemente refletidos em preços de monopólio. Nesse contexto, a crescente financeirização e a propriedade comum na indústria farmacêutica têm remodelado a governança corporativa e a dinâmica competitiva, levantando preocupações de que decisões estratégicas em segmentos altamente inovadores e concentrados — como o mercado de anticorpos monoclonais — possam estar cada vez mais orientadas por interesses financeiros, e não pela eficiência inovativa ou pelas necessidades de saúde pública. Este estudo investiga a propriedade comum — situação em que múltiplas empresas compartilham grandes investidores — no mercado de inovação em anticorpos monoclonais (mAbs), por meio de uma análise de redes transversal dos vínculos de propriedade. Para a análise de abrangência, foram desenvolvidos dois modelos de rede: uma rede não direcional para mapear poder, influência e posição estratégica, e uma rede direcional para captar a influência entre acionistas e empresas. Adicionalmente, para a análise de propriedade comum, foi construída uma rede unimodal ligando acionistas, com o cálculo de razões de propriedade comum tanto para investidores quanto para empresas. Os resultados indicam que o poder das empresas é relativamente mais proeminente na rede do que sua posição estrutural ou influência, enquanto os acionistas tendem a ocupar posições mais estratégicas e a se conectar, de forma direcional, a nós altamente influentes. A análise de propriedade comum mostrou que alguns acionistas são mais bem conectados do que outros, destacando-se BlackRock, UBS e JPMorgan Chase como os proprietários comuns mais proeminentes. Entre as empresas, Abbott, Eli Lilly, BMS, Biogen, Pfizer e Amgen apresentaram os acionistas mais influentes na rede. A concentração observada de poder e influência nas mãos de poucos atores-chave sugere a possível existência de um fenômeno de ‘clube dos ricos’ que direciona decisões no mercado de inovação

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em mAbs, indicando que a propriedade comum nesse mercado é altamente concentrada, com um pequeno grupo de investidores moldando a dinâmica competitiva, a governança e, potencialmente, a inovação, o que reforça a necessidade de examinar como a concentração financeira influencia o desenvolvimento de medicamentos, a precificação e o acesso.

Palavras-chave: Propriedade comum; financeirização; anticorpos monoclonais; economia da saúde; mercado de saúde.

Código JEL: L22, L65, I11.

Área Temática: 4.4. Redes de inovação – alianças de P&D, interações universidade-empresa, outras redes

Shareholders and common ownership in the market for monoclonal antibodies: A network analysis

Abstract: Innovation in the pharmaceutical industry has been a central driver of improvements in population health, generating substantial gains in life expectancy and quality of life, albeit through a development model characterized by high R&D intensity, long timelines, and elevated costs that are often reflected in monopoly pricing. In this context, increasing financialization and common ownership have reshaped corporate governance and competitive dynamics, raising concerns that strategic decisions in highly innovative and concentrated segments—such as the monoclonal antibody market—may be increasingly guided by financial interests rather than by innovation efficiency or public health needs. This study investigates common ownership—defined as the situation in which multiple firms share major investors—in the monoclonal antibody (mAb) innovation market through a cross-sectional network analysis of ownership ties. For the breadth analysis, two network models were developed: an undirected network to map power, influence, and strategic position, and a directed network to capture influence between shareholders and companies. Additionally, for the common ownership analysis, a unimodal network linking shareholders was constructed, with common ownership ratios calculated for both investors and firms. The results show that the power of companies is relatively more prominent in the network than their structural placement or influence, whereas shareholders tend to occupy more strategic positions and are often connected to highly influential nodes in a directional manner. The common ownership analysis further indicates that some shareholders are better connected than others, with BlackRock, UBS, and JPMorgan Chase emerging as the most prominent common owners; in terms of companies, Abbott, Eli Lilly, BMS, Biogen, Pfizer, and Amgen were identified as those associated with the most influential shareholders in the network. The observed concentration of power and influence in the hands of a few key players suggests the possible existence of a ‘rich-club’ phenomenon that directs decisions in the mAb innovation market, indicating that common ownership in this market is highly concentrated, with a handful of investors shaping competitive dynamics, governance, and potentially innovation, and underscoring the need to examine how financial concentration influences drug development, pricing, and access.

Keywords: Common Ownership; Financialization; Monoclonal Antibodies; Health Economics; Healthcare Market.

1 INTRODUCTION

Innovation in the pharmaceutical market has led the development of new technologies that significantly enhance the prevention, diagnosis, and treatment of numerous diseases, substantially improving public health outcomes, quality of life, and life expectancy (CRAIG; MALEK, 1995; CUTLER, 2020; LAKDAWALLA, 2018; LLANO-SENARIS; CAMPILLO-ARTERO, 2015; NEWHOUSE, 1992). Researchers argue that few industries have contributed as profoundly to human welfare as the pharmaceutical industry (GRABOWSKI, 2002). However, these benefits have come at high costs for both producers and consumers (BUENO, 2022; DIMASI; GRABOWSKI; HANSEN, 2016; LUIZA et al., 2016; NEGRI et al., 2024). Compared to other industries, pharmaceutical companies invest heavily in research and development (R&D), which carries significant risk, and charge relatively high prices for their new technologies (BANAL-ESTAÑOL; NEWHAM; SELDESLACHTS, 2021; CRAIG; MALEK, 1995; LLANO-SENARIS; CAMPILLO-ARTERO, 2015; ROCHA; GIAMBIAGI; LAGO, 2022). In 2022, the pharmaceutical industry topped the European Union's (EU) Industrial R&D Investment Scoreboard, with an investment of US\$213 billion in absolute terms or 16.5% of their net sales (EUROPEAN COMMISSION, 2024). The average capitalized cost of bringing a new drug to market is estimated at US\$2.6 billion (in 2013 USD), with the development time from inception to marketing ranging between 10 and 12 years (DIMASI et al., 1991; DIMASI; GRABOWSKI; HANSEN, 2016). However, these costs are often reflected in the monopoly price of new technologies, enabled by patent protections, once a new drug reaches the market (HERNANDEZ et al., 2018).

New molecular entities typically yield stable returns on investment (MONTALBAN; SAKINC, 2013). Nevertheless, the continued need for substantial R&D investment throughout the development process makes the pharmaceutical industry susceptible to financialization and common ownership (ANDERSSON et al., 2010; BANAL-ESTAÑOL; NEWHAM; SELDESLACHTS, 2019, 2021; STEIN; SRIDHAR, 2018). *Financialization* refers to the process by which corporate strategies become subordinate to the accumulation of financial capital (MONTALBAN; SAKINC, 2013; STEIN; SRIDHAR, 2018). In this context, pharmaceutical companies manage innovation portfolios and trade products to maximize shareholder value (ANDERSSON ET AL., 2010; BANAL-ESTAÑOL; NEWHAM; SELDESLACHTS, 2019). Investment decisions are thus increasingly influenced by stock market performance rather than operational efficiency or public health priorities. *Common ownership* arises when multiple firms are partially owned by the same investors (BANAL-ESTAÑOL; NEWHAM; SELDESLACHTS, 2021; NEWHAM; SELDESLACHTS; BANAL-ESTAÑOL, 2022). This structure allows shareholders to diversify risk by investing across multiple competing firms, effectively promoting self-insurance (BANAL-ESTAÑOL; NEWHAM; SELDESLACHTS, 2019; LEDLEY et al., 2020; MALERBA; ORSENIGO, 2015; MONTALBAN; SAKINC, 2013; NEGRI et al., 2024; VITALI; GLATTFELDER; BATTISTON, 2011). In addition, common investors hold shares in both innovative (e.g., J&J, Pfizer, Eli Lilly, Amgen, and Novartis) and imitative (e.g., Teva, Sandoz, and Aurobindo) companies (NEWHAM; SELDESLACHTS; BANAL-ESTAÑOL, 2022).

Anecdotal and empirical evidence suggests that institutional investors actively and passively engage with corporate boards and management to influence strategic decisions in pharmaceutical companies (AGHION; VAN REENEN; ZINGALES, 2013; APPEL; GORMLEY; KEIM, 2016; BANAL-ESTAÑOL; NEWHAM; SELDESLACHTS, 2021; BRAV et al., 2018; GENG; HAU; LAI, 2015; NEWHAM; SELDESLACHTS; BANAL-ESTAÑOL, 2022). The greater their stake in a company, the more influence they have over decisions (VITALI; GLATTFELDER; BATTISTON, 2011). Although large institutional investors own at most 5% to 8% of a single company, this is usually enough to position them among the top investors, granting them privileged access to decision-making processes (BANAL-ESTAÑOL; NEWHAM; SELDESLACHTS, 2019; NEWHAM; SELDESLACHTS; BANAL-ESTAÑOL, 2022). This ownership structure in the pharmaceutical industry raises concerns about the shifting locus of control from healthcare stakeholders to financial entities, potentially prioritizing capital market interests over public health needs. Strategic behaviors such as mergers, acquisitions, and monopoly formation to maximize stock prices, in turn, could destabilize industrial ecosystems and inflate market prices (MONTALBAN; SAKINC, 2013; VURAL,

2017). In addition, large pharmaceutical corporations often operate through hierarchical structures with multiple subsidiaries. When companies within the same industry are owned by common shareholders, competitive dynamics may be undermined (BANAL-ESTANOL; NEWHAM; SELDESLACHTS, 2019; NEWHAM; SELDESLACHTS; BANAL-ESTANOL, 2022; O'BRIEN; WAEHRER, 2017; VITALI; GLATTFELDER; BATTISTON, 2011). Subsidiaries of a single parent company typically avoid direct competition, and similar behavior may be expected among firms with overlapping ownership (NEWHAM; SELDESLACHTS; BANAL-ESTANOL, 2022). As a result, structured control over pharmaceutical companies can influence R&D resource allocation, innovation trajectories, commercialization timing, and drug pricing (STEIN; SRIDHAR, 2018).

Technological progress is widely considered a key source of long-term economic growth. However, the relationship between innovation and ownership remains contested (AGHION; VAN REENEN; ZINGALES, 2013; GENG; HAU; LAI, 2015). Vitali et al. (2011) observed the existence of a *rich-club phenomenon*, wherein a small, interconnected group of investors exerts disproportionate influence over the market. Their analysis identified a 'bowtie' network structure among multinational corporations, with a significant portion of market control concentrated in a core group of shareholders, primarily financial institutions, and they potentially function as an economic super-entity. There is no compelling reason to believe that the pharmaceutical industry is exempt from this phenomenon.

The effects of financialization and common ownership should be even more pronounced in the market for monoclonal antibodies (mAbs). This market is characterized by specific features that make it unique. First, the cost of developing new drugs is higher for biological than for chemical drugs (DIMASI et al., 1991; DIMASI; GRABOWSKI, 2007; DIMASI; GRABOWSKI; HANSEN, 2016; DIMASI; HANSEN; GRABOWSKI, 2003; DIMASI; PAQUETTE, 2004). According to DiMasi and Grabowski (2007), the average capital cost to develop a new biopharmaceutical drug was approximately US\$1.2 billion during the 2010s. Furthermore, mAbs are not subject to perfect competition. There are no generic mAbs. Generics are derived from drugs that are identical to the reference product. However, it is impossible to produce an identical mAb once the patent has expired. Biosimilars are biological therapies that are highly similar to a previously approved reference product, although minor structural differences, such as post-translational modifications, may exist (MANIS, 2022). Moreover, one additional feature of this market should attract investors: very few companies in very few countries possess the technological capabilities to develop, or even replicate, an mAb (MOTTA-SANTOS et al., 2025a).

This study investigates shareholder partnerships and common ownership within the mAb innovation market. In addition to the characteristics previously discussed, this market was selected as a case study owing to its therapeutic relevance and economic significance. mAbs are used to treat hematologic malignancies, solid tumors, ophthalmologic conditions, autoimmune, metabolic, and infectious diseases, as well as drug reversal (GRILO; MANTALARIS, 2019; HERNANDEZ et al., 2018; LIU et al., 2022; MANIS, 2022; MARKS, 2015; PAN; CHEN, 2017; RAJEWSKY, 2019; SINGH et al., 2018). They are also associated with extremely high prices and revenues (BLOK, 2021; CUMBERS, 2021; GODDARD, 2021; SLEEMAN, 2021), with the average annual price of FDA-approved mAbs between 1997 and 2016 reaching US\$96,731 (HERNANDEZ et al., 2018). To the best of our knowledge, this is the first study to identify key shareholders and to quantify their influence in the mAb market.

2 METHODS

This study employed a cross-sectional analysis to examine shareholder structures within the market for mAb innovations. Given the growing concerns surrounding financialization and common ownership, this analysis aims to provide valuable insights for policymakers, healthcare stakeholders, and antitrust behavior analysts (BANAL-ESTANOL; NEWHAM; SELDESLACHTS, 2021). Understanding these dynamics is essential for addressing the implications of high-priced mAbs and for guiding decision-making in health systems.

2.1 Data sources

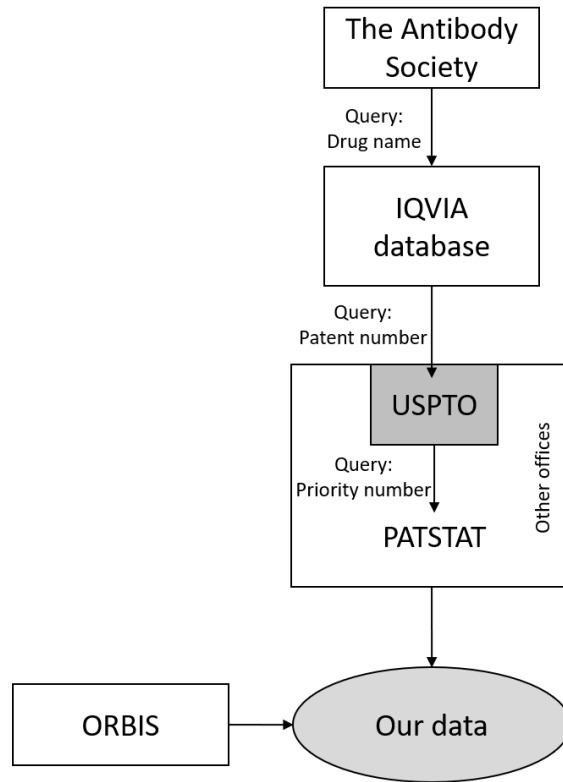
This study relies exclusively on secondary data obtained from a combination of proprietary and publicly accessible databases. Five key sources were used to build the study's analytical database: (i) *The Antibody Society* is an international non-profit organization representing stakeholders in antibody development. It maintains a comprehensive registry of mAbs approved or under regulatory review in the European Union (EU) and the United States (US) (THE ANTIBODY SOCIETY, 2023). (ii) *IQVIA's Ark Patent Intelligence* is a comprehensive database covering patent information from 130 countries. It includes data on drugs from Phase III development through to market commercialization (IQVIA, 2023). (iii) *The US Patent and Trademark Office* (USPTO) is a federal agency responsible for granting patents and registering trademarks in the US. Given the size and influence of the US pharmaceutical market, USPTO data serve as a robust proxy for global patent activity (BRITTO; RIBEIRO; ALBUQUERQUE, 2021; KIM; JEONG; KIM, 2021; PAN; CHEN, 2017). (iv) *PATSTAT* is a comprehensive patent database, maintained by the European Patent Office (EPO), comprising almost 70 million patents from over 100 patent offices worldwide (BRITTO; RIBEIRO; ALBUQUERQUE, 2021; EUROPEAN PATENT OFFICE, 2019). (v) *ORBIS* is a corporate intelligence platform offering standardized and curated data on private companies. It provides detailed information on industrial classification, geographical position, operating revenue, total assets, and other firm-level characteristics (BUREAU VAN DIJK, 2024; VITALI; GLATTFELDER; BATTISTON, 2011).

2.2 Dataset construction

Figure 6.1 outlines the step-by-step process used to construct the study's database. The first step was the identification of mAbs. An initial list of approved mAbs was obtained from the Antibody Society, along with their International Nonproprietary Names (INN) (THE ANTIBODY SOCIETY, 2023). The INNs were then used to extract corresponding patent numbers from the IQVIA database (IQVIA, 2023). In the second step, patent numbers were used to retrieve detailed metadata from the USPTO subset within PATSTAT (EUROPEAN PATENT OFFICE, 2019). The data obtained from PATSTAT were up to 2019 as this was the cut-off point for the IQVIA database accessible for this study. The metadata included application numbers, country codes, filing and publication dates, International Patent Classification (IPC) codes, USPTO identifiers, patent types, priority application numbers, and holders' names, countries, and types. Types of holders include companies, individuals, government non-profit organizations (GNPOs), universities, and hospitals.

In the third step, priority patent numbers were further searched in PATSTAT to identify related patent families and to retrieve additional metadata from other patent offices. Finally, firm-level data for identified patent holders were retrieved from the ORBIS database. These data were retrieved for the companies that participated in the mAbs market from the list of holders identified in the previous steps. The resulting dataset is consistent with the methodologies employed in a previous study published by the authors (MOTTA-SANTOS et al., 2025a), and provides a foundation for analyzing shareholder influence and ownership patterns in the mAb market.

Figure 2.1. Database construction steps.



2.3 Data analysis

The data analysis began with a general characterization of the database, including the number of mAbs, associated patents, and their main holders. Subsequently, ownership profiles were analyzed in terms of breadth, defined as the number of companies in which a given investor holds shares (FICHTNER; HEEMSKERK; GARCIA-BERNARDO, 2017). For this analysis, two types of networks were constructed. First, an undirected network was used to assess the overall structure of relationships between companies and shareholders. Key metrics included: degree centrality (network power), closeness and betweenness centrality (network position), and eigenvector centrality (market influence). Second, a directed network was used to evaluate in-degree centrality (company power), out-degree centrality (shareholder power), eigenvector centrality (overall influence), and hub scores (directional influence). For the common ownership analysis, a third undirected network was constructed, connecting shareholders based on their holdings. This network was used to identify the most influential shareholders using eigenvector centrality. Additional indicators, such as common ownership ratios for both shareholders and companies, were also calculated. All analyses were conducted in R (KOLACZYK; CSÁRDI, 2020; LUKE, 2015; R CORE TEAM, 2025; SCHWEINBERGER, 2022).

2.3.1 Network analyses

Networks can be either directed or undirected. In directed networks, nodes (or *vertices*) are connected by edges with arrows (also called *arcs*) to indicate direction, while undirected networks use simple edges. In this context, vertices represent shareholders (individuals or firms) and pharmaceutical companies, and edges represent the relationships between them. Since this study is interested in ownership structures, the edges in the directed network flow from shareholders to firms. In all networks, blue vertices represent shareholders, pink vertices represent pharmaceutical companies, and purple vertices represent companies that hold shares in other companies. Seven metrics were applied to analyze these networks: degree centrality (C_D), betweenness centrality (C_B), closeness centrality (C_C), eigenvector centrality (C_E), hub scores (h), density (d) and diameter (D).

Degree centrality refers to the number of direct edges a vertex has. The assumption is that the

more connections there are in a vertex, the more important it is for the network. For node i , the degree centrality can be calculated by **Equation 6.1**, in which $G_{i \leftrightarrow j}$ is the value of the edge between the vertices i and j (0 or 1) and N is the number of vertices in the network. Degree centrality can still be divided between in-degree and out-degree centrality. In-degree centrality is the number of edges received by a vertex (**Equation 6.2**, in which $G_{i \leftarrow j}$ is the binary value of the edge from j to i), and out-degree centrality is the number of edges flowing from a vertex (**Equation 6.3**, in which $G_{i \rightarrow j}$ is the binary value of the edge from i to j) (KIM; JEONG; KIM, 2021).

$$G_D(i) = \sum_{j=1}^N G_{i \leftrightarrow j} \quad (6.1)$$

$$G_{ID}(i) = \sum_{j=1}^N G_{i \leftarrow j} \quad (6.2)$$

$$G_{OD}(i) = \sum_{j=1}^N G_{i \rightarrow j} \quad (6.3)$$

In the breadth analysis, degree centrality [$C_D(i)$] is of utmost relevance for the undirected network, while the in-degree centrality and out-degree centrality [$C_{ID}(i)$ and $C_{OD}(i)$] are more important for the directed network. In the undirected network, the degree centrality was used to estimate the power of a shareholder or a pharmaceutical company compared to the whole network. High degree centrality in the undirected network represents either a company with many shareholders or a shareholder with interest in many companies. Firms connected to many others, even indirectly through shareholder intermediaries, may hold an advantageous position for establishing information and technology-sharing agreements (BANAL-ESTANOL; NEWHAM; SELDESLACHTS, 2021). In a directed network, out-degree centrality indicates the number of companies an investor has an interest in, whereas in-degree centrality reflects the number of shareholders with an interest in a given company. The former is an estimate of the influence of the shareholders over the market (i.e., their power). The latter serves as an indirect estimate of decision-making concentration within a company; lower in-degree centrality suggests fewer investors, potentially indicating more centralized influence over corporate decisions.

Power and placement are important in network analyses. The C_D and its variations evaluate how many connections a vertex makes. Betweenness centrality (C_B) and closeness centrality (C_C) consider the placement of a vertex. *Betweenness centrality* measures how often a vertex lies on the shortest paths between two other vertices (**Equation 6.4**, in which G_{jk} is the number of shortest paths between vertices j and k , and $G_{jk}(i)$ is the number of those paths that pass through i , with $i \neq j \neq k$). This measure is particularly important for identifying vertices that serve as potential intermediaries or bridges within the network. In some cases, a node may exhibit low degree centrality yet play a critical role in connecting otherwise separate subnetworks (KIM; JEONG; KIM, 2021). Companies with high betweenness centrality should be important in terms of flux of information and influence between companies for their capacity to connect different groups. They can intermediate contracts and agreements, especially between firms that do not have many shareholders in common or between shareholders who do not invest simultaneously in many companies. The higher the betweenness centrality, the more companies and shareholders must depend on that vertex to transmit influence and information between subnetworks. In the context of patent analysis, these shareholders might be strategic in facilitating licensing and knowledge-sharing agreements between companies.

$$C_B(i) = \sum_{j < k} \frac{G_{jk}(i)}{G_{jk}} \quad (6.4)$$

Closeness centrality measures the proximity of a vertex to all other vertices in the network (**Equation 6.5**, where $d(i, j)$ is the shortest distance between vertices i and j , N is the total number of

vertices in the network, and $i \neq j$). One limitation of betweenness centrality is that a vertex may have a high betweenness centrality while still being relatively distant from most other vertices in the network. Closeness centrality, on the other hand, provides information on how easily a shareholder can transmit influence and information throughout a network without relying very much on intermediaries (BANAL-ESTANOL; NEWHAM; SELDESLACHTS, 2021; KIM; JEONG; KIM, 2021). Therefore, it also reflects strategic positioning in the market, but from a different perspective. In this way, betweenness centrality and closeness centrality serve as complementary indicators.

$$C_c(i) = \frac{1}{\sum_{j=1}^N d(i, j)} \quad (6.5)$$

Eigenvector centrality measures the influence (i.e., status or prestige) of a vertex in a network. It is based on the idea that a vertex is more important if it is connected to other highly central vertices. Formally, as shown in **Equation 6.6**, let E be the set of edges, where $\{i, j\} \in E$ indicates that vertices i and j are connected. The sum runs over all neighbors j of vertex i (with $i \neq j$). Each term in the sum represents the centrality of neighbour j , denoted as $C_E(j)$, and the total is scaled by a constant factor α . The vector $C_E = [C_E(1), \dots, C_E(N)]^T$ is the solution to the eigenvalue problem $A \times c = e_v \times c$, where A is the adjacency matrix of the graph, c is the eigenvector of centralities (i.e., $C_E(i)$ for all vertices i), and $e_v = \alpha^{-1}$ is the eigenvalue. In practice, the igraph package in R calculates eigenvector centrality by constructing the adjacency matrix and computing its principal eigenvector, which yields the centrality score for each vertex (CSÁRDI; NEPUSZ, 2005; R CORE TEAM, 2025). These values are normalized such that the highest score is 1. In economic terms, a higher eigenvector centrality indicates a vertex that is connected to other highly influential vertices.

$$C_E(i) = \alpha \sum_{\{i, j\} \in E} C_E(j) \quad (6.6)$$

Eigenvector centrality is not the only way to measure the influence of a vertex. In directed networks, *hub scores* (h) can be equally relevant for this purpose. Both hub scores and eigenvector centrality measure the importance of a vertex in a network, but they differ in how they interpret connections. Eigenvector centrality assigns higher scores to vertices connected to other highly central vertices, treating all connections symmetrically regardless of direction. In contrast, hub scores specifically apply to directed networks and focus on vertices that point to many important vertices (called *authorities*). Thus, hub scores emphasize a vertex's role as a connector or distributor of influence, while eigenvector centrality captures its overall centrality based on connections to important vertices in either direction (KLEINBERG, 1999). A shareholder with a high hub score is one who invests in many companies that themselves are highly important or central within the market. Economically, this suggests that such a shareholder acts as a strategic investor or key player who can influence multiple prominent firms, potentially facilitating information flow or coordinated actions across the market (JACKSON, 2008). The hub scores are calculated by **Equation 6.7**, where h_i is the hub score of vertex i , a_j is the authority score of vertex j , the sum runs over all vertices j such that there is a directed edge from vertex i to vertex j (i.e., i points to j), and E is the set of directed edges. Simultaneously, the authority scores a_j are defined by **Equation 6.8**. This means the authority score of j depends on the hub scores of vertices pointing to it, and the hub score of i depends on the authority scores of vertices it points to. The scores are usually computed iteratively until convergence (KLEINBERG, 1999).

$$h_i = \sum_{j: \{i \rightarrow j\} \in E} a_j \quad (6.7)$$

$$a_j = \sum_{i: \{i \rightarrow j\} \in E} h_i \quad (6.8)$$

A simpler metric is the diameter, which is the shortest path between the two most distant vertices in a network. In this work, diameter represents the worst-case scenario for transmitting information and influence through the undirected network; i.e., the farther apart vertices are, the more difficult they are to reach. Another straightforward metric is density, which measures network cohesion. Density is defined as the proportion of observed connections relative to the maximum possible number of connections (**Equation 6.9** for directed networks or **Equation 6.10** for undirected networks, where L is the number of actual connections in the network and N is the number of nodes) (KIM; JEONG; KIM, 2021; LUKE, 2015).

$$d_D = \frac{L}{N(N-1)} \quad (6.9)$$

$$d_{UD} = \frac{2L}{N(N-1)} \quad (6.10)$$

2.3.2 Common ownership

Following the construction of the undirected network, pairwise common ownership among shareholders was evaluated using **Equation 6.11**, in which $C2(s, t)$ is the common ownership between two shareholders s and t , W is the total number of companies w , and $I[w(s, t)]$ is a logical function that counts 1 every time shareholders s and t are common owners in a company w and 0 when they are not. The same equation can be used for $C3, C4, \dots, CW$ just by adjusting the companies that should be found together. In this way, we can calculate the shareholders who appear more times together in two to W companies. Therefore, **Equation 6.11** quantifies the number of companies jointly owned, at least in part, by two shareholders s and t , with $s \neq t$.

$$C2(s, t) = \sum_{w=1}^W I[w(s, t)] \quad (6.11)$$

To estimate the frequency with which a single shareholder appears along with others in multiple companies, pairwise values are summed among all other shareholders (**Equation 6.12**, in which T is all shareholders excluding s).

$$c(s) = \sum_{t=1}^T C2(s, t) \quad (6.12)$$

To derive a common shareholding ratio for a single player, it is necessary to understand the maximum value that $c(s)$ can assume. $c(s)$ is maximum when one shareholder s partially owns all companies with all other shareholders in the market, excluding itself. In this case, $\max\{\sum_{t=1}^T \sum_{w=1}^W I[w(s, t)]\} = T \times W$, where W is the total number of companies, $T = S - 1$, and S is the total number of shareholders. Therefore, the common ownership ratio, $\gamma(s)$, of a single shareholder can be calculated by **Equation 6.13**.

$$\gamma(s) = \frac{c(s)}{T \times W} \quad (6.13)$$

The common ownership ratio of companies $[\psi(w)]$ was estimated by the average common ownership ratios of their shareholders; i.e., higher values of $\gamma(s)$ in shareholders of a company suggest that it is more connected to other companies in the market through highly influential shareholders (**Equation 6.14**, where s_w represents the shareholders of company w and S_w represents all shareholders of company w).

$$\psi(w) = \frac{\sum_{s_w} \gamma(s)}{S_w} \quad (6.14)$$

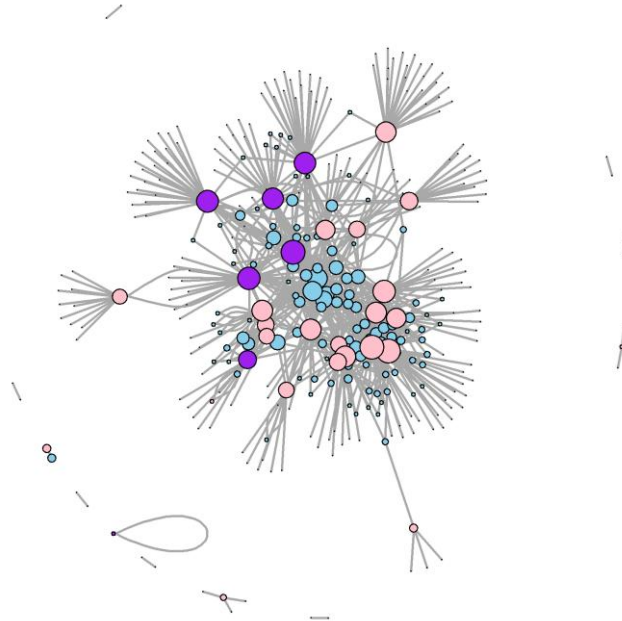
3 RESULTS

The dataset included 63 mAbs associated with 1,732 unique patent identification numbers (PINs). Data on the holder were available for 1,703 general mAb patents, associated with 928 distinct holders, including 51 companies, 18 universities, three hospitals, eight GNPOs, and 848 individuals. Although companies represented only 5.5% of all holders, they accounted for 79.0% of the patents, making them the largest group of patent holders. Roche Group had the highest number of mAb patents (442), followed by AbbVie (199), Amgen (106), Novartis (62), GlaxoSmithKline (GSK, 57), Biogen (54), Bristol Myers Squibb (BMS, 45), Regeneron (44), and Johnson & Johnson (J&J, 43). After ORBIS data were integrated, 37 company owners were identified, associated with 34 global ultimate owners (GUO). Completely owned subsidiaries of already accounted firms were removed from further analysis.

3.1 Breadth analysis

Initially, a network was built using the complete dataset, comprising 316 shareholders and 37 companies, resulting in 346 vertices and 704 edges. **Figure 6.2** shows the complete network, arranged using the Fruchterman-Reingold force-directed layout algorithm. The network is made up of 12 subnetworks, most of which are very small (1 to 4 vertices). One dominant subnetwork has 322 nodes. The complete network showed a density of 0.012 and a diameter of 7. Smaller subnetworks include 11 companies such as Blacksmith Brands, Boehringer Ingelheim, Janssen R&D Ireland Unlimited Company, Jazz Pharmaceuticals Ireland Limited, Liebel-Flarsheim Ireland Limited, Meridian Bioscience, Roche Palo Alto, Smith & Nephew, Sebela Ireland Limited, Mylan Ireland Limited, and CSL Behring. Despite being a part of the network, these small subnetworks are not of interest to this work. These were excluded from subsequent analyses because of limited relevance.

Figure 3.1. Network of shareholders and companies associated with the mAb innovation market.



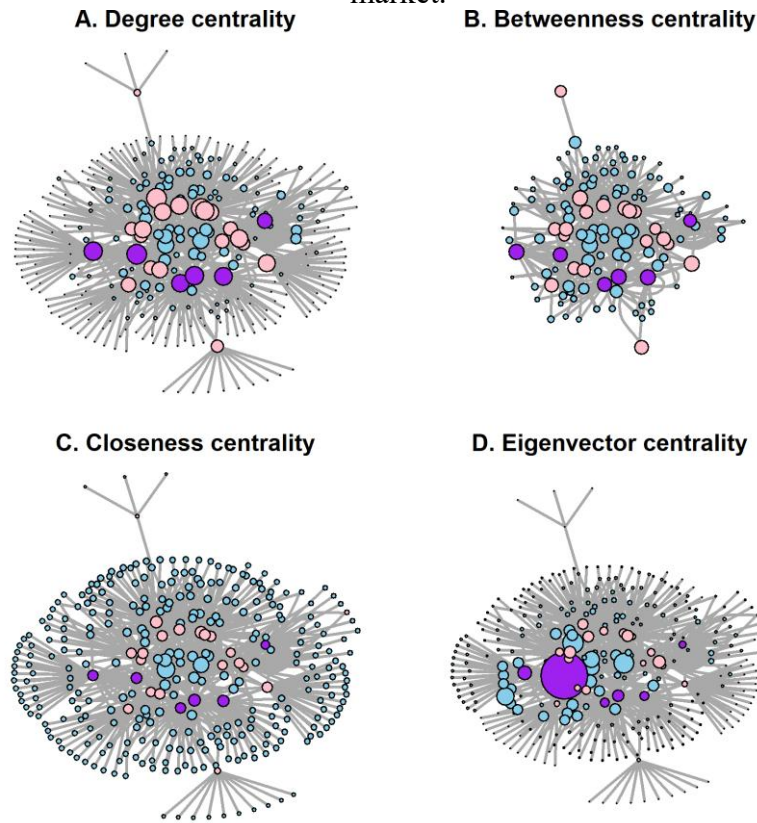
3.1.1 Undirected network

Focusing on the largest subnetwork (322 vertices, 687 edges), the undirected network analysis was conducted. The analysis revealed a low density (0.013), meaning that only about 1.3% of all possible

connections between vertices were present. The diameter of the network was 7, indicating that the longest shortest path between two nodes in the network was 7 steps. The global transitivity (also known as the clustering coefficient) was very low (0.002), indicating that only 0.2% of all possible closed triplets in the network were actually realised. These network properties suggest a sparse but connected network, conducive to the diffusion of influence and information.

Figure 6.3 shows the network with vertex sizes scaled according to four centrality measures: **(A)** degree, **(B)** betweenness, **(C)** closeness, and **(D)** eigenvector centrality. The vertices were arranged using the Kamada-Kawai force-directed layout algorithm (LUKE, 2015). In this network, the vertices with the highest degree centrality were AbbVie ($C_D = 53$), Novartis ($C_D = 52$), Amgen ($C_D = 51$), Sanofi ($C_D = 41$), and BMS ($C_D = 40$). The vertices with the largest betweenness centrality were BlackRock ($C_B = 10630$), Sanofi ($C_B = 8757$), JPMorgan Chase ($C_B = 7920$), AbbVie ($C_B = 7658$), and Roche ($C_B = 7301$). The vertices with the highest closeness centrality were BlackRock ($C_C = 0.465$), JPMorgan Chase ($C_C = 0.429$), UBS ($C_C = 0.392$), AbbVie ($C_C = 0.380$), and Sanofi ($C_C = 0.376$). Lastly, and perhaps most importantly, the vertices with the highest eigenvector centrality were Novartis ($C_E = 1.000$), Capital Group ($C_E = 0.205$), JPMorgan Chase ($C_E = 0.187$), Bank of New York Mellon ($C_E = 0.141$), and UBS ($C_E = 0.124$).

Figure 3.2. Undirected network of shareholders and companies associated with the mAb innovation market.



3.1.2 Directed network

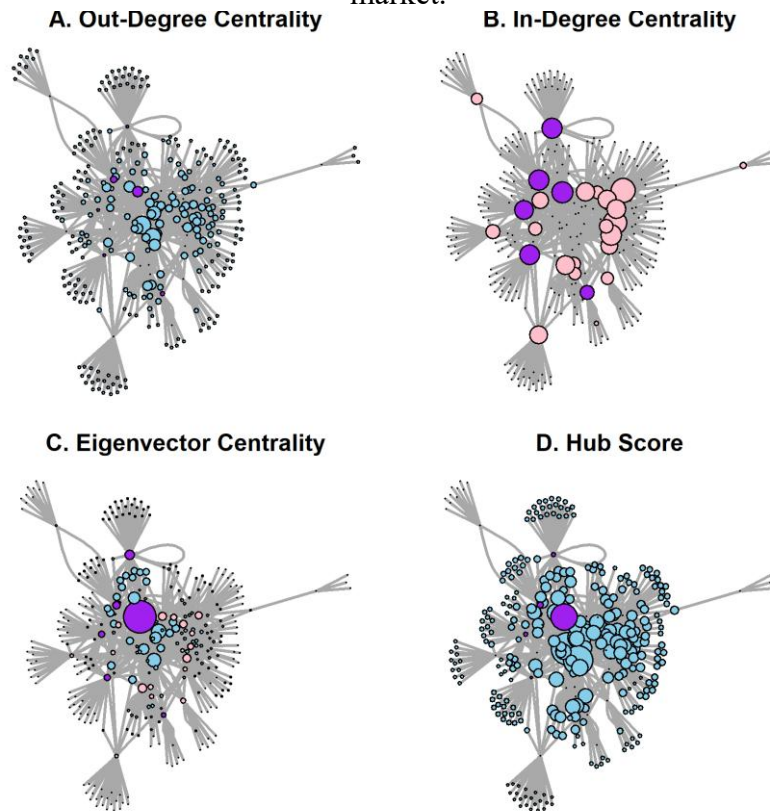
Using the same dataset, a directed network was constructed to evaluate the ownership relationships that flow from shareholders to companies. The resulting network forms a single weakly connected component. The density of the directed network is 0.007, lower than that of its undirected counterpart owing to the increase in the number of possible directional connections. The diameter of the directed network is only 2, indicating that the longest shortest path between any two reachable nodes is relatively short. Although the network is not strongly connected (i.e., not all nodes are reachable via directed paths), it remains connected when directionality is ignored (weakly connected).

Figure 6.4 presents the directed network with vertex sizes scaled according to four measures:

(A) out-degree, (B) in-degree, and (C) eigenvector centrality, and (D) hub scores. The vertices were arranged using the Fruchterman-Reingold force-directed layout algorithm (LUKE, 2015). The most connected shareholders are BlackRock ($C_{OD} = 28$), JPMorgan Chase ($C_{OD} = 24$), UBS ($C_{OD} = 17$), Capital Group ($C_{OD} = 12$), and State Street ($C_{OD} = 12$). In contrast, in-degree centrality identifies the companies with the highest number of investors: AbbVie ($C_{OD} = 53$), Amgen ($C_{OD} = 51$), Novartis ($C_{OD} = 42$), BMS ($C_{OD} = 40$), and Roche ($C_{OD} = 38$). The vertices with the highest eigenvector centrality, indicating connections to other influential nodes, are Novartis ($C_E = 1.000$), Capital Group ($C_E = 0.205$), JPMorgan Chase ($C_E = 0.187$), Bank of New York Mellon ($C_E = 0.141$), and UBS ($C_E = 0.124$). Meanwhile, the highest hub scores, which reflect how well a vertex points to authoritative vertices, are found in BlackRock ($h_i = 1.000$), JPMorgan Chase ($h_i = 0.809$), Novartis ($h_i = 0.658$), UBS ($h_i = 0.520$), and Capital Group ($h_i = 0.494$).

The eigenvector centrality (C_E) and hub score (h_i) graphs were constructed using the same scaling method to improve visual comparability. In both the C_E and the h_i scaled graphs (Figures 4C and 4D), the vertex associated with Novartis (in purple) is clearly visible. However, in the eigenvector centrality graph, Novartis appears significantly larger than any other node and is surrounded by a mix of companies and numerous shareholders, indicating its strong overall influence in the network. In contrast, in the hub score graph, Novartis is no longer the dominant node and is surrounded almost exclusively by shareholders, highlighting the directional nature of hub scores and its focus on vertices that link to important targets. In this case, the most influential vertices were BlackRock, JPMorgan Chase, Novartis, UBS, and Capital Group.

Figure 3.3. Directed network of shareholders and companies associated with the mAb innovation market.



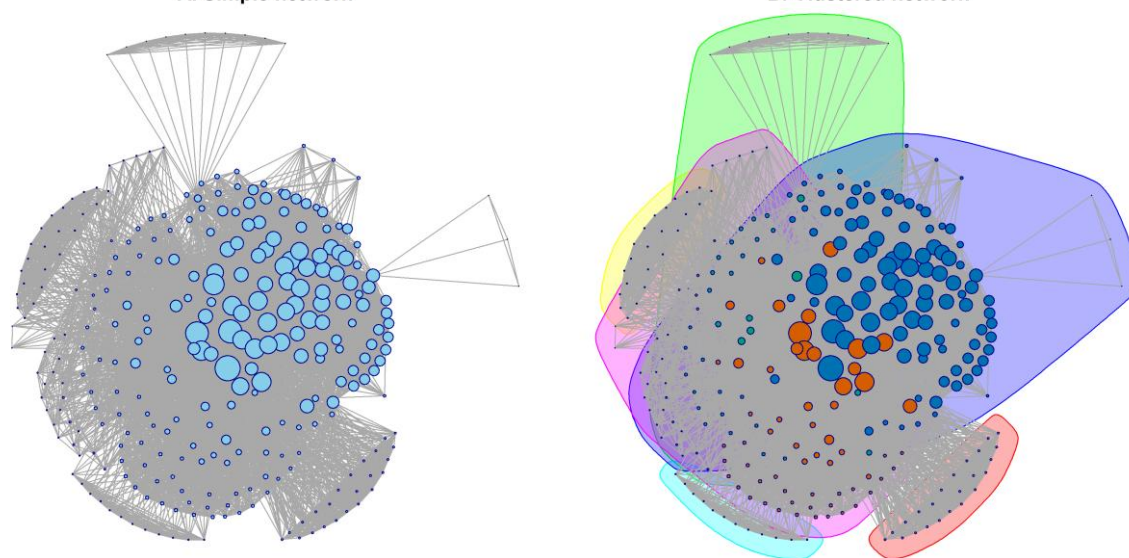
3.2 Common ownership analysis

While previous analyses focused on bimodal networks involving shareholders and companies, this final analysis shifts to an undirected unimodal network, where all vertices represent shareholders. In this configuration, edges indicate that two shareholders hold interests in the same company, forming a

network of common ownership. This network exhibits markedly different structural properties compared to earlier models. It comprises 301 vertices and 7,080 edges, yielding a density of 0.157, meaning that approximately 15.7% of all possible connections are present. This density shows how well-connected these investors are through common ownership. The higher density, mean distance of 1.934, diameter of 4, and relatively high transitivity of 0.567 suggest the presence of a small-world property—a network structure in which most vertices can be reached from any other through a small number of steps and exhibit a high degree of local clustering (KOLACZYK; CSÁRDI, 2020). The transitivity value implies that 56.7% of all possible triplets are closed, indicating a strong interconnection among neighboring vertices.

Figure 6.5 presents a simple (A) and a clustered (B) visualization of the shareholder network, with node sizes scaled by eigenvector centrality. The graph vertices were arranged using the Kamada-Kawai force-directed layout algorithm, and clusters were identified using the fast-greedy community detection algorithm. The simple network representation facilitates the identification of a core group of shareholders who are highly interconnected and central to the network, surrounded by a peripheral fringe of smaller, less connected shareholders. The clustered network shows a total of six clusters, with the following sizes (from cluster 1 to cluster 6): 23, 23, 48, 12, 116, and 79. Across all centrality measures, a few companies appear as powerful, central, and influential in relation to other shareholders. BlackRock is the most relevant of them. Other companies that are important for the networks are JPMorgan Chase, UBS, Ilmarinen Mutual Pension, Sanofi, and Varma Mutual Pension. In terms of community structure, BlackRock belongs to Cluster 5, which includes other major shareholders such as UBS, Capital Group, The Vanguard Group, and T. Rowe Price. JPMorgan Chase is assigned to Cluster 6, alongside Goldman Sachs and State Street. With the exception of Sanofi, which belongs to Cluster 3, all the other top shareholders are part of Clusters 5 or 6.

Figure 3.4. Shareholder network in the mAb innovation market divided by clusters.



The common ownership relationships were initially examined by counting the number of shared investments between pairs of shareholders [$C2(s, t)$]. Consistent with previous findings, BlackRock appears prominently among the shareholders with the most partnerships in the network. Some important connections are BlackRock and UBS ($C2 = 14$), BlackRock and JPMorgan Chase ($C2 = 11$), BlackRock and Ilmarinen Mutual Pension ($C2 = 9$), BlackRock and Varma Mutual Pension ($C2 = 9$), and BlackRock and The Vanguard Group ($C2 = 8$). Other notable partnerships include JPMorgan Chase and UBS ($C2 = 9$), JPMorgan Chase and State Street ($C2 = 8$), The Vanguard Group and UBS ($C2 = 8$), UBS and Varma Mutual Pension ($C2 = 9$), and UBS and Capital Group ($C2 = 7$).

The common ownership and common ownership ratios [$c(s)$ and $\gamma(s)$] were then calculated for each shareholder. In this case, the findings confirm what was previously shown from other analyses. BlackRock ($c = 504$, $\gamma = 6.44\%$), UBS ($c = 421$, $\gamma = 5.38\%$), JPMorgan Chase ($c = 391$, $\gamma =$

5.00%), Varma Mutual Pension ($c = 315$, $\gamma = 4.03\%$), Ilmarinen Mutual Pension ($c = 271$, $\gamma = 3.46\%$), and The Vanguard Group ($c = 250$, $\gamma = 3.19\%$) were the most prominent common owners in the network. Finally, the common ownership ratio of companies [$\psi(w)$] was estimated. With only 26 companies in the final sample, Abbott ($\psi = 2.572$), Eli Lilly ($\psi = 2.306$), BMS ($\psi = 2.176$), Biogen ($\psi = 2.103$), Pfizer ($\psi = 2.099$), and Amgen ($\psi = 1.984$) were the companies with the most influential shareholders in the network.

4 DISCUSSION

The undirected network analysis provided information on the overall connectivity of nodes and the strategic importance of specific vertices in facilitating the flow of information and influence. The vertices with the highest degree centrality were AbbVie, Novartis, Amgen, Sanofi, and BMS. However, these vertices did not exhibit the highest betweenness and closeness centralities, which instead measure the placement of nodes within the network. The vertices with high betweenness and closeness centralities are generally more important to connect different parts of the network, allowing the transmission of information and influence. These were BlackRock, Sanofi, JPMorgan Chase, AbbVie, and Roche. Therefore, a key result of this study is that companies tend to dominate in terms of direct connections compared to their placement in the networks. In contrast, shareholders, particularly large institutional investors, often occupy strategic positions within the network acting as intermediaries or influence hubs despite having fewer direct links. This distinction highlights the nuanced roles of different actors in shaping the structure and dynamics of the pharmaceutical ownership landscape.

Out-degree centrality in the directed network highlights shareholders with interests in the largest number of companies. In this case, the most connected shareholders were BlackRock, JPMorgan Chase, UBS, Capital Group, and State Street. In contrast, in-degree centrality identifies the companies with the highest number of investors, which were AbbVie, Amgen, Novartis, BMS, and Roche, which were expected results after the undirected network. It is clear that shareholders dominate the visualization based on out-degree centrality, with only a few companies that also act as shareholders appearing prominently. The dominating shareholders are mostly large investment funds, such as BlackRock [assets under management (AUM) = US\$11.6 trillion (REUTERS, 2025)], JPMorgan Chase [assets under supervision (AUS) = US\$3.7 trillion (JPMORGAN CHASE, 2025)], UBS [client assets = US\$6.2 trillion (LIAM PROUD, 2025)], Capital Group [AUM = US\$2.8 trillion (CAPITAL GROUP, 2025)], and State Street [AUM = US\$4.3 trillion (STATE STREET, 2025)]. As expected, in-degree centrality highlights only companies, since they are the recipients of investment links in the directed network. The most central companies are mainly the companies dominating the production market, such as AbbVie [assets = US\$116.16 billion in 2025 USD (MACROTRENDS, 2025a)], Amgen [US\$89.37 billion (AMGEN, 2025)], Novartis [US\$99.9 billion (MACROTRENDS, 2025b)], BMS [US\$92.43 billion (MACROTRENDS, 2025c)], and Roche [US\$115.6 billion (MACROTRENDS, 2025d)], as previously stated (GRILO; MANTALARIS, 2019; MOTTA-SANTOS et al., 2025a). In particular, there is an overrepresentation of companies that also act as shareholders within the sample, probably reflecting their larger size and great influence, which enables them to attract and make investments, such as Sanofi [US\$138.9 billion (MACROTRENDS, 2025e)] and Novartis.

Interestingly, the measures of influence and importance differ relevantly between the two networks. A pattern arises from the eigenvector centrality (undirected influence) and hub scores (directed influence). In the first case, the vertices with more influence over the network were Novartis, Capital Group, JPMorgan Chase, Bank of New York Mellon, and UBS. Hub scores show that BlackRock, JPMorgan Chase, Novartis, UBS, and Capital Group were the most influential vertices. The prominence of investment funds across these analyses provides yet further compelling evidence of the financialization of the pharmaceutical industry, where strategic influence is increasingly concentrated among institutional investors.

The common ownership analysis showed BlackRock, UBS, JPMorgan Chase, Varma Mutual Pension, Ilmarinen Mutual Pension, and The Vanguard Group as some of the most prominent shareholders in the network. There seems to be a core group of shareholders who are highly interconnected and central to the network, surrounded by a peripheral fringe of smaller, less connected

shareholders. These frequent co-investments between large shareholders suggest strategic alignment, evidence of the *rich-club phenomenon* previously hypothesized.

The common ownership ratio of companies showed that Abbott, Eli Lilly, BMS, Biogen, Pfizer, and Amgen were the companies with the most influential shareholders in the network. These are some of the same companies that have already been cited as key market players (GRILO; MANTALARIS, 2019; MOTTA-SANTOS et al., 2025a). There is an illuminating relationship among the most innovative companies, common ownership, and the dominating firms in the production market (MOTTA-SANTOS et al., 2025a). The companies that thrive in the patent analysis were Roche, AbbVie, Amgen, Novartis, GSK, Biogen, BMS, Regeneron, and J&J. In 2017, seven companies dominated this market, accounting for 87% of total mAbs sales: (i) Genentech (Roche Group), 31%; (ii) AbbVie, 20.0%; (iii) J&J, 13.6%; (iv) BMS, 6.5%; (v) Merck Sharp & Dohme (MSD), 5.6%; (vi) Novartis, 5.5%; and (vii) Amgen, 4.9% (GRILO; MANTALARIS, 2019; MOTTA-SANTOS et al., 2025a, 2025b). Firms with higher common ownership ratios may benefit from improved information flows, reduced competitive pressure, or enhanced strategic alignment among shareholders, factors that could, in turn, strengthen their capacity to innovate and coordinate production (AGHION; VAN REENEN; ZINGALES, 2013; MULERO, 2023).

Researchers have studied the phenomenon of common ownership in the pharmaceutical market (BANAL-ESTANOL; NEWHAM; SELDESLACHTS, 2019, 2021; HASAN, 2021; NEWHAM; SELDESLACHTS; BANAL-ESTANOL, 2022). Banal-Estañol et al. (2021) investigated ownership networks among active US pharmaceutical firms between 2004 and 2014, revealing a dense and growing network among R&D-intense companies, while generic firms exhibited a sparser and declining network. Common ownership can facilitate strategic partnerships, allowing companies to collaborate on R&D and share technologies (AGHION; VAN REENEN; ZINGALES, 2013; MULERO, 2023), but has also been linked to reduced market competition (ANTON et al., 2022; AZAR; RAINA; SCHMALZ, 2022; AZAR; SCHMALZ; TECU, 2018; NEWHAM; SELDESLACHTS; BANAL-ESTANOL, 2022). While prevalent across industries (BANAL-ESTANOL; NEWHAM; SELDESLACHTS, 2019), common ownership may pose challenges to innovation and market dynamics. Special attention must be given to BlackRock in this case. First of all, BlackRock manages assets in the order of US\$11.6 trillion (REUTERS, 2025). Its large influence over the pharmaceutical market is very impressive. In 2014, BlackRock Inc. was the largest shareholder in the three largest pharmaceutical companies in the US, namely J&J, Merck, and Pfizer, alongside other shared investors. Nowadays, some of the companies in which BlackRock invests are Abbott, AbbVie, Amgen, AstraZeneca, Bayer, Biogen, BMS, Eli Lilly, GSK, Merck, Novartis, Pfizer, Roche, and Sanofi, among others—basically, the largest pharmaceutical companies in the world. Another key result of this study is that power is concentrated in the hands of a few large financial corporations that are orders of magnitude larger than the companies they invest in. These shareholders are mainly from high-income countries (HICs) and commonly invest in the same companies.

There is a relationship between common ownership, financialization, and market prices. Some authors suggest that financialization has reshaped the business models of pharmaceutical companies, leading to a greater focus on blockbuster medicines, which are products that generate annual sales exceeding US\$1 billion (MONTALBAN; SAKINC, 2013). This represents a shift in the locus of investment from healthcare priorities to profit-seeking objectives. Consequently, research interest in relatively inexpensive, high public health impact drugs, such as antibiotics, antipsychotics, antidepressants, lipid-lowering agents, antihypertensives, and other essential medicines, has declined in favor of costly mAbs and gene therapies for rare conditions (BEASLEY, 2024; FLETCHER, 2020; TORREELE, 2024). To add to the problem, the knowledge to develop and even copy an mAb is concentrated in only a few companies from HICs (MOTTA-SANTOS et al., 2025a). Furthermore, the presence of common ownership increases the already important concentration in the market for mAb innovations (NEWHAM; SELDESLACHTS; BANAL-ESTANOL, 2022; O'BRIEN; WAEHRER, 2017; SALOP; O'BRIEN, 2000; SEMOV, 2017; VITALI; GLATTFELDER; BATTISTON, 2011), contributing to the high market prices.

An additional layer of analysis was initially planned to assess the financial representativeness of each shareholder based on their equity stake in the market, a depth analysis. However, this analysis was

ultimately excluded owing to significant data limitations—specifically, missing ownership share data for approximately two-thirds of the cases. This constraint was also encountered by Salop and O’Brien (SALOP; O’BRIEN, 2000). The missing information in the ORBIS database hindered the construction of a more comprehensive market landscape and the use of the mHHI measure for concentration with common ownership (NEWHAM; SELDESLACHTS; BANAL-ESTANOL, 2022; O’BRIEN; WAEHRER, 2017; SALOP; O’BRIEN, 2000; SEMOV, 2017). While it is evident that control is highly concentrated, this alone does not provide information on the nature of interactions among market participants. However, previous research revealed that multinational corporations often form a ‘bowtie’ network structure, with a significant proportion of market control concentrated in a relatively small core of shareholders, primarily financial institutions (VITALI; GLATTFELDER; BATTISTON, 2011).

It is evident that the power of companies is relatively more prominent in the network compared to their structural placement or influence. Shareholders, on the other hand, tend to occupy more strategic positions within the network and are often connected to highly influential nodes in a directional manner. The common ownership analysis showed that some shareholders are better connected than others, with BlackRock, UBS, and JPMorgan Chase among those that most frequently invest in the same companies. In terms of companies, Abbott, Eli Lilly, BMS, Biogen, Pfizer, and Amgen were the companies with the most influent shareholders in the network. The observed concentration of power and influence in the hands of a few key players suggests the possible existence of a rich-club phenomenon that directs decisions in the mAb innovation market. However, more in-depth studies are needed to evaluate this matter properly.

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