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Debunking the interplay between sustainable and technological development: insights from the financial market

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Abstract

The concept of *twin transition* developed pursuant to the idea that sustainable development and digital transformation can operate as mutually reinforcing objectives within a coherent regulatory framework. This article critically investigates this assumption by looking at EU financial market regulation.

Drawing on concrete cases (robo-advisory services, DLTs and AI applications in sustainable finance) the research shows that the digital finance and sustainable finance regulatory streams have developed largely in isolation from one another, favouring "additive complex" frameworks, where each new instrument tend to impose requirements that layer upon, rather than integrate with, existing obligations. Absent genuine regulatory inte-

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gration, financial institutions often face cumulative compliance obligations, rather than efficiency-enhancing synergies; these elements, overall, reduce the capacity of the "twin transition regulation" to achieve its policy goals.

Keywords: Twin transition, sustainable finance, digital finance, EU financial regulation, regulatory integration, robo-advisory, distributed ledger technology, artificial intelligence, compliance, policy coherence

1. The twin transition, its twofold nature, and EU financial markets as a privileged standpoint

In the last decade, European Union and its institutions have been devoting growing attention and strategic commitment to regulate what has become known as the "twin transition", whereas the concept can be generally defined as the (ambitious) attempt to devise actions pertaining to sustainable development and digital transformation into a coherent policy framework.

The concept has gained institutional traction in the early 2020s, following the launch of the European Green Deal and the EU Digital Strategy[1]; the idea of a joint approach to the regulation of "the green and the blue" rests on the assumption that the sustainable and digital transitions can be inspected as mutually reinforcing and interrelated: on the one hand, digital tools and innovative solutions can support sustainability, lowering transactions cost pertaining to the shift towards environmentally-conscious entrepreneurial strategies; on the other one, objectives pertaining to sustainability are supposed to shape *ex ante* technological advancements, guiding operators towards the development and deployment of low-impact innovation.

At the same time, this quest for a synergy in regulatory approaches pertaining to emerging technologies and to the sustainable transition is, in practice, characterised by significant structural tensions and regulatory complexities. In addition, the very own idea that these two transitions can be seamlessly "twinned" appears, upon closer analysis, complex to be applied within a consistent operational framework: as studies occurred in the field have observed, the interplay between sustainability and digitalisation is "neither automatic nor self-evident," and the assumption that both tran-

1 Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment.

sitions can be pursued simultaneously without trade-offs remains largely to be demonstrated. Against this bedrock, it could be even defended that the quests for sustainability and technological innovation might develop in opposition, rather than synergy.

This problem arise as clear, for instance, when observing that digital technologies – while potentially enabling carbon reduction through efficiency gains, and better resource management – themselves generate substantial environmental externalities: energy consumption from data centres and computing infrastructures, electronic waste, and the material intensity of hardware production pose challenges that could be at odds with environmental objectives, as it is growingly demonstrated by research conducted in fields such as electronic vehicle mobility, or looking at data lifecycle management.

Whereas technologies can, at first sight, reduce greenhouse gas emissions or other forms of pollution, the digital infrastructure that are needed for their operationalization may actually have detrimental effects on the environment, with the cost of computational power increasing over time. Intuitively, this problem does not only arise when products are considered, by also applies to digital services: whereas tools such as smart contracts or blockchain infrastructures have been welcome as able to foster inclusion and promote social development, their impact in terms of energy consumption has been lately understood as inherently problematic.

It could be, overall observed that the twin revolution is, in the very end, "twofold": the relationship existing between the two trajectories of the sustainable and technological development is far from straightforward, its two poles are likely to operate – depending on the specific circumstances considered – synergically as well as in opposition.

These elements emerge as particularly clear when examined through the lens of financial market functioning. When looking both at the technological and at sustainable development, the role of financial markets is

often identified as critical: the sustainable transition and the digital transformation both require mobilisation of capital on a scale that exceeds the capacity of any single actor (public or private), and over significant time horizons. In addition, they both demands sustained capital expenditure across infrastructures and human capital dimensions: accordingly financial markets, operating as institutionalised mechanisms for intermediating between savers and investors across time ad space, prove themselves essential to channel the resources toward value-driven goals, while preserving allocative efficiency.

Especially in the case of sustainable development the challenge is, indeed, not merely to mobilise capital but to direct it toward those applications where it generates the greatest value beyond financial returns, to be observed in terms of better environmental impact, or technological advancement and the social welfare it fosters.

Studies on sustainable development have long demonstrated that centralised allocation mechanisms, whether through direct public investment or command-and-control regulation by sovereign entities – national or supranational – face major limitations in their effectiveness and often lead to mere formal compliance or resource dispersion. In contrast, when functioning properly, financial markets can channel capital toward sustainable technologies and business models that offer genuine value creation while, at the same time, pursuing entrepreneurial goals.

Financial markets also promote cost mitigation through risk distribution and maturity transformation. With regards to these aspects, sustainable and digital investments share a common characteristic: they typically require substantial upfront capital expenditure to generate benefits that materialise only over extended periods; this intuitively characterizes sustainable investments and with significant uncertainty that individual investors are generally ill-equipped to bear. In contrast, financial markets enable the disaggregation and redistribution of these risks across diversi-

fied portfolios and specialised risk-bearers: for instance, tools such as green bonds, sustainability-linked loans, or climate risk insurance products, all perform an essential risk transformation function. Without such mechanisms, the cost of financing the twin transition would be substantially higher, as investors should be rewarded with an appropriate compensation for bearing exposure to uncertain and long-term factors, together with the traditional market risk.

Financial markets can contribute to the twin transition also by lowering entry barriers pertaining to the two areas: both sustainable innovation and digital transformation are characterised by significant economies of scale and network effects that, absent countervailing mechanisms, would generally favour incumbents and impede competitors' entry, fostering concentration. In the long term, this could end up hindering the goals of the twin transition, as a competitive environment is generally identified as essential to prevent stagnation in sustainable and technological innovation. Hence, financial markets offset (at least in part) these structural advantages, by providing access to capital for new entrants on terms determined by expected future performance, rather than current asset base, and therefore making the market more permeable. Overt time, tools such as venture capital, growth equity, and public market financing have been instrumental in enabling clean technology startups and digital innovators to challenge established players in fields such as energy, transportation, manufacturing, and services: the democratisation of investment further extends this access, allowing smaller investors to participate in transition financing, and smaller enterprises to enter markets that would otherwise be accessible only to large corporations. This also considering that the alternative – i.e. a transition financed exclusively through retained earnings of incumbent firms or direct public subsidy – would proceed more slowly, and with a lower competitive rate.

Lastly, it should not be overlooked, that the transmission of capital

through financial markets allow to bring the technological and sustainable transition within the boundaries of a heavily regulated and supervised framework: the existence of strict monitoring and governance mechanisms, demanded to supervisory authorities both at national and supranational level, overall can enhance accountability for sustainability and technological commitments, tying it to compliance requirements and information provided through operational guidelines. In addition, the ecosystem of operators in the financial market galaxy (e.g., issuers, intermediaries, rating providers) overall promote discovery and checks, operating a disciplining function and providing incentives for responsible transition-aligned conducts.

2. Fintech and sustainable finance: convergence or regulatory dissonance?

Considering the abovementioned aspects, it is, indeed, not surprising that the "twin revolution narrative" has converged in financial markets as well, presenting the two phenomena of FinTech and Green Finance as naturally complementary phenomena and conceptualising their intersection under different labels such as "green FinTech," "sustainable FinTech" or – more recently – "GreenTech" in its financial applications. Similarly, to what has been observed for "generalist" markets, GreenTech finance defends those digital financial technologies can operate as catalysts for environmental sustainability improving the efficiency, accessibility, and transparency of sustainable investment. This joint effect can be observed, for instance, in the usage of blockchain to trace the circulation of carbon credits; in deploying Artificial Intelligence (AI) to optimize Environmental, Social and Governance (ESG) data analysis for product or to perform automated advisory services that align retail portfolios with sustainability

preferences at scale; or in using digital platforms (e.g. ones) democratise access to green investment opportunities and foster financial inclusion.

Upon a closer examination, though, it can be observed that – even in the field of financial markets – postulating a convergence between technological and sustainable development for general welfare subtends relevant regulatory and operational tensions that should be analysed in depth.

First and foremost, the notion of GreenTech relies on a functional alignment between technological innovation and environmental objectives that, as it was already mentioned, cannot simply be assumed, as financial technology, in its various manifestations, is fundamentally agnostic as to the purposes it serves: for instance, a DLT architecture that could track renewable energy certificates could equally facilitate carbon-intensive cryptocurrency mining (which, indeed, has been the main usage of such tools in practice). AI-based algorithmic trading systems that could optimise sustainable portfolio allocation can amplify short-term speculation detrimental to long-term value creation, as it was observed when analysing sudden economic shocks caused by High Frequency Trading (HFT) strategies. That same artificial intelligence able to process ESG data to ensure the quality of financial products, can be deployed to device "formally" sustainable product, fostering greenwashing opportunities rather than contrasting them.

These elements overall suggest a fundamental criticism in the twin transition narrative (in financial markets, and beyond): whereas technology is, in general terms, an enabler – and not an objective to be attained on its own – sustainable development goals are, as the name suggests, targets to be achieved. As a consequence, the first one can, at most, serve an ancillary function with regards to the attainment of the second one; this always require technological advances to be functional to sustainable development, whereas the opposite relationship – i.e., sustainable investments to promote, or at least preserve, technological development – is not always neces-

sary. In contrast with this view, the claim that FinTech inherently promotes sustainability conflates technological capability with a "prescriptive turn", which is not consistent with the neutral structure of innovation.

Notwithstanding these elements, it remains the case, that certain financial products and services now operate at the intersection of digital innovation and sustainability requirements, as they are subject to regulatory obligations arising from both domains. The examination of regulations insisting on financial products unveils both the potential synergies and the actual frictions between the two regulatory streams.

3. Examples of regulatory dissonance: robo-advisory, DLTs, and AI

Consider, for instance, the abovementioned case of robo-advisory services, to be used for creating ESG-oriented portfolio management: these tools, which employ algorithmic processes to organize investment portfolios with minimal (or even without) human intervention, have proliferated significantly in recent years, with several major operators now offering sustainability-focused investment options.

From a regulatory perspective, such services must simultaneously comply with multiple normative frameworks: the MiFID II suitability requirements, and the guidance pertaining to the use of algorithmic techniques in portfolio composition and management[2]; the disclosure obligations enlisted in the Sustainable Financial Disclosure Regulation (SFDR)[3] regarding the environmental and social characteristics of the financial products offered; the provision contained in the Taxonomy Regulation and its technical screening criteria where the products claim alignment with en-

2 Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence.

3 Regulation (EU) 2023/1114 of the European Parliament and of the Council of 31 May 2023 on markets in crypto-assets.

vironmental objectives[4]; and, where artificial intelligence is employed in the advisory process, the emerging requirements of the AI Regulation regarding AI systems used for creditworthiness assessment or investment recommendation[5].

The practical implications of this regulatory stratification are significant; in practice, a robo-advisor offering Article 8 (i.e. "light green") products under the SFDR must, collect clients' sustainability preferences expressed in relation to the Taxonomy categories technical screening criteria's thresholds; in addition, the algorithmic systems underlying these platforms must therefore be capable of processing and matching these multidimensional preferences against the sustainability characteristics of other available financial instruments and, in doing so, comply with the suitability guidelines as established by MiFID II.

Similar concerns arise when the application of distributed ledger technologies to sustainable finance instruments is considered: blockchain-based platforms have been proposed and, in some cases, implemented for green bond issuance and trading, carbon credit verification, exchange and tracking, and more in general for the development of supply-chain monitoring for financial products. The advantages of such techniques include the immutability of records – and, therefore, the ability to mitigate fraud and greenwashing risk – automated compliance verification through smart contracts; the possibility to promote fractional ownership and enhanced liquidity through tokenization, and the elimination of single points of failure through distributed architecture.

Once again, though, the regulatory treatment of these applications reveals, on the one hand, a significant disjunction between the digital finance and sustainable finance frameworks and, on the other one, require a major

4 Regulation (EU) 2024/3005 of the European Parliament and of the Council of 27 November 2024 on the transparency and integrity of Environmental, Social and Governance (ESG) rating activities.

5 Regulation (EU) 2022/2554 of the European Parliament and of the Council of 14 December 2022 on digital operational resilience for the financial sector.

effort to ensure consistency and interoperability across the various regulations considered. In addition to the abovementioned bodies of law – when tokens are considered – the Markets in Crypto-Assets Regulation (MiCAR)[6], establishes further comprehensive requirements for crypto-asset service providers and issuers of asset-referenced tokens and e-money tokens, which could come into relevance.

It should be noted, though, that MiCAR explicitly excludes from its scope financial instruments as defined under MiFID II, creating a classification challenge for tokenised green bonds or other securities that might otherwise fall within its scope. This means, for instance, that voluntary carbon credits which are not financial instruments under MiFID II might fall within MiCAR when tokenised on a distributed ledger. At the same time, though, their "environmental integrity" is governed by separate frameworks, and there is no regulatory mechanism ensuring that the digital infrastructure requirements imposed by MiCAR align with or reinforce the environmental verification requirements applicable to the underlying credits, or that the SFDR rules can apply also to products falling outside the scope of MiFID II. Overall, the two regulatory streams, in other words, tend to often operate in parallel rather than in integration.

The situation becomes even more complex still when AI applications are introduced into sustainable finance processes; for instance, the EU AI Regulation (s.c. AI Act) classifies AI systems used for creditworthiness assessment as high-risk, and subject them to stringent requirements regarding data governance, transparency, human oversight, and accuracy. While ESG rating systems are not explicitly enumerated in the AI Act's list of high-risk applications, the broader category of "AI systems intended to be used to evaluate the creditworthiness of natural persons or establish their credit score" could potentially encompass AI-driven sustainability assessments that are employed to inform lending or investment decisions. Ad-

6 See Recital 165, Artt. 59 and 95.

ditionally, the recently adopted ESG Ratings Regulation establishes (additional and separate) governance and transparency requirements for ESG rating providers; this creates another regulatory layer that must be coordinated with AI Act obligations where algorithmic systems are employed.

The situation is further complicated by the fact that the Digital Operational Resilience Act (DORA)[7] impose comprehensive ICT risk management requirements on financial entities employing high-tech solutions, including specific provisions regarding third-party risk and the externalization of activities to Third-Party Providers (TPP). This means that, if financial institutions were to rely on an external provider for, *inter alia*, the development of AI-powered systems for ESG analysis or the construction of a blockchain-based infrastructure for sustainability verification, DORA's requirements regarding contractual arrangements, concentration risk, and critical third-party oversight will add to any sustainability-related obligations, as well as to the MiFID II provisions in the case of financial products, and to the MiCAR when tokenized assets are concerned.

Financial institutions must, therefore, construct composite compliance architectures that satisfy parallel obligations; this, often without the benefit of regulatory guidance on how the various requirements should be coordinated.

4. Tech and sustainable finance regulations as sources of "additive complexity"

Once observed that, when the different regulatory framework pertaining to the "twin revolution" in finance are considered simultaneously, they to tend to overlap rather than to dynamically interact, the critical question

7 Regulation (EU) 2022/858 of the European Parliament and of the Council of 30 May 2022 on a pilot regime for market infrastructures based on distributed ledger technology.

becomes whether these overlapping actually produce mutual enrichment or, instead, generate friction, inconsistency, and compliance burden.

Indeed, the sustainable finance and digital finance regulatory streams have overall – and despite the frequent twin revolution *desiderata* – developed largely in isolation from one another, are driven by distinct policy objectives, informed by heterogeneous expert communities, and oftentimes subject to different political turmoil: the Sustainable Finance Action Plan and the Digital Finance Strategy proceeded on parallel tracks, with limited systematic consideration of how their respective implementing measures would interact.

The result is a regulatory environment characterised by what might be termed as "additive complexity": each new instrument imposes requirements that layer upon, rather than integrate with, existing obligations.

Beyond the abovementioned cases (AI, DLTs and robo-advisory), referring to specific products or services invested by both these strands of regulation, the dissonance between Green and Tech financial regulation is observable also when looking at the theoretical structures of the relevant bodies of law. For instance, the temporal frameworks of the various tech and sustainable finance regulations are misaligned. The SFDR's disclosure requirements, the MiFID II sustainability amendments, the Taxonomy Regulation's delegated acts, the AI Act's implementation phases, MiCAR's transitional provisions, and DORA's obligation all follow different schedules – generally determined by the specific development of the priorities of EU institutions regarding the two areas; this originates what could be defined as an "everlasting compliance process", where. financial institutions developing digital products with sustainability features shall often anticipate regulatory requirements that are not yet finalised, while implementing obligations that may be revised before full implementation occurs, therefore constantly revise their internal processes and techniques. This intuitively introduces major costs and hinders the dynamic develop-

ment of tech- and sustainability-oriented financial markets.

Additionally, the definitional framework employed across the various regulations is generally not consistent: for instance, the concept of "sustainability" employed in the SFDR and in the Taxonomy Regulation is wider than the notion of sustainability referenced in the AI Act, which seems to limit its scope to environmental sustainability only[8]. Where digital systems must process and integrate sustainability data from multiple sources for multiple regulatory purposes, these definitional inconsistencies translate into technical implementation challenges and heightened legal uncertainty.

Lastly, the regulatory strategies are different: the sustainable finance framework, increasingly relies on principle-based regulation, that delegates significant interpretive discretion to market participants and supervisory authorities. The digital finance framework, by contrast, tends toward more prescriptive requirements, particularly in areas such as operational resilience or cybersecurity, where technical specificity is necessary for effective oversight and standard protocol are already present in the industry. Significantly, these differences can be observed even when similar monitoring tools are used, as in the case of impact assessments. Overall, the divergent regulatory approaches complicate the task of constructing coherent compliance programmes for financial products.

The European Commission's recent proposals to simplify the frameworks involved in sustainable and tech-finance[9] acknowledges these difficulties but, at the same time, do not fundamentally address the coordination problem. Without a doubt, introducing clearer product categorisations and reducing informational complexity should facilitate financial operators to encompass the different regulatory requirements in their business pro-

8 Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data.

9 Directive (EU) 2024/1760 of the European Parliament and of the Council of 13 June 2024 on corporate sustainability due diligence.

cesses. Yet, the proposal does not systematically address how, for instance the revised sustainability framework should interact with digital finance regulations; this still mandate financial institutions to navigate the intersection without clear guidance, while delegating a heavy regulatory burden to supervisory authorities.

5. Debunking the complexity of the twin transition

In the attempt to reconcile the different aspects observed in the previous sections, it could be observed that the complexity inherent to the twin transition in finance can manifest itself in two (distinct and, yet, interrelated) dimensions.

The first is dimension is *synchronic*: at any given moment, the regulatory and normative constraints governing sustainable and digital development stem from a multiplicity of overlapping sources. Hard law, soft law, technical standards, delegated acts, and privately developed benchmarks all contribute to defining what counts as "sustainable" or "digitally compliant" conduct in financial markets. In addition, this regulatory stratification is also found within each specific strand (i.e. in bodies of law pertaining to sustainable finance or to fintech), and is particularly evident in the sustainable finance domain, where the ESG criteria – commonly mentioned as unifying framework – can be deconstructed into an articulated set of requirements: the Taxonomy Regulation, while providing a seemingly unified definition, fragments the environmental factor alone into six principal objectives, which the relevant delegated regulation further declines into more than thirty technical screening criteria. To this vertical complexity one must add the horizontal conditionality introduced by the *Do Not Significant Harm* principle, which establishes interdependencies among factors that further complicate any straightforward application of the three-pillar

ESG architecture.

Similar concerns are present in the regulations pertaining to FinTech: a crypto-asset service provider operating a trading platform for tokenised securities must simultaneously satisfy MiCAR's authorisation and conduct requirements for Crypto Asset Service Providers, MiFID II's provisions where the traded assets qualify as financial instruments, DORA's ICT risk management and incident reporting obligations, the DLT-pilot regime regulation[10] if the market infrastructure for the circulation of products is based on distributed ledgers, and satisfy the General Data Protection Regulation's requirements for any personal data processed in the course of operations. Furthermore, where the platform employs algorithmic systems, the AI Act's requirements apply, imposing data governance, transparency, and human oversight obligations that must be reconciled with the operational frameworks mandated by the other instruments. The regulatory stratification across these instruments is not merely cumulative but interactive: compliance with one framework may generate data processing activities that trigger obligations under another or impose governance structures that must be reconciled with differently conceived requirements that are found in other bodies of law.

The second dimension of complexity is *diachronic*. Sustainability, by its very conceptual structure, incorporates a temporal dimension that extends beyond immediate market transactions: the Brundtland Report's foundational reference to intergenerational equity as a defining characteristic of sustainable development (while perhaps now somewhat worn from overuse) captures an essential truth: sustainability cannot be assessed solely through the lens of present-day resource allocation but must account for future consequences that are, by definition, uncertain.

10 Directive (EU) 2024/1619 of the European Parliament and of the Council of 31 May 2024 amending Directive 2013/36/EU as regards supervisory powers, sanctions, third-country branches, and environmental, social and governance risks.

This temporal extension finds formal expression in EU financial regulation as well: the Corporate Sustainability Due Diligence Directive, for instance, explicitly requires assessment of negative impacts (environmental and on human rights) deriving from conduct throughout the production chain, evaluating both actual and potential effects. Similarly, the European Banking Authority's interpretation of ESG risk management under the Capital Requirements Directive 6 mandates that transition risk be considered across short, medium, and long-term horizons, with the latter defined as a temporal span of at least ten years. Such provisions institutionalise the diachronic dimension of sustainability, transforming it from a normative aspiration into a compliance obligation with concrete operational implications.

In contrast, it is often observed that FinTech law tends to focus on emerging technologies, and to adopt short-sighted perspective: whereas this could be, in part, justified by the fact that the industry develops at a much higher pace than regulation – as EU institutions are essentially information takers when it comes to technological understanding – the "temporal mismatch" existing by the technological and the sustainable trajectories further hinders an effective functionalization of the bodies of law pertaining to the two areas.

In addition, financial markets *per se* occupy a peculiar position within this framework of dual complexity.

Financial markets are not merely passive recipients of sustainability and digitalisation requirements, as they operate as enabling mechanisms for value creation throughout the economy: the process of financialization that has characterised contemporary markets over time that financial institutions and intermediaries exert significant influence over the allocation of resources across economic sectors.

On the one hand, this leverage is precisely what makes the financial sector a privileged site for sustainability-related intervention: by conditioning

access to capital on environmental and social performance, financial regulation can theoretically widespread sustainability requirements across the entire productive chain. The EU institutions have explicitly recognised this potential, positioning sustainable finance as a central pillar of the transition strategy and increasingly extending regulatory requirements to encompass the downstream circulation of financial products.

On the other hand, this enabling function also implies that financial markets must absorb and process the complexity described above. Furthermore, whereas the regulatory proliferation has occurred – both for FinTech and for Sustainable Finance – within an extraordinarily compressed timeframe, its full implementation is expected within roughly a decade of the Sustainable Action Plan's publication, and the concurrent development of the Capital Markets Union framework adds yet another layer of regulatory complexity that must somehow be integrated with sustainability requirements.

Overall, a paradox seems to emerge from this regulatory proliferation: while the quantity of binding norms has increased dramatically, their prescriptive character has, in many respects, diminished.

This is well exemplified by the fact that – as it was already mentioned – the EU sustainable finance framework heavily relies on principle-based regulation rather than detailed rules specifying precise conduct. It is worth noting that this regulatory strategy manifests a relevant departure from the traditional Kelsenian model of legal drafting, in which the legislator defines an abstract factual situation, attaches a legal effect, and connects this to a sanction, leaving to the interpreter the task of reconstructing the *ratio* for application to concrete cases.

In contrast, the sustainable finance framework frequently subverts this logic: it foregrounds the *ratio* or purpose of the discipline while leaving the determination of the applicable factual situation to the regulated entity or the supervisory authority. The semantic indeterminacy characterising

the positivisation of sustainable development in EU law thus requires the interpreter to concretise its scope through an operation of interpretive integration that, in the final analysis, expresses a value judgment about the meaning of sustainability in specific circumstances. Similar considerations can be made for some of the principles found in regulations pertaining to digital technologies, such as the one of human oversight.

This shift has also significant implications for the relationship between public and private actors in financial market regulation: as a result of this trend, the role of public powers shifts from the "positive-definitional moment" (i.e., the creation of the norm" toward the evaluative-supervisory one, with supervisory authorities assuming a pivotal role in clarifying the content of tech and sustainability-related obligations. With the sanctioning moment acquiring a policy dimension, administrative enforcement increasingly operates as a tool for steering market conduct toward objectives of social interest, rather than merely penalising deviation from predetermined norms. From the private actor's perspective, this introduces both greater operational flexibility but, at the same time, heightened uncertainty risk, which in turn produces higher costs on the industry. In addition, the risk arises, that principle-based regulation may end up facilitating merely formal compliance, without achieving the substantive behavioural changes that the regulatory framework purports to seek.

6. Concluding remarks

Overall, the recognition of these multiple complexities surrounding the interventions occurred in financial markets in the field of sustainable and technological regulation suggest that any serious analysis of the twin transition must move beyond both uncritical enthusiasm and dismissive scepticism: financial markets, with their capacity for rapid resource reallocation

and their influence over economic decision-making throughout the productive chain, play a fundamental role in facilitating the transition toward more sustainable economic models; this role could – or could not – imply recurring to emerging technologies to further increase the impact and the effectiveness of sustainability-oriented solution. However, this goal cannot be attained if the relevant regulatory frameworks that assume away complexity, or that do not properly consider the interaction amongst the two areas: the internalisation of externalities associated with both environmental degradation and digital transformation requires a more sophisticated and coordinated approach.

Ignoring this aspect has profound implications for market participants: rather than benefiting from regulatory synergies that might reduce compliance costs while enhancing both digital resilience and sustainability performance, in the current framework financial institutions are generally exposed to cumulative obligations, that must be satisfied independently, and overall the promise that digitalisation would facilitate sustainability compliance by enabling more efficient data processing and automated verification remains largely unrealized at the regulatory level. From a normative perspective, the existing regulatory fragmentation represents, without a doubt, a missed opportunity.

The "twin transition" will effectively operate as a welfare-enhancing narrative only when translated in integrated policy responses, able address digital and sustainable development in a coordinated fashion. In contrast, the actual regulatory landscape falls considerably short of this ambition: the current regulatory landscape emerges instead as a patchwork of sector-specific and objective-specific regulations, that uncertainly interact and impose significant transaction costs on actors seeking to operate at their intersection.

Whether future regulatory developments will move toward greater coherence or whether the current fragmentation will solidify into a perma-

nent feature of the European financial regulatory architecture remains to be seen. What is clear, is that the rhetoric of synergy between the twin transition in financial markets significantly overstates the degree of actual regulatory integration achieved to date.

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