COLECCIÓN CONOCIMIENTO CONTEMPORÁNEO

El papel de la economía, la empresa y el derecho ante los nuevos entornos globales

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URGENT AND EMERGING SKILLS IN THE EUROPEAN MARITIME SECTOR: ALIGNING WORKFORCE COMPETENCIES WITH INDUSTRY EVOLUTION

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1. INTRODUCTION

Rapid technological advancements, stringent environmental regulations, and increasing global competition are profoundly transforming the European maritime sector. These factors are reshaping the industry's operational frameworks and highlighting critical skill shortages, prioritising workforce development to ensure future competitiveness and sustainability.

The LeaderSHIP project, conducted under the Erasmus+ Programme, seeks to address these challenges by enhancing skills development across the maritime industry. The project aligns with the European Union's Smart and Sustainable Mobility Strategy with a focus on upskilling and reskilling 200,000 workers and attracting 230,000 new talents. This initiative spans 16 countries and integrates a sectoral skills strategy to modernise curricula, emphasising digitalisation, green technologies, and innovative training approaches. By fostering partnerships between educational institutions and industry leaders, the project aims to ensure that the maritime workforce is prepared to meet the evolving demands of an increasingly dynamic global market.

Despite its critical economic and strategic role, the maritime sector faces persistent challenges, including a mismatch between educational offerings and industry needs, a growing demand for specialised green and digital skills, and demographic issues such as an ageing workforce. These gaps threaten the sector's ability to maintain its leadership in innovative, autonomous, and sustainable shipping technologies, essential for supporting over 1 million jobs and sustaining economic activity across Europe.

1.1 Significance of the Maritime Sector

The European maritime sector is a cornerstone of the continent's economy, environment, and strategic framework. Its expansive maritime domain, comprising over 70,000 kilometres of coastline across 23 coastal member states, is integral to global trade, energy security, and cultural heritage. By facilitating diverse activities such as shipping, port operations, shipbuilding, and marine tourism, the sector generates substantial economic value, sustains coastal communities, and positions Europe as a global leader in maritime innovation.

Economic Significance

The maritime sector contributes over €650 billion annually to the EU economy, directly employing 5.4 million people across subsectors such as shipbuilding, offshore energy, and logistics (Oxford Economics, 2020). Its economic impact extends beyond direct contributions, as it drives related industries like port logistics, manufacturing, and marine biotechnology (Polyzogopoulos, 2021). European ports play a pivotal role in global trade, handling 75% of the EU's external trade and 35% of intra-EU trade by volume, underscoring their importance in maintaining supply chain connectivity and resilience (Chortareas et al., 2021).

Strategic and Geopolitical Role

The maritime sector is critical to Europe's energy security and strategic autonomy. Key infrastructure such as LNG terminals and offshore wind farms enhances energy independence while supporting the transition to renewable energy sources (European Commission, 2020). European

ports and maritime routes are vital to global supply chains and geopolitical stability, ensuring the secure flow of goods during disruptions such as the COVID-19 pandemic or geopolitical tensions (Reuters, 2024). Moreover, the shipbuilding sector contributes to Europe's defence capabilities, specialising in naval applications and advanced maritime technologies (Oxford Economics, 2020).

Environmental and Sustainability Contributions

The European maritime sector plays a dual role in economic development and environmental stewardship. It supports marine conservation efforts through initiatives like the Marine Strategy Framework Directive, aiming to achieve sustainable use of marine resources (Polyzogopoulos, 2021). Though representing just 3% of global shipbuilding volume, European shipyards generate 15% of their value by focusing on high-complexity vessels such as cruise ships and research craft, integrating cutting-edge green technologies and energy-efficient solutions (Chortareas et al., 2021).

The sector's leadership in sustainable practices extends to its role in setting global maritime standards. For example, advancements in ship recycling and circular economy initiatives reflect the EU's commitment to minimising environmental impacts while maintaining its competitive edge (European Commission, 2020).

Cultural and Societal Impact

Beyond its economic and environmental contributions, the maritime sector has a profound societal and cultural impact. It sustains the livelihoods of coastal communities through activities like fishing, tourism, and marine industries, providing critical economic support to these regions (Polyzogopoulos, 2021). The sector's cultural heritage is deeply embedded in European traditions, celebrated through maritime festivals, museums, and historical shipbuilding crafts. Additionally, ongoing workforce development initiatives aim to attract diverse talent and equip workers with skills in emerging fields such as digitalisation and green technologies (Reuters, 2024).

Technological Leadership

The European maritime sector is a global leader in technological innovation. Ports like Rotterdam and Hamburg are hubs for research and development in automation, green shipping, and digitalisation, supported by funding from initiatives such as Horizon Europe (Polyzogopoulos, 2021). R&D investments have enabled the sector to maintain a competitive edge, with European shipyards leading advancements in alternative fuels, emission reduction technologies, and energy-efficient designs (Chortareas et al., 2021).

Resilience and Adaptability

The sector has demonstrated remarkable resilience during crises, such as the COVID-19 pandemic, by maintaining critical supply chains and supporting economic stability (Reuters, 2024). Its ability to adapt to challenges underscores its strategic importance and ensures its ongoing contribution to Europe's economic and environmental objectives.

1.2. Challenges Facing the Maritime Sector

The European maritime industry confronts many interconnected challenges that require strategic and coordinated responses. These challenges span technological, environmental, demographic, and societal dimensions, creating a multifaceted transformation landscape.

Digital Transformation and Automation

Digital transformation and automation represent critical challenges for the maritime sector, as they necessitate the integration of advanced technologies, workforce adaptation, and modernising legacy systems. Rapid technological change requires maritime companies to address vulnerabilities, improve operational efficiency, and remain competitive in an increasingly interconnected and data-driven industry.

Enhanced maritime connectivity is critical for the successful implementation of digital transformation initiatives. AI-driven 6G solutions that integrate terrestrial and non-terrestrial networks are being explored to improve real-time data transmission and enable seamless operation of

advanced technologies (Saafi et al., 2022). Such solutions promise to revolutionise maritime communication systems, but their deployment requires substantial investment and global standardisation.

Adopting innovative port technologies revolutionises maritime logistics by enabling real-time data analysis, predictive maintenance, and process optimisation. However, challenges remain in harmonising legacy systems with modern digital infrastructures. For instance, many maritime organisations struggle with integrating big data analytics, blockchain, and IoT technologies, which are essential for improving efficiency and decision-making (Sakita et al., 2023; An, 2024). Smart ports, such as those implementing Port 4.0 strategies, are leading the way in automation, but scaling these solutions across the industry is hindered by financial and technical barriers (Heikkilä et al., 2022).

The shift toward automation, including autonomous ships, requires significant technological advancements and workforce training. Autonomous vessel traffic management systems, powered by AI and advanced sensing-actuation infrastructures, are being developed to enhance navigation safety and operational efficiency (Martelli et al., 2022). However, the transition to fully automated systems remains constrained by regulatory, technological, and skill-related challenges.

Digital twin technology is emerging as a transformative tool for the maritime industry, allowing for real-time monitoring and predictive maintenance of vessels. These virtual replicas of physical assets help operators anticipate system failures and optimise performance, enhancing efficiency and reducing operational costs (Zocco et al., 2023). Despite its potential, widespread adoption of digital twins is hindered by high implementation costs and a lack of skilled personnel trained to operate such systems.

Advanced performance monitoring systems powered by machine learning are increasingly used to detect anomalies in vessel operations. These systems enable smart retrofitting and enhance safety by identifying performance deviations early (Moghadam et al., 2023). However, widespread adoption requires overcoming technology costs and industry-wide standardisation challenges.

The sector has seen a significant increase in cyberattacks, with maritime operations and logistics systems prime targets. As digitalisation progresses, cybersecurity vulnerabilities in interconnected systems onboard vessels and port infrastructures pose serious risks to global supply chains (Sakita et al., 2023). Practical strategies to counter these threats include implementing advanced monitoring systems and strengthening security protocols to safeguard digital ecosystems.

A significant barrier to digital transformation is the shortage of workers with advanced digital competencies, including data analysis, machine learning, and IoT integration. Training programs to upskill and reskill the workforce are essential to bridging this gap (Sakita et al., 2023). Additionally, the resistance to change and high turnover rates in the maritime workforce further complicate the adoption of new technologies.

Environmental and Regulatory Pressures

The maritime sector faces mounting environmental and regulatory pressures as it strives to align with global sustainability goals and comply with increasingly stringent environmental standards. These multifaceted challenges encompass the urgent need to reduce emissions, manage marine pollution, and navigate the complexities of international and regional regulatory frameworks.

One of the most pressing issues for the maritime industry is transitioning toward low-carbon shipping to meet climate goals, such as the European Union's 2050 climate neutrality target and the International Maritime Organization's (IMO) decarbonisation objectives. However, this transition is fraught with barriers, including high costs of alternative fuels such as hydrogen and ammonia, limited infrastructure for their adoption, and technological constraints (Andrade, Vinicius et al., 2022). The container shipping industry, in particular, faces significant disruptions as it adapts to new environmental regulations while adopting automation and reshoring strategies (Ahn, Junkeon, 2019).

Maritime transport contributes significantly to air pollution, responsible for approximately 11% of the EU’s transport emissions (Koilo, 2019). Beyond greenhouse gas emissions, the industry is a significant source of

marine pollution, including oil spills, plastic waste, and ballast water discharge. These environmental impacts underscore the need for stricter enforcement of existing regulations and the development of new policies to mitigate the sector's ecological footprint (Serkan Karakas et al., 2023).

Environmental regulations are reshaping the operational and financial landscape of the maritime industry. While these regulations aim to enhance environmental performance and resilience, their implementation often imposes significant economic burdens, particularly on small and medium-sized enterprises (SMEs) (Lanting Zhang et al., 2023). Moreover, compliance with these regulations varies across regions, with discrepancies in standards creating global competitive conditions (School of Law, Nankai University, 2021).

The complexity of environmental regulations and the need for robust data collection systems present a significant challenge for maritime companies. Many operators struggle to meet compliance requirements due to inadequate infrastructure, insufficient financial resources, and limited access to technology (Freese, Thea et al., 2019). For instance, while comprehensive, the IMO's regulatory governance framework often requires significant investment from member states and industry stakeholders, creating disparities in implementation (School of Law, Nankai University, 2021).

Meeting the demands of new environmental policies requires substantial investments in green technologies, alternative fuel systems, and retrofitting existing vessels. These costs are particularly prohibitive for SMEs, which may lack the financial resilience to adapt quickly (Lanting Zhang et al., 2023). In addition, the lack of supporting infrastructure, such as refuelling stations for alternative fuels and recycling facilities for ship dismantling, further hinders progress toward sustainability (Ahn, Junkeon, 2019).

Environmental regulations also play a pivotal role in enhancing the resilience of the marine economy. By promoting sustainable practices, these policies aim to mitigate ecological risks while ensuring long-term economic viability (Lanting Zhang et al., 2023). However, achieving these objectives requires coordinated efforts among industry players,

governments, and international organisations to overcome barriers to implementation and foster global alignment on sustainability standards.

Public Perception

The maritime industry faces significant challenges in reshaping its public perception and addressing systemic talent attraction and retention issues. These challenges, rooted in outdated industry images, workforce demographics, and structural barriers, hinder the sector's ability to compete for skilled professionals in an increasingly competitive labour market.

Despite its strategic importance, the maritime sector is often perceived as traditional and less innovative than other industries. This perception is particularly prevalent among younger generations, with surveys showing that only 12% of STEM graduates consider maritime careers attractive. The outdated image of the industry as physically demanding and lacking technological innovation further exacerbates these challenges (Yuthana Autsadee et al., 2023).

Improving the sector's image must focus on promoting its technological advancements, sustainability initiatives, and critical role in global trade. Highlighting the industry's integration of cutting-edge technologies such as automation, green shipping, and digital transformation can attract new workers (Trade Only Today, 2024).

Workforce Demographics and Talent Attraction

The maritime workforce faces a demographic crisis, with an ageing population and limited gender diversity. Approximately 45% of maritime professionals are expected to retire within the next decade, creating a significant talent gap. Additionally, women represent only 2% of the global maritime workforce in operational roles, underscoring the need for targeted recruitment and retention strategies (SAFETY4SEA, 2024).

Addressing these issues requires implementing inclusive hiring practices, mentorship programs, and workplace policies that promote gender equality and support work-life balance, particularly for seagoing roles (Funmilayo Ajayi, Chioma Ann Udeh, 2024).

The maritime industry struggles to attract and retain talent due to concerns over stagnant wages, limited career advancement opportunities, and inadequate management practices (Kallenberg, Matt R, 2024). Furthermore, many employees perceive the sector as offering less competitive benefits than other industries (SAFETY4SEA, 2024).

Retention strategies must prioritise competitive compensation, clear career pathways, and robust training programs. For example, adopting a skill resilience framework can help bridge the gap between workforce capabilities and evolving industry demands (Caesar, 2024). Leadership development programs that emphasise sustainability and innovation can also foster employee engagement and satisfaction (Pantouvakis, 2022).

The industry must align its human resource development practices with future skill requirements to ensure long-term workforce sustainability. This includes investing in training programs that address skill gaps in areas such as digitalisation, automation, and green technologies (Yuthana Autsadee et al., 2023). Partnerships with educational institutions and targeted campaigns to promote maritime careers among younger generations are also essential for attracting new talent (Trade Only Today, 2024).

In conclusion, transforming the perception of the maritime sector and addressing talent attraction and retention challenges are critical for its sustainability. By adopting innovative recruitment strategies, fostering diversity, and prioritising workforce development, the industry can build a skilled and resilient workforce that meets future demands.

This article draws on findings from the LeaderSHIP project to explore these challenges in-depth, providing insights into the urgent and emerging skills required for the sector's transformation. The study underscores the importance of aligning workforce capabilities with technological and environmental demands, offering a foundation for strategic workforce development in the European maritime industry.

2. OBJECTIVES

This study aims to identify the critical skill gaps hindering the European maritime sector's ability to adapt to rapid technological, environmental,

and demographic changes. By focusing on the urgent and emerging skills required for workforce transformation, the research seeks to:

- Analyse Workforce Competencies: Assess the current state of skills within the maritime industry, highlighting deficiencies in digital, green, and interdisciplinary capabilities.
- Identify Educational Gaps: Examine the alignment between industry needs and existing educational and training programmes.
- Support Strategic Planning: Provide actionable insights to guide stakeholders in designing targeted skill development initiatives that ensure long-term competitiveness and sustainability.

By addressing these objectives, this study contributes to shaping a workforce capable of navigating the challenges of the evolving maritime landscape.

3. METHODOLOGY

A comprehensive survey-based approach was employed to explore the critical skill gaps and challenges faced by the European maritime sector. This methodology was designed to capture diverse perspectives from stakeholders across multiple countries involved in the industry.

3.1 Procedure

The study utilised a structured questionnaire distributed through the Qualtrics platform between March and April 2024. Industry professionals and academic experts collaboratively designed the questionnaire to ensure relevance and robustness. It covered six key themes:

- General information
- In-house expertise issues
- Education
- Training and recruitment
- Urgent skills
- Emerging skills

The survey link was shared with maritime organisations, shipping companies, and professional forums across participating countries, resulting in 163 initial responses. Following data cleaning and validation, 112 responses with over 60% completion were included in the analysis. This ensured a reliable dataset representing a broad spectrum of stakeholders in the maritime industry.

3.2. Participants

The study focused on respondents in positions of strategic oversight within their organisations, including managers and human resource professionals. Approximately 66% of the responses came from small and medium-sized enterprises (SMEs), with the remaining contributions from large companies, research institutes, industrial associations, and educational institutions. This distribution provided a holistic view of skill demands and challenges across organisational types.

3.3. Analysis

Data analysis involved quantitative and qualitative techniques to identify patterns and trends in skill shortages and workforce needs. Geographical representation was examined to capture regional variations in skill requirements, while thematic analysis highlighted emerging competencies and persistent gaps. Insights from the analysis were used to propose actionable recommendations for addressing workforce challenges in the maritime sector.

4. RESULTS

The study's findings highlight critical challenges and opportunities in aligning workforce competencies with the evolving demands of the European maritime sector. Key results are summarised as follows:

4.1. Skill Gaps and Emerging Needs

The survey revealed significant gaps in both urgent and emerging skills:

– Green Skills: 74% of respondents emphasised the need for expertise in environmental management and sustainability practices. Competencies such as energy-efficient operations and compliance with environmental regulations were identified as crucial yet underdeveloped. One participant noted, “Our organisation struggles to find professionals who understand green propulsion systems and their operational impact,” highlighting the acute demand for specialised expertise in this area.

– Technological Skills: A majority (65%) indicated a pressing demand for skills in automation, augmented and virtual reality (AR/VR), 3D/4D design tools, and data analytics. Digital transformation across maritime operations necessitates proficiency in integrating advanced technologies. Another respondent stated, “While we are ready to implement 3D design tools, we lack the in-house expertise to leverage their capabilities fully.”

– Soft Skills: Leadership, adaptability, and problem-solving emerged as essential traits. Nearly 58% of respondents cited difficulties finding candidates with a potent blend of technical expertise and interpersonal capabilities. A survey participant remarked, “We often find individuals with strong technical backgrounds, but their inability to manage teams or resolve conflicts effectively becomes challenging.”

4.2. Educational Mismatch

A recurring theme was the misalignment between educational curricula and industry requirements. Over 40% of respondents reported that current training programmes fail to address the specific technical and digital skills needed in the sector. **One participant explained, “Many graduates are well-versed in traditional maritime practices but lack exposure to cutting-edge technologies like AI and blockchain.”** The lack of interdisciplinary training further exacerbates this issue, leaving critical areas like green technologies and cybersecurity insufficiently covered.

4.3. Workforce Challenges

Participants identified several barriers to talent attraction and retention:

- Competition for Talent: Half of the respondents (50.97%) highlighted intense competition among employers as a significant hurdle. One respondent said, “Retaining talent has become increasingly difficult as larger companies offer more competitive salaries and benefits.”
- Geographical Imbalances: Regional disparities in talent availability were noted, with northern European countries reporting stronger STEM pipelines than southern regions.
- Demographic Challenges: An ageing workforce and the limited appeal of maritime careers among younger generations pose long-term risks to sector sustainability. One respondent noted, “The maritime industry is perceived as outdated, making it difficult to attract young, tech-savvy professionals.”

4.4. Employer Insights

Small and medium-sized enterprises (SMEs), representing 66% of the respondents, expressed specific concerns:

- Difficulty finding candidates with a blend of technical and soft skills (15.56%).
- Limited availability of industry-specific expertise (26.67%).
- Challenges attracting candidates with the desired certifications or qualifications (11.11%). “We are struggling to compete with larger organisations with better visibility and resources,” commented an SME representative.

4.5. Regional Perspectives

Geographical analysis revealed distinct regional trends:

- Northern Europe: Strong emphasis on digitalisation and green technologies, with relatively advanced training infrastructures.

– Southern Europe: Greater need for interdisciplinary and soft skills development, alongside strategies to attract younger talent. A southern European respondent remarked, “We urgently need targeted training programmes to bridge the skills gap in our region.”

These results underscore the urgency of addressing skill gaps and fostering collaboration between industry and educational institutions to align workforce capabilities with emerging demands.

5. DISCUSSION

The results of this study highlight the urgent need for strategic interventions to address skill gaps and workforce challenges in the European maritime sector. These challenges are deeply rooted in systemic issues, including misalignment between education and industry needs, regional disparities, and demographic shifts. Multi-stakeholder collaboration is essential to ensure the sector's long-term competitiveness and sustainability.

5.1. Aligning Education with Industry Needs

The misalignment between educational curricula and industry requirements is a persistent issue. Policy interventions should prioritise partnerships between educational institutions and maritime employers to co-develop curricula integrating green and digital skills. For instance, public-private initiatives could fund training programmes focusing on advanced technologies like AI, blockchain, and AR/VR. Furthermore, embedding soft skills training, such as leadership and conflict resolution, into technical education would create a more versatile workforce.

5.2. Regional Skill Development Strategies

Regional disparities in skill availability require tailored solutions. Policymakers should incentivise the establishment of regional training hubs, particularly in southern Europe, where skill shortages are more pronounced. These hubs could focus on interdisciplinary training, combining technical and sustainability competencies with leadership and adaptability. EU funding mechanisms, such as the European Social Fund

(ESF), could be leveraged to provide financial support for such initiatives, ensuring equitable access to training opportunities across regions.

5.3. Addressing Demographic Challenges

The ageing workforce and limited appeal of maritime careers to younger generations pose significant risks to the sector's sustainability. Policies that promote the maritime industry as a dynamic, innovative, and environmentally conscious career path are crucial. Governments and industry associations should collaborate on marketing campaigns highlighting the sector's role in advancing green technologies and digital transformation. Additionally, tax incentives or subsidies could be offered to companies investing in apprenticeships and internships for young professionals.

5.4. Fostering Retention through Workplace Innovation

Retention challenges, particularly among SMEs, are exacerbated by high competition for talent and a perceived lack of career progression. Policymakers should explore strategies to support SMEs, such as grants for workforce development and access to shared resources for recruitment and training. At the organisational level, adopting flexible work policies and improving work-life balance could enhance employee satisfaction. For instance, companies could implement hybrid work models for onshore roles, reflecting broader trends in workplace innovation.

5.5. Future-Ready Workforce Policies

Building a future-ready workforce requires a proactive approach. Policymakers should encourage lifelong learning initiatives by providing financial incentives for reskilling and upskilling programmes. Industry-wide certifications in emerging fields, such as green shipping and digital logistics, could standardise competencies and create clear career pathways. Furthermore, fostering cross-border mobility for maritime professionals through streamlined visa policies and mutual recognition of qualifications would enhance the sector's capacity to address regional skill shortages.

5.6. Strategic Collaboration Frameworks

The findings underscore the importance of collaboration between industry, academia, and policymakers. Establishing strategic frameworks like maritime sector councils could facilitate regular dialogue and joint planning. These councils should identify emerging skill needs, monitor industry trends, and align workforce strategies with technological and environmental demands.

5.6. Preparing for Future Workforce Trends

The maritime industry is on the cusp of significant transformation, driven by technological advancements and the imperative for sustainable practices. Anticipating these changes is crucial for developing a resilient and adaptable workforce.

- Technological Integration: The increasing adoption of automation, artificial intelligence (AI), and data analytics is reshaping maritime operations. A report by YourMaritime emphasises the necessity for a tech-savvy workforce proficient in data literacy, cybersecurity, and AI to maintain competitiveness. In-house expertise issues (Your Maritime)
- Sustainable Practices: Environmental regulations are steering the industry toward greener operations. The International Maritime Organization (IMO) aims to reduce emissions by 40% by 2030, necessitating a workforce skilled in sustainable technologies and alternative fuels. (Reuters)
- Evolving Career Aspirations: Changing career aspirations among youth present challenges in attracting talent to the maritime sector. The perceived laborious nature of work and lengthy career progression may deter potential entrants, highlighting the need for industry image enhancement and career development opportunities. (Safety4Sea)
- Diversity and Inclusion: Promoting diversity within the maritime workforce is becoming increasingly important. Inclusive policies and practices can enhance innovation and adaptability, which is essential for future industry challenges. (Marsh)

Proactively addressing these trends through targeted training programs, policy reforms, and strategic investments will prepare the maritime workforce for the future.

6. CONCLUSIONS

This study has provided valuable insights into the critical skill gaps and workforce challenges confronting the European maritime sector. As the industry navigates rapid technological advancements, increasing environmental pressures, and demographic shifts, the alignment of workforce competencies with evolving demands emerges as an urgent priority.

The findings highlight three key areas requiring immediate attention:

- Educational Alignment: The gap between current training programmes and industry needs, particularly in green technologies, digitalisation, and interdisciplinary competencies, must be addressed. Collaborative initiatives between educational institutions and maritime organisations are essential to redesign curricula and provide practical, hands-on learning opportunities.
- Regional Disparities: Addressing geographical imbalances in skill availability is vital. While northern Europe has made significant strides in integrating advanced technologies and sustainability practices, southern regions require targeted interventions to close the gap and foster a more equitable distribution of expertise.
- Talent Retention and Attraction: The demographic challenges of an ageing workforce and limited appeal to younger talent demand innovative strategies to make the sector more attractive. Emphasising clear career progression paths, work-life balance, and a modern, inclusive workplace culture will be crucial for retaining and attracting skilled professionals.

A coordinated effort involving policymakers, industry leaders, and academia is necessary to achieve these goals. Investment in leadership development, hybrid skill programmes, and regional training

infrastructures will ensure that the maritime workforce is equipped to drive innovation and sustainability in the coming decades. By addressing these challenges, the sector can secure its global competitiveness and continue to play a pivotal role in the European economy.

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