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FINANCIAL INNOVATION AND SUSTAINABLE ECONOMIC DEVELOPMENT IN DEVELOPED ECONOMIES: THE INTERPLAY OF FINANCE, TECHNOLOGY, AND RENEWABLE TRANSITIONS

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Abstract

In developed economies, financial innovation has transformed from just a tool for efficiency and market growth into a key player in driving sustainable economic development (SED). This paper takes a closer look at how financial innovation, financial development, renewable energy consumption, and information and communication technology (ICT) work together to influence sustainable growth in OECD and G7 countries. By employing a dynamic panel model estimated through the two-step system Generalized Method of Moments (GMM), the study analyzes data from 28 developed nations over the period from 2000 to 2024. The findings reveal that financial innovation and development are crucial indicators of sustainable economic advancement. Additionally, renewable energy consumption and ICT serve as supportive elements, enhancing the sustainability effects of financial innovation by fostering efficiency, optimizing resources, and reducing carbon emissions. Socioeconomic factors like trade openness, foreign direct investment (FDI), and demographic structure also play a significant role in shaping the sustainability paths of nations. The results indicate that achieving SED in developed countries isn't just about technological progress; it's about implementing integrated policies that connect finance, innovation, and environmental governance. The paper wraps up with practical recommendations for policymakers, highlighting the importance of regulatory alignment, green financial ecosystems, and inclusive digital transitions as vital components for long-term sustainability.

INTRODUCTION

1.1 Background and Context

The global economy is currently experiencing a significant shift towards sustainability, driven by the need to balance economic competitiveness with environmental protection. In this scenario, developed economies especially those in the Organization for Economic Co-operation and Development (OECD) and the Group of Seven (G7) are crucial in shaping the financial, technological, and policy frameworks that support sustainable growth. Over the last twenty years, the conversation around integrating financial innovation into sustainability has really picked up speed, thanks to digital advancements, climate commitments, and the emergence of the green economy (OECD, 2023). Financial innovation involves creating, adopting, and

spreading new financial tools, technologies, and organizational structures that enhance how we manage finances and allocate resources (Liu et al., 2021). In developed markets, this includes things like digital finance, fintech platforms, blockchain systems, green bonds, carbon-credit markets, and sustainability-linked investment options. These innovations not only make markets more efficient but also play a role in reducing carbon emissions and promoting inclusive growth (Chen & Volz, 2023). At the same time, financial development the expansion and diversification of financial markets and institutions provides the essential groundwork for sustaining innovation. When financial systems are well-established and transparent, they can effectively channel capital into long-term sustainable investments (Beck et al., 2020). Since the Paris Agreement, developed countries have increasingly aligned their financial sectors with environmental goals, incorporating climate risk into regulations and launching green finance initiatives through central banks and market institutions. Alongside these financial trends, technological advancements have become a key factor in driving sustainability. Information and communication technology (ICT) infrastructure enhances energy efficiency, promotes data transparency, and supports circular economy models. Additionally, the rapid expansion of renewable energy sources is playing a vital role in this transition.

In tandem with these financial trends, technological advancements have become a key player in driving sustainability. The infrastructure of information and communication technology (ICT) plays a vital role in enhancing energy efficiency, ensuring data transparency, and supporting circular-economy models. The impressive rise in renewable energy consumption (REC) notably in regions like Europe, Japan, and Canada illustrates how the fusion of technological adaptation, innovation incentives, and finance-driven policies can help meet both environmental and economic objectives (IEA, 2024). Yet, even with significant strides made, challenges remain. Developed nations grapple with structural trade-offs involving energy security, digital transformation, and economic competitiveness. According to the International Monetary Fund (2024), while investment in renewable energy among G7 countries surged by 45% from 2015 to 2023, global emissions reductions still fall short of the targets set by the Paris Agreement. Additionally, the gap in technological access within advanced economies between bustling urban innovation centers and more remote areas creates hurdles for achieving inclusive sustainability. In light of these challenges, this study takes a fresh look at how financial innovation can foster sustainable economic development in developed countries. It does this by weaving together financial, technological, and environmental factors into a cohesive analytical framework, tackling three essential research questions:

1. Does financial innovation play a significant role in promoting sustainable economic development in developed economies?
2. How do renewable energy and ICT amplify the effects of financial innovation on sustainability outcomes?
3. What influence do financial development and socioeconomic structures have in shaping these relationships?

1.2 Rationale of the Study

The motivation behind this study stems from the ever-evolving relationship between finance and sustainability. In the past, traditional macroeconomic models tended to treat financial and environmental goals as separate entities. However, in today's world, especially in the 21st century, financial innovation and sustainability are closely linked. We now see green finance mechanisms, digital assets, and sustainable investment technologies forming the backbone of the low-carbon transition (Afonso & Blanco-Arana, 2022). While earlier research has looked into these connections in developing countries, there's been relatively little focus on how innovation plays out in already-developed economies, where financial systems are well-established but still face sustainability challenges. Developed nations are now grappling with what's being called the "second-generation" sustainability challenge shifting from mere environmental compliance to fostering sustainability through structural innovation (Gomber et al., 2023). This transition calls for not just policy tools but also innovative market solutions. This paper aims to

bridge that gap by utilizing a dynamic-panel GMM framework to assess the causal impacts of financial innovation, financial development, renewable energy usage, and advancements in ICT on sustainable economic growth across OECD countries from 2000 to 2024.

1.3 Contribution of the Study

This research makes several important contributions to the existing literature:

1. Conceptual Contribution: It shifts the perspective on financial innovation, viewing it as a driver of sustainability rather than just a tool for financial efficiency.
2. Empirical Contribution: By employing a system GMM estimator, it tackles the issue of endogeneity, providing strong, causally interpretable results across developed nations.
3. Policy Contribution: It offers practical policy recommendations for G7 and OECD countries aiming to weave financial innovation, digital transformation, and green investment strategies into their national sustainability agendas.

1.4 Structure of the Paper

The rest of this paper is organized as follows: Section 2 reviews the theoretical and empirical literature that connects financial innovation, financial development, renewable energy, and ICT with sustainable growth. Section 3 outlines the data, model, and methodology used. Section 4 shares empirical findings and discussion. Section 5 wraps up with policy implications, while Section 6 lists references and supporting data tables.

2. Review of the Empirical Studies

2.1 Conceptual Foundation of Financial Innovation

The link between innovation and development traces back to Schumpeter's (1934) theory of economic development, which suggests that innovation drives structural change. In the financial sector, we see innovation through new tools (like green bonds), institutions (such as digital banks), and technologies (including blockchain), all of which boost efficiency and inclusivity (Laeven et al., 2015). In developed nations, financial innovation thrives in a well-established institutional framework, yet its potential for transformation is still significant. The rise of sustainable fintech, climate finance, and green digital assets showcases a new approach where finance not only supports but actively guides sustainable transitions (OECD, 2023). By enabling precise risk pricing, lowering transaction costs, and broadening access to eco-friendly finance, financial innovation plays a crucial role in fostering sustainable growth (Bocken et al., 2021). Additionally, the digitalization of finance has intensified these impacts. Mobile banking, open data APIs, and blockchain verification systems have reshaped capital flows. These technologies not only enhance investment efficiency but also promote accountability and transparency, which are vital for environmental governance. In this context, financial innovation acts as both a technological driver and a governance tool. Research conducted after 2015 backs up these assertions. Studies by Liu et al. (2021) and Chen & Volz (2023) indicate that OECD countries with higher levels of financial innovation make more significant strides toward decarbonization and environmental efficiency. However, these advantages hinge on how regulations are structured unregulated innovation can also heighten financial instability, as seen during the 2008 global financial crisis (Laeven et al., 2015). Therefore, a well-balanced innovation ecosystem one that merges flexibility with regulatory oversight is crucial for financial innovation to make a sustainable impact on economic growth.

2.2 Financial Development as a Structural Enabler

Financial development plays a crucial role in fostering innovation by ensuring that we have the right institutions and a robust capital market to support sustainable investment flows. Levine (2005) explains that financial development is all about how financial intermediaries gather savings, allocate capital wisely, and manage risks effectively. In more developed economies, financial development impacts sustainability through four key mechanisms:

1. Capital Mobilization: Well-established financial markets help reduce borrowing costs for green infrastructure projects (Beck et al., 2020).
2. Risk Diversification: Tools like derivatives and insurance help investors navigate climate and transition risks.

3. Corporate Governance: Established financial institutions promote accountability in environmental, social, and governance (ESG) practices.
4. Innovation Diffusion: Advanced capital markets facilitate the spread of sustainable technologies (Nguyen et al., 2021).

Both the European Central Bank (2023) and the Bank of England (2022) have started to weave sustainability into their financial oversight, marking a shift in financial development from being just an economic concern to becoming part of an eco-financial system. Research, such as that by Paun et al. (2019), shows that when high financial development is paired with strong institutions and green incentives, it leads to better environmental outcomes. In essence, financial development serves as the structural foundation for putting financial innovation into action. The relationship between financial development and financial innovation creates a beneficial cycle: as innovation advances, it deepens development, and in turn, that development paves the way for further innovation.

2.3 Renewable Energy Consumption and Sustainability

Renewable energy consumption (REC) is a key player in both the tech and policy aspects of sustainable growth. In more developed countries, REC signifies a shift away from fossil fuels and towards cleaner, low-carbon energy sources like wind, solar, hydro, and bioenergy. Research has consistently shown a strong connection between REC and sustainable economic development (SED). For instance, Bhuiyan et al. (2021) discovered a two-way causal link between the use of renewable energy and GDP growth in OECD nations. Similarly, Güney (2020) pointed out that a 1% rise in renewable energy consumption can lead to a 0.3% increase in long-term sustainable output. Financial innovation also plays a significant, albeit indirect, role in this area. The green bond market, which is projected to exceed $2 trillion globally by 2024 (Climate Bonds Initiative, 2024), directs private investments into renewable projects. Additionally, financial tools like carbon futures and energy certificates help mitigate investor risks and encourage participation in green markets. However, the advantages of renewable energy are heavily reliant on supportive regulatory frameworks. Without consistent policy signals, investments in renewable energy can experience what's known as "green volatility" (Zhang et al., 2022). Thus, the interplay between policy stability, financial innovation, and energy technology is crucial for the success of sustainability transitions in developed economies.

2.4 ICT Development and Sustainability Synergy

The impact of information and communication technology (ICT) on sustainability is quite complex. It boosts productivity, helps optimize resources, and promotes digital inclusivity. In wealthier countries, innovations driven by ICT lower transaction costs, enhance energy efficiency, and provide valuable data for monitoring the environment (Raghupathi & Raghupathi, 2021). Moreover, ICT plays a crucial role in financial innovation: think digital payment systems, AI-powered investment analytics, and decentralized finance (DeFi) platforms, all of which rely on a strong ICT backbone. As noted by Habibi & Zabardast (2020), ICT greatly enhances environmental performance in high-income nations by enabling smart cities, e-governance, and green logistics. However, the benefits of ICT come with their own set of challenges. The energy demands of data centers and blockchain activities raise important sustainability issues. Ulucak & Khan (2020) caution that if we don't power our data infrastructure with renewable energy, the growth of ICT could negate its environmental benefits. To address this, developed countries are increasingly pouring resources into green ICT initiatives, such as using AI to optimize energy systems and investing in renewable-powered cloud computing (European Commission, 2023). In summary, ICT serves as both a facilitator and a litmus test for sustainability governance in our digital economies.

2.5 Socioeconomic and Institutional Variables

When we look beyond just the tech and financial aspects, we see that socioeconomic factors play a big role in sustainability outcomes. For instance, being open to trade helps spread clean technologies, and foreign direct investment (FDI) brings in both technology and capital that supports sustainable industries (Essandoh et al., 2020). On the flip side, reliance on natural resource rents can actually stifle

diversification and innovation (Mert et al., 2020). Plus, in advanced economies, an aging population can slow down workforce dynamism, but this can be countered with automation and green innovation (Chapman & Shigetomi, 2018). The quality of institutions and governance also significantly impacts these results. Countries that have robust environmental regulations, transparent financial systems, and stable political institutions tend to perform better in terms of sustainability (Stern, 2017). These connections lay the groundwork for this study's empirical model, which looks at how financial, technological, and socioeconomic factors come together to foster sustainable development in developed economies.

3. Empirical Methodology

3.1 Empirical Research Design

This study takes a deep dive into the intricate relationship between financial innovation, financial development, renewable energy consumption, information and communication technology (ICT), and sustainable economic development (SED) in developed countries, using a quantitative, longitudinal panel research design. The analytical framework weaves together financial, technological, and environmental aspects to better understand the complex interactions that drive sustainability in high-income nations. Our empirical analysis spans 28 OECD countries from 2000 to 2024, a period marked by significant sustainability milestones like the Kyoto Protocol, the Paris Agreement, and the post-COVID recovery phase that emphasizes green transitions. To tackle the challenges of endogeneity, autocorrelation, and unobserved heterogeneity that often pop up in macroeconomic panel studies, we employ the two-step system Generalized Method of Moments (GMM) estimator (Arellano & Bover, 1995; Blundell & Bond, 1998). Choosing GMM makes perfect sense here, as it allows us to include lagged dependent variables and endogenous regressors both essential for analyzing the long-term impacts of financial innovation on sustainability. Unlike static models such as Fixed Effects or Random Effects, dynamic GMM models capture feedback mechanisms and persistence effects, reflecting the reality that sustainability outcomes develop over time.

3.2 Conceptual Framework Construction and Model Specification

Building on Schumpeter's innovation theory from 1934, along with the endogenous growth theories proposed by Romer in 1986 and Lucas in 1988, as well as various environmental governance frameworks, this model presents SED as influenced by a mix of financial, technological, and institutional elements. It suggests that factors like financial investment (FI), financial development (FD), renewable energy consumption (REC), and information and communication technology (ICT) have a positive impact on SED. However, it also points out that issues like resource dependence and an aging population could have negative repercussions.

$$SED_{it} = f(FI_{it}, FD_{it}, REC_{it}, ICT_{it}, SOCIO_{it})$$

The empirical model is specified as:

$$SED_{it} = \alpha_0 + \alpha_1 FI_{it} + \alpha_2 FD_{it} + \alpha_3 REC_{it} + \alpha_4 ICT_{it} + \alpha_5 SOCIO_{it} + \mu_i + \varepsilon_{it}$$

Where:

- SED_{it}: Sustainable Economic Development Index (proxy for adjusted GDP, environmental performance, and human development)
- FI_{it}: Financial innovation index (fintech usage, digital payment adoption, green financial instruments)
- FD_{it}: Financial development indicator (private credit, stock market capitalization, financial inclusion)
- REC_{it}: Renewable energy consumption (% of total energy use)
- ICT_{it}: ICT development index (internet penetration, broadband density, ICT infrastructure quality)
- $SOCIO_{it}$: Socioeconomic and structural controls (trade openness, FDI inflows, natural resource rents, aging dependency ratio)
- μ_i: Country-specific effects (unobserved heterogeneity)
- ε_{it}: Error term

The model hypothesizes that FI, FD, REC, and ICT positively influence SED, while resource dependence and aging demographics may exert negative effects.

3.3 Variable Construction

Dependent Variable

Sustainable Economic Development (SED): We measure SED using a composite index that looks at three key areas: economic growth (specifically, real GDP per capita growth), environmental impact (like reducing carbon intensity), and social factors (which we gauge through adjustments to the Human Development Index). To make sure we can compare data across different countries, we normalize it using z-scores (World Bank, 2024; UNDP, 2023).

Independent Variables

1. Financial Innovation (FI): This is a composite index that takes into account the fintech adoption rate, the number of green bonds issued, and R&D spending in the financial sector. We pull this data from the OECD (2023) and IMF (2023).
2. Financial Development (FD): We measure this through domestic credit to the private sector as a percentage of GDP, stock market capitalization as a percentage of GDP, and various bank efficiency indicators.
3. Renewable Energy Consumption (REC): This looks at the share of renewable energy in total final energy consumption, expressed as a percentage. The data comes from the IEA (2024).
4. Information and Communication Technology (ICT): We create an ICT development index using metrics from the ITU, which includes the number of internet users per 100 inhabitants, broadband subscriptions, and ICT exports.
5. Socioeconomic Variables (SOCIO): This category includes trade openness as a percentage of GDP, FDI inflows as a percentage of GDP, natural resource rents as a percentage of GDP, and the aging dependency ratio, which is the population aged 65 and over divided by the working-age population.

3.4 Data Sources and Variables Categories

Variable	Source	Indicator Type
Sustainable Economic Development	World Bank (WDI, 2024)	Dependent
Financial Innovation	OECD (2023), IMF Financial Access Survey	Independent
Financial Development	World Bank Global Financial Development Database (GFDD)	Independent
Renewable Energy Consumption	IEA Energy Statistics (2024)	Independent
ICT Index	ITU World Telecommunication Database (2023)	Independent
Trade Openness, FDI, Natural Resources, Demographics	WDI (2024), UNCTAD (2023)	Controls

To make sure our data is more stable and easier to work with, we convert all variables into natural logarithms. This helps to even out any skewed distributions.

3.5 Estimation Strategy

In this approach, we use a two-step system GMM method that relies on lagged values of our endogenous regressors as internal instruments. This helps us tackle the simultaneity bias that can arise between financial variables and sustainability outcomes. Here's how it works: Transformation: We start by applying first-difference to get rid of fixed effects (μ_i). Instrumentation: Next, we use lagged values of FI, FD, REC, and ICT as our valid instruments. Estimation: We then implement the two-step GMM method, incorporating the Windmeijer (2005) correction to address any finite-sample bias. Validation: Finally, we perform Hansen and Sargan tests to check the validity of our instruments, along with Arellano–Bond tests to assess serial correlation.

3.6 Hypotheses Development

H1: Financial innovation has a positive impact on sustainable economic development.

H2: Financial development plays a beneficial role in promoting sustainable economic growth.
H3: The use of renewable energy contributes to sustainable economic development.
H4: Advancements in ICT support sustainable economic development.
H5: Socioeconomic factors significantly influence the relationship between financial innovation and sustainability.

Results and Discussion

Table 1. Descriptive Statistics (2000–2024, OECD Countries)

Variable	Mean	Std. Dev.	Min	Max	Observations
Sustainable Economic Development Index (SED)	6.84	0.52	5.21	7.92	700
Financial Innovation (FI)	4.67	0.81	3.01	6.12	700
Financial Development (FD)	7.32	0.63	5.98	8.42	700
Renewable Energy Consumption (REC, %)	36.25	9.84	15.2	63.9	700
ICT Index	8.04	0.72	6.45	9.25	700
Trade Openness (TO, % of GDP)	118.7	42.5	45.3	235.9	700
FDI Inflows (% of GDP)	3.85	2.41	0.21	9.66	700
Natural Resource Rents (% of GDP)	1.98	1.13	0.15	5.82	700
Aging Dependency Ratio	30.5	5.2	21.3	41.9	700

The descriptive statistics presented in Table 1 show that developed economies are quite advanced in terms of financial sophistication, renewable energy use, and ICT development. The average SED index score of 6.84 indicates ongoing progress towards achieving a balance between economic growth and environmental sustainability. Countries in the Nordic and Western European regions are leading the way in integrating renewable energy and ICT, while North American economies are at the forefront of financial innovation. The standard deviations suggest that there's not much variability, pointing to a trend of structural convergence among these developed nations. However, the differences in policy ambitions and industrial structures help explain the regional disparities we observe.

Table 2. Correlation Matrix

Variables	SED	FI	FD	REC	ICT	TO	FDI	NRR	ADR
SED	1								
FI	0.72	1							
FD	0.68	0.61	1						
REC	0.64	0.45	0.49	1					
ICT	0.69	0.74	0.66	0.53	1				
TO	0.47	0.38	0.51	0.36	0.45	1			
FDI	0.55	0.48	0.52	0.42	0.46	0.57	1		
NRR	−0.31	−0.22	−0.25	−0.29	−0.20	−0.17	−0.18	1	
ADR	−0.27	−0.19	−0.21	−0.18	−0.16	−0.14	−0.12	0.11	1

All correlations significant at $p < 0.05$.

Looking at the correlation matrix in Table 2, we can see strong positive relationships among Financial Innovation (FI), Financial Development (FD), Renewable Energy Consumption (REC), and ICT. Notably, there's a solid correlation between FI and SED ($r = 0.72$). On the flip side, the negative

correlation between SED and natural resource rents (r = −0.31) highlights the ongoing issue of the "resource curse," which still affects advanced economies like Australia and Canada. The multicollinearity tests show VIF values below 3, indicating that our model is sound.

Table 3. Two-Step System GMM Estimation Results

Variable	Coefficient (β)	Std. Error	z-Statistic	p-Value	Expected Sign
Financial Innovation (FI)	0.278***	0.054	5.15	0	+
Financial Development (FD)	0.193**	0.078	2.47	0.014	+
Renewable Energy Consumption (REC)	0.315***	0.061	5.16	0	+
ICT Index	0.221**	0.092	2.4	0.017	+
Trade Openness (TO)	0.102**	0.044	2.32	0.021	+
FDI Inflows (FDI)	0.086*	0.048	1.79	0.074	+
Natural Resource Rents (NRR)	−0.118*	0.067	−1.76	0.079	−
Aging Dependency Ratio (ADR)	−0.063	0.041	−1.54	0.123	−
Constant	0.925***	0.215	4.3	0	

*Notes: ***p < 0.01, **p < 0.05, p < 0.10

GMM Estimation Results The two-step system GMM results in Table 3 supporting all the key hypotheses.

• Financial Innovation (FI): This shows a positive and significant impact (β = 0.278, p < 0.01), confirming that financial innovation plays a crucial role in driving sustainable development by promoting efficient resource allocation and fostering green capital formation.

• Financial Development (FD): Also, positive and significant (β = 0.193, p < 0.05), indicating that mature markets improve access to sustainable finance.

Renewable Energy Consumption (REC): This is strongly significant (β = 0.315, p < 0.01), meaning that a 1% increase in REC leads to a 0.3% enhancement in SED.

• ICT Development (ICT): This shows a significant effect (β = 0.221, p < 0.05), suggesting that robust ICT infrastructure encourages green innovation and boosts energy efficiency.

• Socioeconomic Controls: Trade openness (β = 0.102, p < 0.05) and Foreign Direct Investment

Table 4. Diagnostic and Robustness Tests

Test	Statistic	p-Value	Interpretation
Arellano–Bond AR(1)	−3.61	0.000	First-order correlation present (expected)
Arellano–Bond AR(2)	−1.12	0.261	No second-order correlation
Hansen J-Test	23.47	0.317	Instruments valid
Sargan Test	19.86	0.275	No over-identification bias
Wald χ^2	142.5	0.000	Model jointly significant
Number of Instruments	32		Within acceptable range

*All tests confirm robustness of GMM estimates

Diagnostic tests results provided in table 4 have confirmed that our model is robust:

The AR (1) term is significant, while the AR (2) term is not, indicating there's no serial correlation.

• The Hansen J statistics (p = 0.317) confirms the validity of our instruments.
• The Wald χ^2 test shows overall model significance with a p-value of less than 0.001.

4.4 Discussion of Empirical Findings

Financial Innovation as the Engine of Sustainability The findings highlight that financial innovation plays a crucial role in driving sustainable development, especially in developed countries. Tools like green bonds, ESG funds, and carbon-credit derivatives help steer investments toward low-carbon industries. Additionally, fintech platforms are making sustainable investment options more accessible, allowing more households and small to medium-sized enterprises (SMEs) to get involved. These insights align with the work of Liu et al. (2021), who found that financial innovation in OECD countries significantly aids in reducing emissions and boosting productivity. This is evident in initiatives such as the EU Green Deal Investment Plan and Japan's Green Transformation Bonds.

Financial Development and Institutional Resilience Financial development enhances sustainability by creating stable investment climates and reducing risk premiums. In countries with well-regulated financial systems, like the Netherlands and Germany, innovation spreads effectively throughout the markets. However, too much deregulation can lead to speculative risks, reminding us of the lessons learned before the 2008 financial crisis. Therefore, the quality of institutions plays a key role in the relationship between financial innovation and sustainable economic development (Nguyen et al., 2021).

Renewable Energy and Economic Transformation The use of renewable energy stands out as the most significant factor contributing to sustainable economic development. The shift towards renewable energy has led to a reduction in the carbon intensity of GDP by more than 25% across OECD countries (IEA, 2024). Financial innovation supports this transition by providing risk-mitigation tools and crowd-funding options for renewable startups.

ICT as a Cross-Sector Catalyst The substantial impact of information and communication technology (ICT) highlights the need for digital sustainability. Innovations like artificial intelligence, blockchain verification, and IoT-based energy systems enhance both transparency and efficiency (Habibi & Zabardast, 2020). However, it's essential to manage the energy demands of data infrastructure through green computing and the integration of renewable energy sources.

Socioeconomic and Structural Moderators Trade openness and foreign direct investment (FDI) play a crucial role in boosting sustainable economic development (SED) by enabling the flow of international knowledge. However, challenges like an aging population and reliance on specific resources can create long-term hurdles. To counter these issues, we can look to automation, training in digital skills, and initiatives focused on a circular economy.

Regional Perspectives When we take a closer look at different regions, we see a variety of trends:

• Europe: Striking a balance between innovation and environmental goals, thanks to the EU's green taxonomy and digital market strategies.
• North America: While innovation is thriving, the shift to renewable energy is slow, largely due to the lingering influence of fossil fuels.
• Asia-Pacific: Leading the way in information and communication technology (ICT) with countries like Japan and South Korea but still catching up on integrating green finance. These insights highlight that the path to sustainability in developed nations is not one-size-fits-all; it's shaped by each region's unique history and the consistency of its policies.

5. Conclusion and Policy Implications

5.1 Summary of Key Findings

This study delved into the intricate relationships among financial innovation, financial development, renewable energy consumption, ICT advancement, and sustainable economic development (SED) in developed countries. By analyzing dynamic panel data from 28 OECD nations between 2000 and 2024 and utilizing a two-step system Generalized Method of Moments (GMM) estimator, the findings strongly suggest that financial systems driven by innovation are crucial for achieving long-term sustainability. The results indicate that financial innovation plays a significant role in boosting sustainable development by enhancing the efficiency of capital allocation and attracting private investment into low-carbon sectors. Financial development

works hand in hand with innovation by broadening credit access, lowering investment costs, and promoting regulatory stability. Additionally, renewable energy consumption (REC) and advancements in ICT contribute to sustainability by encouraging technological modernization, improving energy efficiency, and fostering productivity growth. The evidence also points to the important roles of trade openness and foreign direct investment (FDI) in speeding up the spread of clean technologies. On the flip side, reliance on natural resources and an aging population have slight negative impacts, highlighting some structural challenges in certain developed economies. Overall, this study illustrates that sustainable economic development in advanced nations isn't just a standalone policy area; it's a complex system that intertwines financial innovation, technological advancement, and effective governance.

5.2 Theoretical Implications

The findings add to the existing literature by broadening Schumpeterian innovation theory to include sustainability. Financial innovation serves as a powerful engine for growth, aligning with endogenous growth models (Romer, 1986; Lucas, 1988), where the accumulation of knowledge and advancements in technology fuel long-term output. Additionally, the results support the Environmental Kuznets Curve (EKC) hypothesis, suggesting that as income and innovation increase, environmental degradation tends to decrease after reaching a certain point.

5.3 Policy Implications

1. Integrate Innovation with Sustainability Frameworks: Developed economies need to formalize how financial innovation fits into sustainability governance. National innovation agencies, central banks, and financial regulators should work together to align fintech and green finance policies within cohesive frameworks.
2. Develop Green Financial Infrastructure: Governments should encourage the issuance of green and sustainability-linked bonds, enhance carbon-trading platforms, and motivate financial institutions to direct credit towards renewable and low-carbon sectors.
3. Digital Transformation for Green Growth: ICT policies should focus on building green digital infrastructure like renewable-powered data centers and energy-efficient AI to ensure that digitalization promotes sustainability rather than detracts from it.
4. Regulatory Coordination and Risk Management: Post-crisis caution should go hand in hand with innovation. Regulators need to implement climate-related financial disclosures (TCFD), conduct environmental stress tests, and establish green accounting standards to maintain stability while encouraging innovation.
5. International Collaboration: OECD and G7 countries should enhance cross-border cooperation in climate finance, standardize green-bond taxonomies, and expand collaborative research initiatives for low-carbon technologies.
6. Tackle Structural Challenges: As our populations age and we rely more on certain resources, it's crucial to implement policies that promote automation, retraining initiatives, and circular-economy practices. These strategies will help maintain productivity in societies with older demographics.
7. Boosting Private Sector Innovation: We should expand public-private partnerships to enhance venture capital investments in green startups and fintech innovations that prioritize environmental sustainability metrics.

5.4 Future Research Directions

Looking ahead, future research should broaden its scope to examine the connections between developing and developed nations, particularly how technology transfer and financial globalization impact sustainability on a global scale. Additionally, incorporating artificial intelligence, digital currencies, and decentralized finance (DeFi) into sustainability strategies presents a promising avenue for ongoing exploration.

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