

RESOURCE-BASED DETERMINANTS OF INNOVATION IN POLISH OFFSET PRINTING FIRMS

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Purpose: The purpose of this paper is to identify the relative importance of internal and external resources as determinants of innovation in Polish offset printing firms operating under technological, environmental and market pressure.

Design/methodology/approach: The study is based on a survey of 123 Polish offset printing firms, including 85 firms that implemented innovations within the previous three years. The empirical analysis uses descriptive statistics, the Mann-Whitney U test, Spearman correlations and the Kruskal-Wallis test to examine links between resources, innovation types and outcomes.

Findings: The findings show a high level of innovation activity. Product and process innovations are the most common, while internal intangible resources play a stronger role than external sources. External resources are important mainly as complementary inputs, especially for selected innovation types such as marketing innovations.

Research limitations/implications: The study is limited to Polish offset printing firms and is based on survey data. Future research could extend the analysis to other countries, include longitudinal data and compare offset printing with other manufacturing industries.

Practical implications: Managers should strengthen intangible internal assets, especially knowledge, employee competences, managerial and technological expertise, and in-house R&D, while using external resources selectively as complementary sources of innovation.

Social implications: The findings support the sustainable development of a strategically important industrial sector by indicating how firms can maintain competitiveness while responding to technological, market and environmental pressures.

Originality/value: The paper contributes to innovation and resource-based theory by clarifying how resource configurations shape innovativeness in a mature but transforming manufacturing sector that remains under-researched in management studies.

Keywords: innovation; firm resources; intangible resources; competitive advantage; offset printing.

Category of the paper: Research paper.

1. Introduction

Innovation in the printing industry plays a significant role in shaping the development prospects of the Polish economy. Over recent decades, the industry has recorded dynamic growth (Cetera, 2015), positioning Poland as a major global player with the sixth-largest share in world exports with revenue exceeding PLN 7 billion (Poland on the global map..., 2026). Much of this global competitiveness stems from the offset printing sector, which accounts for a substantial share of export value. The offset printing sector remains an important part of industrial production in Poland, particularly because of its role in high-volume packaging for food, pharmaceutical, and consumer goods industries. Despite the rapid technological progress of digital printing, offset continues to dominate applications requiring high quality, colour consistency and cost efficiency in long production runs, where digital technologies still face performance limitations (Yilmaz, 2018).

Although the process is technologically mature - defined as the indirect transfer of an image from a plate to a rubber blanket and then onto a substrate (Bălan, 2021) - the sector is currently undergoing profound transformation driven by competitive, environmental and organisational pressures. These forces shape the conditions under which firms must innovate to maintain operational efficiency, cost advantages and market position.

A major driver of innovation in offset printing is the growing competitive pressure from increasingly efficient and versatile digital printing technologies, often perceived as faster, more flexible and easier to operate (Mirković, 2024). To sustain its advantages, the offset sector must continuously improve process efficiency, enhance compatibility with evolving substrates and inks (Pogačar, 2023), and aggregate print orders through diverse sales channels to maximise run lengths and fully leverage the speed and cost benefits of offset production. These tendencies are accompanied by broader structural changes, including vertical integration and cross-industry convergence, which strengthen the strategic position of firms operating within offset-based production systems (Magadán-Díaz, 2021).

Environmental and regulatory pressure constitutes another important source of innovation. Traditional offset printing involves the use of chemicals, including heavy metals, that increasingly fall under regulatory scrutiny, generating strong incentives to reduce environmental impact (Viluksela, 2010). Although the sector has long been associated with circular-economy practices due to the widespread recyclability of paper (Dumea, 2009; Vukoje, 2021), the adoption of more ecological inks and advanced curing technologies complicates recycling processes, as new formulations tend to bond more strongly with substrates (Rojas García, 2023; Yang, 2022; Klemenčič, 2023; Strižić Jakovljević, 2024). As a result, printing companies must increasingly integrate environmental considerations into their technological and organisational development strategies, making sustainability a key dimension of innovation.

A third transformative force reshaping the sector is the evolution of business models. Recent studies highlight that competitive advantage increasingly emerges from service-oriented and data-driven models rather than exclusively from product-based strategies, driven by digitalisation, workflow automation and hybrid offerings combining print and digital services (Magadán-Díaz, 2021; Salwin, 2020; Meissner, 2021; Afifa, 2022). This shift requires not only technological innovation, but also organisational and marketing innovations, including new forms of customer engagement, process integration and internal capability development.

Taken together, these trends demonstrate that sustaining and strengthening the role of the offset printing sector requires continuous implementation of product, process, organisational and marketing innovations. Yet, despite extensive research on the transformation of the printing industry, relatively little is known about the specific conditions that shape innovation in offset printing firms - particularly regarding the role and configuration of organisational, technological and relational resources. The literature does not provide a clear answer as to whether internal resources (Magadán-Díaz, 2021; Afifa, 2022) or external resources such as cooperation networks and institutional support (Salwin, 2020; Meissner, 2021) form the primary foundation of innovative capacity in this sector. Moreover, the relationship between different types and levels of innovation and the competitive benefits derived from them remains insufficiently explored.

The present study addresses these gaps by examining how innovations implemented by Polish offset printing companies contribute to their competitive advantage in the context of technological, environmental and business transformation. The analysis covers the structure and scale of implemented innovations, including new or significantly modified product, process, organisational and marketing solutions and evaluates their impact on operational performance, product development and market expansion. Particular emphasis is placed on identifying which types and degrees of novelty generate the most substantial competitive gains, enabling offset printing firms to maintain strong market positions despite growing competition from digital technologies. The article proceeds by outlining the theoretical foundations of the study, describing the research methodology, presenting the empirical findings and discussing their implications for both industry practice and innovation theory.

2. Innovation and Firm Resources

Innovation is one of the most frequently discussed concepts in management studies, and its importance continues to grow as it is widely regarded as a primary driver of entrepreneurial development and economic growth. Despite the extensive attention devoted to innovation, the academic literature provides no universally accepted definition of the term. Innovation may be understood as a concrete outcome of human activity (Glińska-Neweś, 2017),

a novelty itself (Matjaz, 2005), a process leading to novelty (Courvisanos, 2007), or a result of introducing novelty into practice (Quintane, 2011). These perspectives highlight the central role of “newness”, yet they differ in whether novelty is treated as the cause, the result, or the defining identity of innovation.

A major attempt to unify these perspectives is offered by the Oslo Manual (OECD/Eurostat, 2018), which defines innovation as a new or significantly improved product or process (or a combination of both) that is made available to users (customers or internal users) or implemented in practice. The Manual distinguishes four types of innovation: product, process, organisational and marketing innovations. According to this definition, a change qualifies as an innovation only if it (1) represents novelty and (2) is implemented or delivered to users.

The capacity of firms to innovate is determined by the interaction of internal and external resources. In Three-Factor Innovation Development Model (TRI), innovation-driven growth occurs when three interconnected elements are present: (1) innovation capability (the resources a firm possesses and its ability to deploy them), (2) innovation propensity (the motivation and readiness to introduce new solutions), and (3) the external environment, which stimulates and shapes the direction of change (Stanisławski, 2022). This model underscores that innovation depends not only on resource availability but also on organisational willingness and contextual conditions.

Building on this framework, existing research seeks to identify which categories of resources most strongly determine innovation outcomes in practice (Abdulsamad, 2025; Veiga, 2024; Audretsch, 2023). This is important primarily for the search for optimal strategies for the innovative development of companies (Abbass, 2025; Perotti, 2025; Hock-Doepgen, 2025).

However, the literature does not provide consensus on which categories of resources - internal or external, material or immaterial - are the stronger determinants of innovation. Evidence suggests that the answer depends heavily on the firm’s sector, institutional environment, maturity and technological profile.

Research by Zhu et al. on science-based firms shows that internal scientific capabilities, such as in-house basic research, substantially increase innovation performance. External resources (e.g., collaboration with research institutions) also matter, but their effectiveness depends on the firm’s ability to absorb and utilise external knowledge. For these organisations, internal intangible resources are a stronger driver of innovation than external or material resources (Zhu, 2025). Similar patterns are found in R&D-intensive manufacturing sectors such as the pharmaceutical one. Wu et al. demonstrate that internal R&D investments strongly correlate with higher innovation output (e.g., patents), whereas external R&D expenditure has a weaker or negligible effect. Large firms treat external partnerships as complementary, while small firms rely on them only as a transitional mechanism to build internal R&D capacity. These studies indicate that material resources - especially financial resources - are effective only when supported by internal intangible capabilities that ensure their productive use (Wu, 2022).

A comprehensive review by Mališić et al. confirms that internal determinants such as strategy, organisational structures, human-resource practices and culture constitute the foundation of innovation activity. Human-resource management practices that foster knowledge absorption - such as interdisciplinary teams, appropriate decision-making processes and job rotation - play a central role in building dynamic capabilities. Organisational culture, understood as shared values and norms that guide behaviour, communication and decision-making, is also a significant determinant of innovation (Mališić, 2025). Case-based evidence shows that knowledge-sharing cultures strongly facilitate innovation implementation (Lee, 2018).

These findings emphasise that knowledge and the firm's ability to acquire, develop and apply it are essential for innovation. Consequently, the external environment plays a crucial role, as it shapes the opportunities for firms to access complementary knowledge. The strength of institutional surroundings determines whether external or internal resources become more important. Using process innovation as an example, Phung et al. demonstrate that having an innovation strategy - regardless of whether it is internally or externally oriented - always supports innovation, but the importance of external resources increases in stronger institutional environments. In weak environments, internal resources become more critical (Phung, 2021). Thus, the more favourable the external conditions, the lower the threshold for achieving innovation capability, because firms do not need to accumulate large internal knowledge bases to innovate.

The above suggests that the importance of individual resources depends on the specific organizational context, particularly the nature of the organization's environment. This relationship is explored in further empirical research.

Nguyen and Minh's review adds further evidence that external knowledge sources generally exert a positive influence on innovation performance. External resources reduce the cost of exploring new solutions, accelerate problem solving and allow firms to understand emerging challenges more rapidly (Nguyen, 2023). Their analysis also shows a global statistical increase in the importance of external knowledge, consistent with the growing relevance of open-innovation approaches (Perotti, 2025).

External resources are therefore not only an important source of innovation but also a necessary component of contemporary innovation strategies. By sharing risk and development costs with partners, firms can reduce the financial burden of innovation and shorten product-development cycles (Audretsch, 2022). No organisation today holds a monopoly on knowledge, even within narrow domains, which makes external openness an important determinant of competitive success.

The literature also suggests the existence of an optimal balance between internal and external resources a threshold that may vary by industry and sector. In European contexts, external R&D collaboration, especially with scientific institutions, improves product innovation outcomes (Carboni, 2021). However, beyond a certain level of dependency on external sources, benefits diminish and excessive reliance may lead to coordination problems and inefficiencies (“over-outsourcing”) (Carboni, 2021).

Over the past decade, there has been growing attention to recombinant innovation, defined as innovation arising from the novel combination of existing knowledge elements (Cecere, 2014). Zhao et al. conceptualise innovation as a stochastic process of recombining ideas, where more complex combinations may yield greater returns (Zhao, 2024). Some researchers argue that recombination is a primary mechanism of technological evolution (Goodman, 2025). The increasing relevance of recombination reinforces the role of external sources of knowledge and diverse collaboration networks. Empirical studies show that broader technological networks, more intensive cooperation and higher diversity of information sources contribute to improved innovation performance (Keil, 2008) and ultimately to stronger competitiveness (Audretsch, 2023). The effectiveness of recombinant innovation depends not only on the number of external partners but also on the multiplicity and heterogeneity of knowledge bases on which firms rely.

Incorporating these insights into the three-element model of innovative development model (Stanisławski, 2022) leads to a refined interpretation of the conceptual framework supporting this study. The relative importance of internal versus external resources - and of material versus intangible ones - is not universal but depends on industry characteristics, the institutional environment and the firm’s strategic orientation. Understanding this configuration is essential for analysing innovation development in the offset printing sector, where technological maturity, environmental pressures and evolving business models collectively shape resource structures and their effects on innovation outcomes. Figure 1 summarises these relationships by illustrating how different categories of resources, environmental conditions and innovation-related benefits jointly influence both the capability and the propensity to innovate.

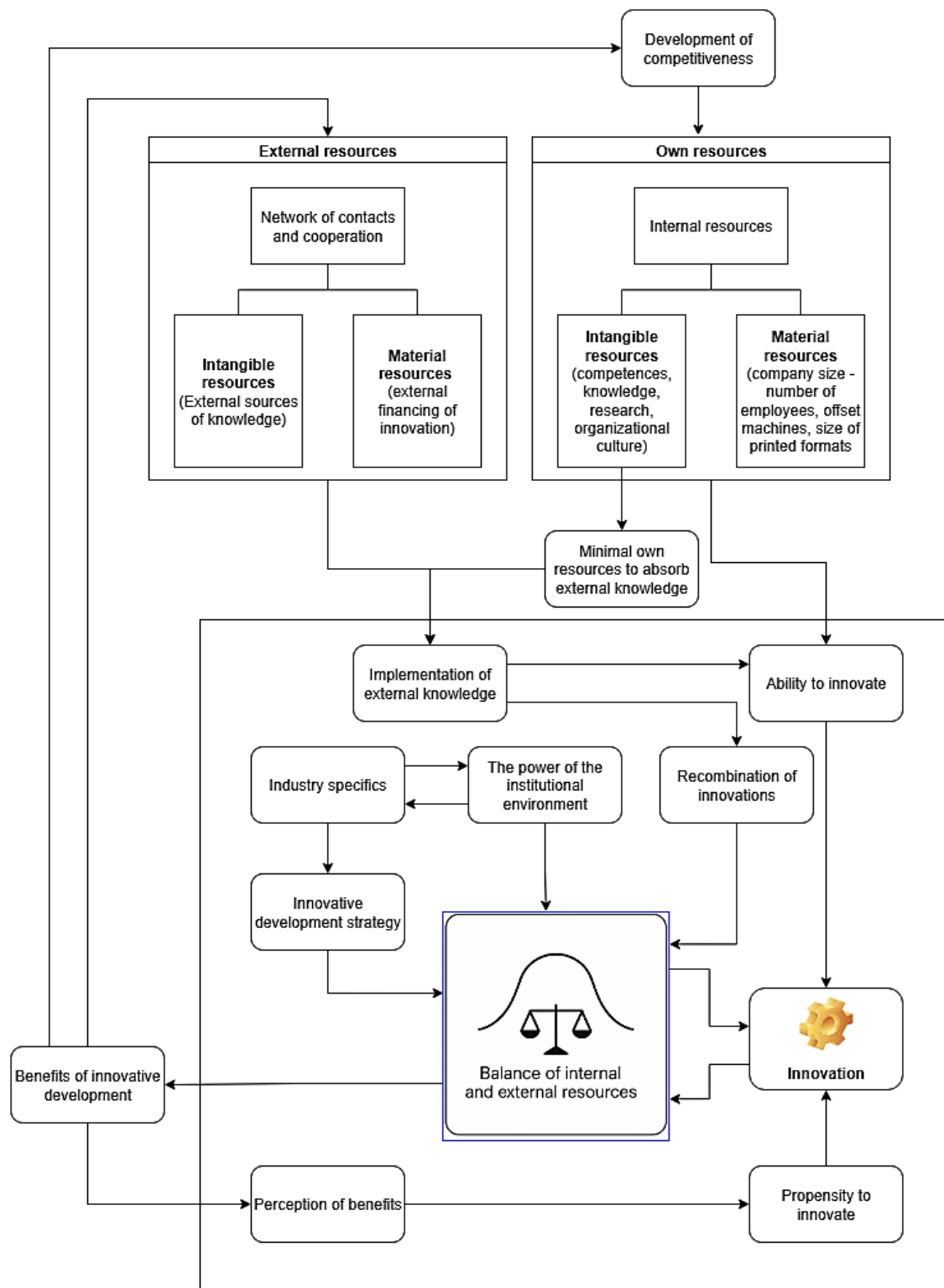


Figure 1. Factors shaping the innovative development of a firm based on the literature review.

Innovation and the development of an enterprise's competitiveness are therefore the result of balancing internal and external resources, the ability to absorb and use knowledge from the environment, which together determine the ability to create and implement innovations.

3. Drivers of Innovation in the Offset Printing Sector

Identifying the likely importance of specific factors within a particular industry requires defining them in the context of the processes that shape innovation-oriented development strategies in that sector (Figure 1).

The offset printing sector is not currently gaining significance on a global scale. The worldwide printing industry is undergoing major transformations, driven particularly by digitalisation, which is reflected in the shift from offset to digital printing. Digital printing technologies offer several advantages over offset, especially in enabling small-scale printing, on-demand printing outside a dedicated printing plant, and generally lower energy use and waste generation (Mirković, 2024).

At the same time, offset remains widely used because the advantages of digital printing diminish with increasing print volumes (Sesli, 2023; Phillips, 2008). While the print runs of books and especially newspapers (are generally not increasing), the demand for large-scale packaging production is certainly not declining (Strižić Jakovljević, 2024). Traditional offset printing provides excellent detail quality for these and similar applications, typically superior to that of large-scale digital printing (Vukoje, 2021; Spiridonov, 2020).

Despite the visible decline in the relative importance of offset printing, numerous innovations can be observed in this sector, particularly process innovations (Hauck, 2015). Alongside competitive pressure from digital printing, an important driver of such innovations is the green transition and the need to reduce environmental impact (Viluksela, 2010). Among the most significant developments is the digital transformation of offset printing firms toward Industry 4.0 solutions (Salwin, 2020), particularly through the implementation of Internet of Things technologies (Meissner, 2021), while maintaining offset-based production. Business models are also evolving, with growing diversification of services offered by printing houses, leading to hybrid business models - especially the product-service model (Magadán-Díaz, 2021). In these models, printing firms are transformed from providers of printed products into providers of printing, design, publishing and even creative services.

In general, the preferred business model in offset printing involves a shift from production-centric to digitally oriented market strategies, implemented through websites and social media applications (Afifa, 2022). A key benefit of this approach is the expansion of the customer base and sales channels, including entry into new markets that may be geographically distant from the printing plant itself (Magadán-Díaz, 2021).

This transformation is not limited to printing firms themselves but also influences their interactions with technology providers. A parallel shift is occurring from product-oriented to service-oriented models among machine and technology suppliers, who no longer merely sell equipment but increasingly provide production capacity as a service, actively shaping the processes and business models of printing firms (Salwin, 2020). As a result, the offset printing

firm evolves from a recipient of products (machines, materials) and a supplier of printed goods into both a service user and a service provider.

These phenomena are illustrated in Figure 2. The figure shows that each of the identified cause–effect areas require competitive firms to undertake comprehensive, dynamic and far-reaching changes, which can be broadly classified into the four main types of innovation: product, process, organisational and marketing innovations.

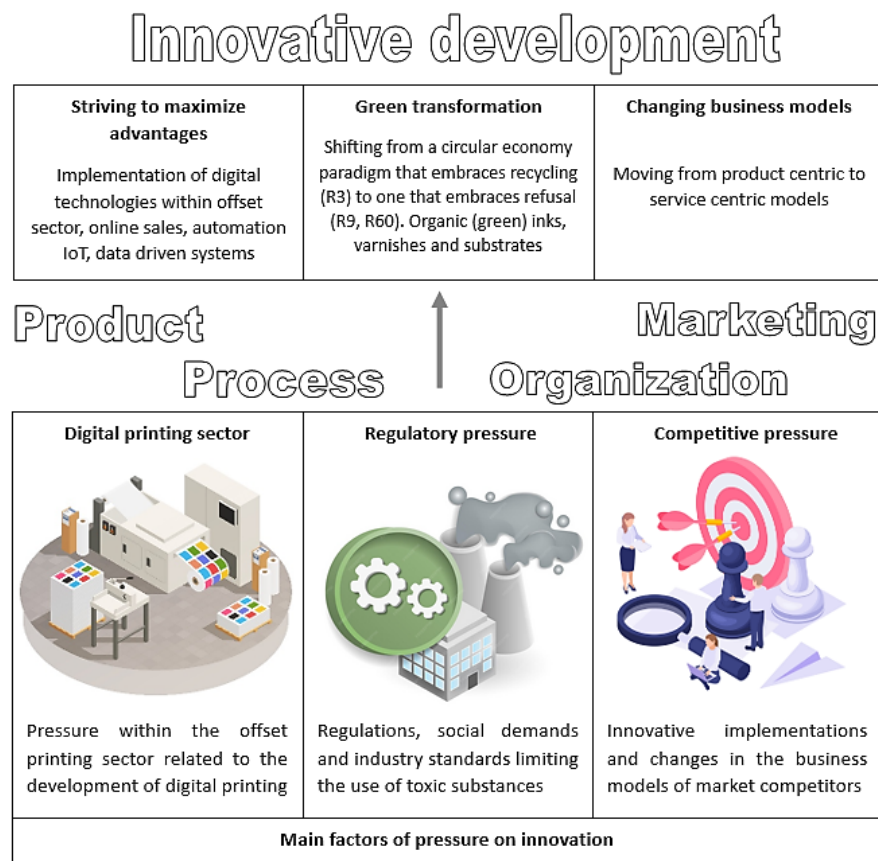


Figure 2. Phenomena stimulating innovation in the offset printing sector.

Source: own elaboration.

One may argue that although offset printing is technologically mature and losing ground to digital printing, the sector is becoming increasingly knowledge-intensive and supported by a growing institutional environment. Consequently, innovations in this sector are likely to rely increasingly on external rather than internal resources. However, this relationship remains insufficiently studied. In the case of the offset printing sector, dynamics of innovation development take on a specific form shaped by technological and market-specific factors.

In the printing industry, correlations have been observed between past innovation implementation and the likelihood of subsequent innovations (Rothenberg, 2007). This aligns with the logic of the Three-Factor Innovation Development Model, in which innovation depends on capability (particularly internal and external resources) and propensity (the perceived role of innovation in improving firm performance). Nonetheless, the role of resources has not been extensively examined in this sector, especially in offset printing.

It appears likely that internal and intangible resources play a particularly important role in the printing sector, including offset, as some studies suggest that a certain minimum level of know-how - achievable even in small firms - is essential for innovation to occur (Reyes-Rodríguez, 2022). Earlier research even indicates that the printing industry has historically exhibited substantial variation in managerial attitudes and organisational cultures, influencing the pace of innovation adoption (Coleman, 2012).

Nevertheless, sustaining competitiveness in this sector requires continuous adaptation, leading to a range of innovations within offset printing firms. Despite these indications, the specific role of different categories of firm resources as determinants of innovation in the printing sector - and particularly in offset printing - remains insufficiently defined.

Although these observations help indicate which types of resources may contribute to innovation in the printing industry, the role of specific resource categories as determinants of innovativeness remains insufficiently defined, particularly in the context of the offset printing sector. Existing studies highlight multiple relationships between internal and external resources, as well as between material and intangible assets, yet they do not provide a clear or comprehensive explanation of how these categories shape the innovative development of firms operating in this technologically mature and increasingly knowledge-intensive industry. This lack of clarity becomes especially relevant considering the ongoing digital transformation, the growing importance of external knowledge sources and the strategic pressures affecting the sector.

To address this gap, the present study formulates a set of research hypotheses that reflect the potential influence of different resource categories on the innovation performance of offset printing firms. These hypotheses are integrated into the conceptual framework and are intended to capture both the complexity and the diversity of resource dependencies observed in the offset printing sector:

- H0.** Firm resources, including relationships with external entities and the strategic orientation of printing companies, have a positive effect on the innovative development of the offset printing sector.
- H1.** The implementation of innovations by offset printing firms is influenced by specific internal and external resources.
- H2.** Internal firm resources are more important for innovative development than external resources.
- H3.** Material resources are more important for a firm's innovative development than intangible resources.
- H4.** Different types of innovation - product, process, marketing and organisational - are shaped by distinct internal and external determinants.

These hypotheses, which collectively form the basis for the empirical analysis, are incorporated into the research model presented in Figure 3, illustrating the assumed relationships between resource categories and innovation outcomes in the offset printing sector.

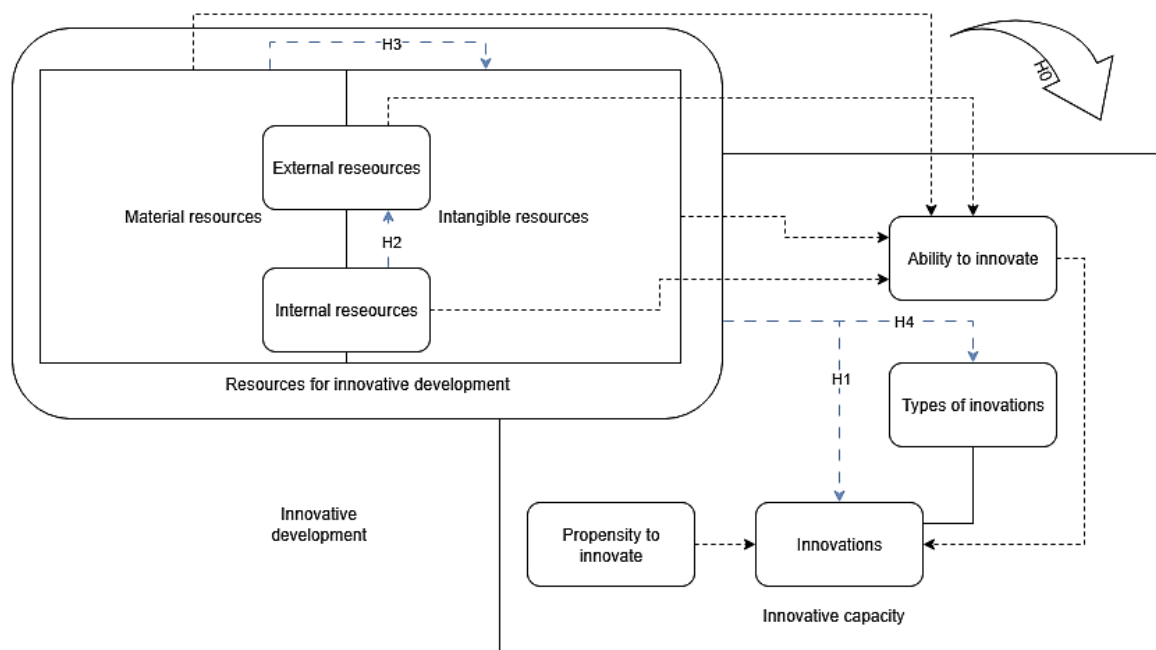


Figure 3. Research model indicating the proposed research hypotheses.

Source: own elaboration.

The above figure incorporates the assumption that the factors of innovation are the areas of external (environmental) and internal (own) resources as well as the tendency and readiness to use them (propensity to innovate), which reflects the Three-Factor Model of Innovative Development (Stanisławski, 2022).

4. Research Methods

4.1. Subject and Method of Study

The research was conducted among Polish printing companies (physically located in Poland) equipped with at least one offset printing machine. Accordingly, entities that did not operate offset presses - those working exclusively with digital printing or located abroad - were excluded from the study (in the case of multinational firms, only the Polish operations were considered).

Data collection was carried out using an online survey administered between March and May 2024 through a structured questionnaire hosted on a web-based platform (Google Forms). A total of 123 responses were obtained from representatives of offset printing companies across the country (Table 1).

Table 1.
Characteristics of the research sample

Factor	Number of answers (n = 92)
Company size	
Micro	9 (7,32%)
Small	60 (48,78%)
Medium	49 (39,84%)
Large	5 (4,07%)
Dominant market	
Global	7 (5,69%)
National	42 (34,15%)
International	53 (43,09%)
Regional	20 (16,26%)
Local	1 (0,81%)
Dominant printing profile (focus sector)	
Books / magazines / art	24 (19,51%)
Labels (including in-mould labelling – IML)	6 (4,88%)
Forms / personalisation	4 (3,25%)
Packaging (food and non-food)	32 (26,02%)
Advertising	56 (45,53%)
Newspaper	1 (0,81%)
Number of offset printing machines	
1-2	72 (58,54%)
3-4	31 (25,20%)
5-6	18 (14,63%)
7 or more	2 (1,63%)

Source: own elaboration.

Table 1 shows that the surveyed enterprises differ in terms of resources, but small and medium-sized enterprises dominate among them.

4.2. Statistical Methods

Statistical methods were used to describe the distribution of responses and the structural characteristics of the surveyed firms. The Mann-Whitney U test (Mann, 1947), a semi-parametric test, was applied to identify between-group differences. The jamovi® statistical software (2024) was used to facilitate hypothesis testing based on data from the 85 companies that had implemented innovations (The jamovi project, 2024).

Initially, the Mann-Whitney U test was employed to determine whether firms implementing specific types of innovation - product, process, marketing, organisational and recombinant - experienced statistically significant, measurable benefits compared with firms that did not implement these innovations. The test also examined between-group differences regarding specific benefits associated with innovation development.

At each stage of hypothesis testing, the p-value was used to determine the statistical significance of differences between groups, while effect size was measured for the second and third analytical tasks.

5. Results

5.1. Description of the research sample

A total of 123 responses were obtained from Polish companies operating in the offset printing sector, representing a broad cross-section of firms differing in size, market orientation and production profiles. Among these respondents, 85 firms (69.11%) reported having implemented at least one form of innovation within the past three years, indicating a relatively high and widespread level of innovation activity across the sector. As illustrated in Figure 4, product innovations were implemented by 43.09% of firms, process innovations by 39.02%, organisational innovations by 33.33% and marketing innovations by 23.58%. This distribution highlights both the overall prevalence of innovation in the offset printing sector and the varying emphasis placed on different innovation types, with product and process innovations being the most common.

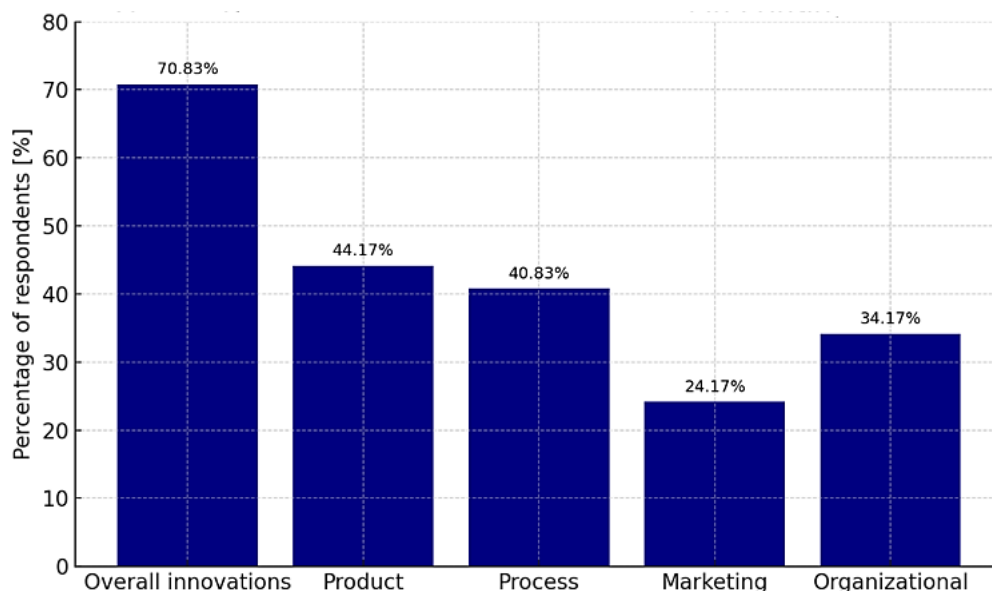


Figure 4. Frequency of innovation implementation in the surveyed offset printing houses.

Source: own elaboration.

The data were collected from all seventeen regions of Poland and were relatively evenly distributed geographically. Most innovative firms in the Polish offset printing sector are medium-sized (54.1%) or small enterprises (36.5%). It is noteworthy that medium-sized companies are disproportionately represented among innovators (54.1%) compared with the overall sample (39.8%). Conversely, innovations are implemented less frequently in small firms (36.5% vs. 48.8%) and micro-enterprises (3.53% vs. 7.32%). This pattern shows that while medium-sized firms lead in innovation activity, small and micro-enterprises also play an active role, demonstrating that innovation is not limited to larger organisations.

Innovative firms are located primarily in metropolitan areas or regional capitals (40.00%) and in larger cities with more than 100,000 inhabitants (22.35%). This urban concentration is more pronounced among innovators (40.00%) compared with the entire sample (35.77%).

Most innovative firms operate in international (57.65%) or national markets (30.59%), with minimal focus on regional or local markets. This global orientation is more significant among innovators (57.65%) than among all surveyed firms (43.09%). In contrast, innovators place less emphasis on regional or local markets, even though these markets are relatively important for the broader sample (17.07%).

The sectoral distribution among innovative firms indicates that packaging printing (37.65%) and advertising (29.41%) dominate, followed by book printing (23.53%). Innovative firms are more strongly represented in packaging printing compared with the overall sample (37.65% vs. 26.02%), but are less engaged in advertising printing (29.41% vs. 45.53%).

Production infrastructure further highlights the number and types of machines as key structural characteristics. The largest group of innovators consists of firms with 1-2 offset presses (45.88%), followed by those with 3-4 machines (31.76%). Fewer firms operate five or more presses, although innovators generally possess larger machine parks. For example, 22.35% of innovators use five or more offset presses, compared with only 16.26% in the overall sample. This indicates that while many innovative firms operate with relatively few machines, larger machine parks are more common among innovators.

The dominant printing format further differentiates firms into three main groups. Format B1, used by 57.65% of innovators, is the most common, reflecting the advanced capabilities of offset machines for large-format production such as posters and packaging. Format B0, found in 7.06% of innovators, supports even larger sheet sizes. These formats highlight the concentration of innovative firms on large-scale, high-value production.

Format B2, used by 23.53% of innovators, is the second most common and is typically associated with medium-sized production such as brochures, catalogues or books. Smaller formats - including A1 (5.88%), A2 (2.35%) and B3 (3.53%) - are used less frequently and usually serve specialised or small-volume products such as promotional materials or personalised prints.

5.2. Enterprise resources as determinants of innovativeness

In verifying hypothesis H1, the structural differences observed between firms that implemented innovations and those that did not (Table 2) were confirmed using the Mann-Whitney U test. Statistically significant discriminatory power was identified for the operational market ($p < 0.001$, $r = 0.693$, large effect size), number of employees ($p < 0.001$, $r = 0.556$, large effect size), dominant printing sector ($p < 0.001$, $r = 0.576$, large effect size), number of machines ($p < 0.001$, $r = 0.425$, large effect size) and dominant print format ($p < 0.001$, $r = 0.540$, large effect size). Company location, however, was not significant ($p = 0.313$, $r = 0.110$).

To further verify the hypothesis, the relationships between enterprise resources and the characteristics of implemented innovations were analysed. Partial correlations using Spearman's rho demonstrated statistically significant associations between the degree of novelty (novelty at firm, national or global scale) of product innovations and the number of machines ($p = 0.001$), between the degree of novelty of process innovations and the number of employees ($p = 0.012$) as well as the number of machines ($p < 0.001$), and between the novelty of organisational innovations and the dominant print format ($p = 0.009$). Additionally, the novelty of product innovations correlated with the novelty of organisational innovations ($p = 0.009$), the number of machines correlated with the number of employees ($p < 0.001$) and the number of employees correlated with dominant print format size ($p < 0.001$).

Spearman's partial correlation analysis also revealed statistically significant positive relationships between the novelty of innovations and their sources. For product innovations, higher novelty was associated with the use of scientific research ($p = 0.021$) and sector events ($p = 0.016$). For process innovations, significant correlations were found for sector events ($p < 0.001$) and imitation ($p = 0.026$). For marketing innovations, the novelty of solutions correlated with customer suggestions ($p = 0.027$) and the acquisition of intellectual property rights or licences ($p = 0.015$). For organisational innovations, novelty was significantly associated with in-house market research ($p = 0.004$), customer suggestions ($p = 0.022$) and the acquisition of intellectual property or licences ($p = 0.002$).

Among the firm's resources relevant to hypothesis H1, knowledge resources - alongside material resources such as machine capacity - play a pivotal role. To assess their influence, the relationships between the types of innovation implemented and the knowledge sources used by firms were examined. The Kruskal–Wallis test showed that several innovation sources significantly contributed to measurable benefits derived from innovation: in-house market research ($p = 0.042$), customer suggestions ($p = 0.035$), ideas generated by the sales force ($p = 0.039$), internal R&D activities ($p = 0.003$), business support institutions ($p = 0.045$) and scientific research ($p = 0.012$). These findings are summarised in Table 3.

Table 3.

Differences between firms that achieved measurable benefits from innovation development and those that did not, in terms of the importance of innovation sources

Factor	χ^2	df	P	ϵ^2
Scale of organisational innovativeness	0.5260	1	0.468	0.01315
In-house market research	4.1308	1	0.042	0.04918
Customer suggestions	4.4277	1	0.035	0.05271
Supplier proposals	0.0596	1	0.807	0.00071
Management ideas	0.0694	1	0.792	0.000826
Technologists' ideas	0.9560	1	0.328	0.01138
Machine operators' ideas	0.4757	1	0.490	0.00566
Sales force ideas	4.2707	1	0.039	0.05084
Internal R&D activities	9.1375	1	0.003	0.10878
Consulting firms	2.4732	1	0.116	0.02944
Business support institutions	4.0193	1	0.045	0.04785

Cont. table 3.

Open sources	1.4529	1	0.228	0.01730
Purchase of IP / licences	3.7855	1	0.052	0.04506
Scientific research	6.3254	1	0.012	0.07530
Sector events	0.1985	1	0.656	0.00236
Imitation	0.3097	1	0.578	0.00369

Source: own elaboration.

Table 3 shows that the benefits of innovation are linked to the sources of innovation, with the ability to independently create innovations and cooperation with entities capable of conducting research and implementation work (e.g. scientific organizations) constituting a significant added value for achieving benefits or the innovative development of the company.

5.3. Importance of external and internal sources of innovation

The innovations implemented in the surveyed firms differed noticeably in terms of their sources (Figure 5). Among companies that introduced innovations, managerial ideas stood out most prominently: 36.67% of respondents rated them as highly important, and an additional 10.83% as very highly important. Technologists' ideas were also evaluated strongly, with 33.33% of respondents assigning them high importance and 8.33% very high importance. Industrial events received 24.17% indications of high importance and 7.50% of very high importance, while imitation was rated as highly important by 24.17% of firms and as very highly important by 1.67%.

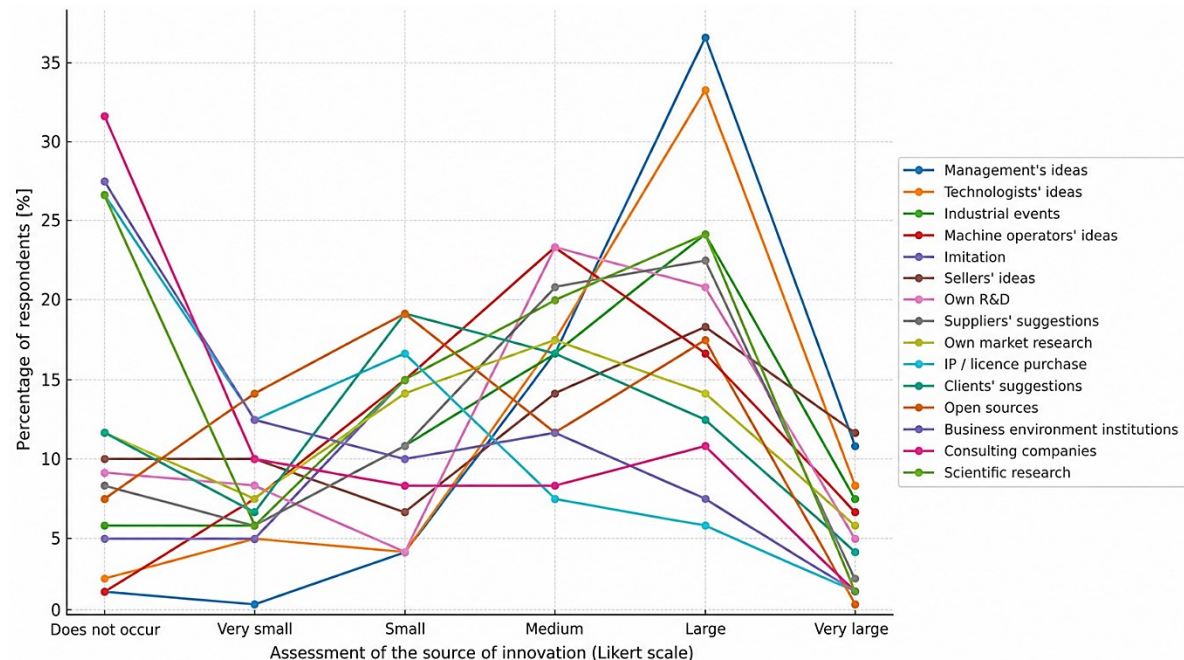


Figure 5. Full distribution of responses in percentage scale on the importance of internal and external sources of innovation, including cases where a given source does not occur.

Source: own elaboration.

The importance of ideas generated within the organisation was rated as high by 18.33% of firms and as very high by 11.67%, while ideas originating from machine operators were rated as highly important by 16.67% of respondents and as very highly important by 6.67%. Internal R&D activities were assessed as highly important by 20.83% of firms and as very highly important by 5.00%. Supplier suggestions received 22.50% high-importance ratings and 2.50% very-high-importance ratings, whereas in-house market research was rated as highly important by 14.17% of firms and as very highly important by 5.83%.

Less significant innovation sources included customer suggestions (12.50% high importance, 4.17% very high importance), open knowledge sources (17.50% and 0.83%), scientific research (24.17% and 1.67%), business support institutions (7.50% and 1.67%), consulting firms (10.83% and 1.67%) and the purchase of intellectual property rights or licences (5.83% and 1.67%).

Overall, internal resources were most frequently identified by firms as sources of high or very high importance - particularly managerial and technologists' ideas, internal R&D activities and supplier suggestions. External sources of knowledge, including even business support institutions and research conducted by academic bodies, were more often positioned outside the firms' core innovation sources. Exceptions included industrial events, open-source knowledge and imitation, which reached importance levels comparable to some internal resources.

Subsequently, the Kruskal–Wallis test was applied to examine whether the availability of external resources differentiated firms that reported benefits from innovation development and firms that had implemented any of the four primary innovation types (Table 4).

Table 4.

Differences between firms that achieved measurable benefits from innovation development and those that did not, in terms of the availability of external resource sources

Availability factor	χ^2	df	P	ϵ^2
Availability – material resources	0.921	1	0.337	0.01097
Availability – financial resources	2.471	1	0.116	0.02941
Availability – human resources	0.242	1	0.623	0.00288
Availability – intellectual resources	0.404	1	0.525	0.00481

Source: own elaboration.

No statistically significant differences between groups were observed regarding access to any external resources in the case of product innovations ($p > 0.223$), process innovations ($p > 0.0684$) or marketing innovations ($p > 0.067$). A statistically significant between-group difference appeared only for the availability of external material resources between firms that implemented organisational innovations and those that did not ($p = 0.015$). Importantly, the availability of external resources did not significantly distinguish firms that reported benefits from innovation development from those that did not ($p > 0.0116$), suggesting that external resource availability did not translate into a higher propensity to innovate.

5.4. Importance of material and intangible resources

Among the 85 firms that implemented innovations during the past three years, material resources (movable and immovable assets) were absent or of no importance in 5.83% of cases (5 firms), of high importance in 16.67% (14 firms) and of very high importance in another 16.67% (14 firms). Financial resources were absent or of no importance for 0.83% of firms (one response), highly important for 26.67% (23) and very highly important for 14.17% (12). Human resources were absent or of no importance for 0.83% of firms (1), of high importance for 20.00% (17) and of very high importance for 29.17% (25). Organisational practices were absent or unimportant in 0.83% of firms (1), of high importance in 19.17% (16) and of very high importance in 21.67% (18). Relational resources were absent or unimportant in 2.50% of firms (2), of high importance in 29.17% (25) and of very high importance in 18.33% (15). Intellectual resources were absent or unimportant in 0.83% of firms (1), of high importance in 25.00% (21) and of very high importance in 23.33% (20).

As with innovation sources, the descriptive analysis already reveals a clear dominance of intangible resources - particularly human, relational and intellectual - over material and financial resources, although the latter also played a relevant role in the assessment of offset printing firms. These findings indicate that, in the perception of managers, it is people and the associated intangible capabilities rather than financial inputs that determine the success of innovation implementation.

Statistically significant differences ($p < 0.05$) between firms that achieved measurable benefits from innovation development and those that did not were identified for material resources ($p = 0.039$), financial resources ($p = 0.034$), human resources ($p = 0.010$) and intellectual resources ($p = 0.032$), whereas differences in the importance of organisational practices ($p = 0.176$) and relational resources ($p = 0.603$) were not statistically significant.

Average values further indicate that across all resource categories, importance ratings were higher among firms that achieved measurable benefits from innovation development (2.66-3.54) than in the group that did not (1.87-2.87). The largest difference concerned human resources (3.54 vs. 2.87), while the smallest occurred for relational resources (2.89 vs. 2.87).

The greater importance of intangible resources is further supported by differences in the presence of relational resources (absence, current presence or expected future presence as ordinal characteristics) in achieving innovation-related benefits, tested using the Kruskal-Wallis test (Table 5). Firms that achieved measurable benefits from innovation development differed significantly from those that did not in terms of the importance of relationships with business support institutions ($p = 0.007$), research organisations ($p = 0.033$) and universities ($p < 0.001$). Differences in relationships with SMEs ($p = 0.120$), large enterprises ($p = 0.217$) and public organisations ($p = 0.079$) were not statistically significant.

Table 5.

Differences between firms that achieved measurable benefits from innovation development and those that did not, in terms of the availability of external relational resources

Relational factor	χ^2	df	P	ε^2
Relations – SMEs	2.41	1	0.120	0.0287
Relations – large firms	1.53	1	0.217	0.0182
Relations – business support institutions	7.20	1	0.007	0.0857
Relations – research organisations	4.55	1	0.033	0.0541
Relations – universities	12.12	1	< 0.001	0.1443
Relations – public organisations	3.09	1	0.079	0.0368

Source: own elaboration.

Table 5 shows that benefits are generally more strongly visible in case of relations with entities that can conduct or significantly facilitate company's own R&D, rather than provide ready-made innovative solutions.

5.5. Resources as individual determinants of specific types of innovation

To conduct a more detailed examination of the above factors within the subgroup of firms that implemented innovations ($n = 85$), the Kruskal–Wallis test was applied. The results indicate that structural characteristics most directly linked to firm resources (number of employees, number of machines, dominant print formats) do not differentiate firms that implemented product innovations from other innovative offset printing firms ($p > 0.218$). Similarly, these characteristics were not significant for process innovations ($p > 0.074$) or organisational innovations ($p > 0.127$). In the case of marketing innovations, however, the number of machines proved statistically significant ($p = 0.026$). It should be noted that, due to the widespread adoption of service-oriented business models among manufacturers of offset printing equipment (Salwin, 2020), this factor reflects external resources no less than internal ones.

In the Kruskal–Wallis test examining differences in the perceived importance of resources between firms that implemented product innovations and those that did not, statistically significant differences concerned the importance of customer suggestions ($p = 0.005$), open-source innovation inputs ($p = 0.010$) and the acquisition of external intellectual property or licences ($p = 0.008$).

For process innovations, the differentiating factors were the importance assigned to the inventiveness of technologists ($p = 0.013$), the inventiveness of sales personnel ($p = 0.008$), the purchase of intellectual property or licences ($p = 0.034$), sector events ($p = 0.030$) and imitation ($p = 0.025$).

Firms that implemented marketing innovations differed significantly from others in their declared importance of: in-house market research ($p = 0.005$), technologists' ideas ($p = 0.004$), consulting firms ($p < 0.001$), business support institutions ($p = 0.009$), open-source knowledge ($p = 0.005$), the purchase of intellectual property rights or licences ($p = 0.005$) and scientific research ($p = 0.040$).

These factors are summarised in Table 6. The results indicate that internal resources play a significant role across all types of innovations, while the importance of external factors increases progressively - from organisational innovations, through process and product innovations, to marketing innovations. Moreover, intangible resources become particularly important as drivers of product and process innovations.

Table 6.

Resource factors associated with the occurrence of specific types of innovation, categorised according to the theoretical classification.

Innovation type	Internal resources – material	Internal resources – intangible	External resources – intangible
Product innovation	–	–	Customer suggestions; open-source innovation inputs; acquisition of external intellectual property or licences
Process innovation	–	Inventiveness of technologists; inventiveness of sales personnel	Acquisition of intellectual property or licences; sector events; imitation
Organisational innovation	–	–	–
Marketing innovation	Number of machines	In-house market research; technologists' ideas	Consulting firms; business support institutions; open-source knowledge; acquisition of intellectual property or licences; scientific research

Source: own elaboration.

Table 6 shows that the types of innovations are differentiated to a greater extent by external resources than by internal resources.

6. Discussion

As the results indicate, packaging companies proved to be more innovative. This finding should be interpreted in light of three key contextual characteristics of these firms.

First, packaging constitutes one of the most prospective segments of the printing industry. Unlike traditional offset print products (books, newspapers, printed forms, leaflets, posters, or other printed materials), whose functions may be partly or wholly displaced by digital technologies, packaging performs an indispensable economic function. Its role is not limited to the transmission of information but primarily involves the protection, containment, storage, transport, and distribution of physical goods. This applies in particular to food packaging, whose production remains non-substitutable so far (Pascal et al., 2022). Against the background of the European printing industry as a whole, packaging represents one of the main areas of growth, whereas the overall value of the European print market is characterized by lower growth dynamics and less favorable growth forecasts than the packaging sector. This is

primarily associated with the intensive development of e-commerce, which increases demand for packaging, ranging from simple corrugated cardboard boxes to complex, high-value products (Horváth, Koltai, Orgován, 2025). Consequently, the allocation of long-term investment and the strategic orientation of production toward packaging may be regarded as a rational development strategy, and such a strategy is closely linked to innovation.

Second, packaging companies primarily serve manufacturers of consumer goods, for whom packaging constitutes an important instrument of market competition, marketing differentiation, and regulatory compliance. This generates continuous pressure to modify packaging design, functionality, print quality, environmental performance, and protective features. In contrast to more traditional segments of the printing industry, demand for innovation in packaging is therefore generated directly by industrial customers (Beckeman, Olsson, 2010). This interpretation is partly supported by the observed significance of customer suggestions as a factor associated with marketing and product innovations, but not with process or organizational innovations.

Third, the higher innovativeness of packaging firms may also result from the relatively greater capital intensity and technological complexity of packaging production, which requires a specific and more advanced machinery base. The study showed that the number of machines is among the strongest factors differentiating innovative firms from non-innovative ones. Moreover, it correlates with the degree of novelty of product and process innovations, that is, with technological innovations. Packaging production, particularly in B1 and B0 formats, requires more advanced equipment than many other segments of the printing industry. Firms possessing such resources therefore have, under the conditions examined in this study, a greater capacity to implement new technological solutions.

The last of these interpretations provides a point of departure for explaining why medium-sized enterprises exhibit a statistically higher level of innovation implementation. The relationship between innovativeness and medium firm size may be interpreted in terms of the greater resources available to larger firms, which are necessary for the implementation of innovation (Gachmann, Kataishi, 2025). This assumption is related to the debate over whether innovativeness is a direct function of firm size, meaning that after a certain threshold it increases proportionally with firm size rather than more rapidly (Symeonidis, 1996), or whether certain innovations generate effects proportional to the scale of production, making them economically rational only in larger firms and thereby producing economies of scale (Cohen, Klepper, 1996; Iammarino, McCann, 2006; Archibugi, Evangelista, Simonetti, 1995). Small firms tend to exhibit above-average innovativeness only under conditions of clear market dominance by large firms (Gachmann, Kataishi, 2025; Acs, Audretsch, 1988), which is not the case in the present study. Since the sample consisted predominantly of small and medium-sized enterprises, the greater share of medium-sized firms in the innovative group may be interpreted as an outcome of the positive relationship between innovativeness and firm size.

At the same time, innovativeness is higher among firms oriented toward international markets. This may be explained in two main ways.

First, exporting firms are subject to substantially stronger competitive pressure. In local markets, a firm competes with a limited number of entities, whereas in international markets it must confront larger producers from multiple countries. Under such conditions, the development of competitive advantage requires continuous improvement through innovation (Onodera, 2008).

Second, firms present in foreign markets gain access to broader knowledge resources. Contact with foreign customers, suppliers, competitors, and business partners increases the number of sources of information on new technologies, market trends, and organizational solutions, in line with the mechanism of “learning by exporting” (Freixanet, Federo, 2023; Rafique, Abbas, 2025). This mechanism is relatively strong among small and medium-sized enterprises (Almeer, 2026), especially when it is linked to their digital transformation (Said, Soi, 2025).

The study confirms the prevailing view in the literature that innovation depends on both internal and external resources. However, the interpretation proposed by Nguyen and Minh (Nguyen, 2023) - that external resources dominate in an open, innovation-driven economy - appears premature. The analysis demonstrates that the offset printing sector is an area of intensive innovation activity, driven by strong market-shaping mechanisms (regulatory pressure, internal and external competitive pressures), which is reflected in the high prevalence of all types of innovations among the respondents. In this sector, external determinants of innovativeness did not dominate; moreover, the availability of external material, financial, human or intellectual resources generally did not differentiate firms that achieved innovation-related benefits from those that did not.

These findings align with the observations of Wu et al. (Wu, 2022) and Zhu et al. (Zhu, 2025), who argue that internal intangible resources are more important than external and material resources. They also support the conclusions of Mališić et al. (Mališić, 2025) regarding the role of human resource management and absorptive capacity: the highest-rated sources of innovation included managerial ideas, technologists’ ideas and internal R&D activities, indicating the critical role of internal organisational processes and likely reflecting an innovation-oriented organisational culture.

Partial support was found for the observation by Phung et al. (Phung, 2021) that the relevance of external resources increases alongside the strength of the institutional environment. In marketing-related offset innovations - where business support institutions, scientific research and consulting were more frequently involved - external factors were more important than in other innovation types. However, there was no full confirmation of the claim that innovativeness is determined exclusively by external sources, as process, product and organisational innovations remained predominantly driven by internal factors - most of them directly linked to the firm’s human resources.

Similarly, although Keil et al. (Sesli, 2023) emphasise the role of broad networking, the analysed sector did not exhibit a dominance of network-related effects over those stemming from internal innovation activities. The threshold effect proposed by Carboni and Medda (Cecere, 2014) concerning the diminishing returns of external resources found direct support in this study. Given that no clear differences in access to external resources were found between firms that did and did not achieve innovation-related benefits, it follows that access alone - without the capability to utilise it - is insufficient for innovation development. Considering that firms also differ in their perceived benefits from innovation development, it can be assumed that the propensity to innovate - operating alongside innovative capability - acts as a moderating factor (Stanisławski, 2022).

7. Conclusions

The study confirmed that the implementation of innovations depends on both internal and external resources, manifested in structural characteristics as well as in the relationships between the degree of innovativeness, novelty and resources. Accordingly, **Hypothesis H1** was positively verified.

Structural characteristics (operational market, number of employees, dominant sector, number of machines and dominant print format) significantly distinguished firms that implemented innovations from those that did not. The degree of novelty of innovations was also associated with specific resources, differentiated across innovation types.

The study further demonstrated that internal sources of innovation generally carried more weight than external ones, leading to the positive verification of **Hypothesis H2**. Innovative firms in the offset printing sector more frequently identified and highly assessed internal sources - such as managerial ideas, technologists' ideas and internal R&D activities - than external ones. At the same time, different innovation types varied in the relevance of internal and external resources and in their links with the degree of novelty (e.g., marketing innovations were more strongly associated with external factors, while organisational innovations were shaped exclusively by internal structural characteristics). The availability of external resources generally did not significantly differentiate firms that reported innovation-related benefits, indicating that external resources alone are insufficient drivers of innovation development.

With respect to **Hypothesis H3**, the findings showed that intangible resources - particularly human, relational and intellectual resources - were more important than material resources. This hypothesis was therefore also positively verified. Firms more often pointed to intangible resources as crucial for innovation development, and the perceived importance of both material and intangible resources significantly differed between firms that achieved and those that did

not achieve measurable innovation-related benefits. Significant differences were found for material, financial, human and intellectual resources.

Innovation types differed in their determinants, confirming **Hypothesis H4**. Structural factors did not differentiate all firms; they were more relevant for marketing innovations (number of machines), while for other types of the effects were not statistically significant. Only when considered as independent determinants of innovativeness can these factors be treated as relevant across innovation types. Both internal and external sources were significantly associated with innovation types and their degree of novelty, though the relevance varied by innovation type. Different relational resources favoured different types of innovations, indicating variation in the importance of intangible and external resources.

Overall, the Polish offset printing sector is highly innovative. Most firms implemented innovations of various types, drawing on diverse sources reflected in both internal and external resources. Possessing specific internal resources - particularly intangible ones - is fundamental. These resources are more important than external ones, which are readily accessible but not always convertible into innovation-related benefits.

Intangible resources, especially human and intellectual resources, are essential for innovation development because they enable the effective use of material resources and determine the capacity to leverage external resources. **For innovation development (which depends on both the propensity and capability to innovate) the presence of core resources is necessary to recognise the need for innovation (and the associated benefits) and to implement innovation strategies.**

Considering the findings, innovation development based solely on the transfer of financial means for accessing external resources appears unfeasible. The primary drivers of innovation are internally generated, particularly those rooted in the inventiveness of employees: managers who shape an innovation-oriented organisational culture and in-house specialists, including technologists. These human-centred intangible resources constitute the foundational condition for achieving sustainable innovation outcomes in the offset printing sector.

8. Managerial Implications

Offset printing companies operate in an environment characterised by rapid technological change, intensifying competitive pressure and increasing regulatory demands associated with the green transformation of the printing industry. Competition arises not only from other offset printers but also from the expanding digital printing market, whose technological advantages - particularly at low volumes - force offset printers to implement continuous innovation. In this context, sustainable competitiveness requires adopting new business models grounded in service-oriented rather than product-centric value propositions. This shift necessitates the

ongoing implementation of multiple innovation types - process, product, organisational and marketing - which were shown in this study to be increasingly widespread across the sector.

Managers should translate open innovation, Environmental, Social, and Governance (ESG) foresight and ESG competence development into specific actions concerning barriers identified in the study. To reduce the high costs of product and process innovation associated with environmental requirements, firms should intensify cooperation with suppliers, and research organisations in order to share knowledge, testing infrastructure and other sources of developmental costs. To cope with short regulatory implementation deadlines in the European Union, managers should use ESG monitoring and foresight mechanisms that enable the early identification of upcoming environmental requirements and allow sufficient time for adaptation. Given the limited financial and human resources characteristic of many offset printing firms, ESG-related investments should be prioritised according to their expected operational and market benefits, while external support programmes and industry partnerships should be used to complement internal capabilities. Employee resistance to change should be addressed through continuous training, cross-functional involvement in innovation projects and transparent communication of the business and environmental benefits of new solutions. Such measures can strengthen ability to implement sustainability-oriented innovations while maintaining competitiveness in a rapidly changing market environment.

For managers, the findings highlight that the effectiveness of innovation strategies hinges on a targeted and rational allocation of resources. In an environment where external resources - knowledge, technologies, networks or market information - are relatively easily accessible, competitive advantage stems not from access itself but from the capability to absorb, interpret and utilise these resources. This capability is strongly rooted in internal intangible assets: human capital, managerial and technological expertise, organisational culture and internally generated intellectual resources.

Managers should therefore prioritise the development of internal absorptive capacity, understood as the ability to recognise the need for innovation, integrate new knowledge, and apply it to commercial ends. Strengthening internal knowledge creation processes - through training, recruitment of technologically skilled staff, cross-functional collaboration and internal R&D - should be treated as a strategic investment, not a cost. The study clearly indicates that firms with strong internal creative capabilities (especially managerial and technological ideation) are significantly more likely to achieve measurable benefits from innovation.

At the same time, relational assets - collaboration with research organisations, universities, business support institutions and specialised suppliers - remain essential enablers. However, these relationships create value only when the firm possesses the internal competencies necessary to transform them into innovative outcomes. Thus, managers should design relational strategies not as substitutes for internal capacity, but as complementary mechanisms that extend the firm's innovation potential.

To build a lasting competitive advantage, offset printing companies must adopt strategies that:

- systematically strengthen intangible assets, particularly human, relational and intellectual resources,
- embed innovation into organisational routines, enabling continuous recombination and improvement of products, processes and business models,
- leverage external resources selectively, prioritising those that align with the firm's internal capabilities and strategic direction,
- develop service-oriented and digital business models that utilise both material (machines, formats, production capabilities) and intangible assets to deliver higher customer value,
- cultivate an organisational culture that rewards creativity, experimentation and learning, particularly among managers and technologists, who play a central role in generating innovative ideas.

Managers who fail to recognise the strategic importance of intangible resources and rely solely on external inputs - such as the purchase of machines, technologies or licences - risk limiting their company's innovation potential. In highly dynamic market conditions, such firms are unlikely to fully benefit from innovation-driven development and may face substantial long-term disadvantages.

In contrast, firms that leverage their internal creative capacity, supported but not replaced by external collaborations and material assets, are best positioned to adapt, compete and thrive within the transforming global printing industry.

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