The Importance of Sustainable Supply Chain Financing from a Corporate Perspective

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Abstract. In an increasingly complex and unpredictable world, sustainable supply chain finance (SSCF) is important for organizational capability and performance. In this study we look at the role of SSCF for the return on investment (ROI) at the firm level and integrate digitalization, macroeconomic stochastic trends, and supply chain dynamics. We used a simulated panel data set incorporating advanced econometrics techniques including Markov-Switching regression model designs to produce findings that showed complex variation in the role of both financial and operational conditions in different economic states. The key findings show that, outcomes based on the findings indicate digital supply chain finance, as well as profit will contribute to ROI, based on macroeconomic certainty (stable), while inflation and complexity will be mitigated in uncertain times. The findings will be useful for corporate managers and policy-makers whose goal is financing sustainable, resilient supply chain entities.

Keywords: Sustainable supply chain finance; corporate performance; digitalization; Markov-Switching model; supply chain complexity; inflation; macroeconomic regimes

1 Introduction

Today, in an ever-connected world and a growing environmental awareness, sustainable supply chain financing (SSCF) has established itself as a strategic representative of the finance function to better financial performance and long-term sustainability. Since a push for responsible businesses practices has impacted stakeholders, firms are embedding sustainability in their financial decision-making and operations. SSCF can facilitate ESG commitments, supplier relationship improvements, and operational efficiencies in a firm. SSCF attempts to align the flow of finance with sustainability as it relates to practices in organizations such as ethical

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sourcing, low-carbon supply chains, etc.. Furthermore, it offers firms the ability to manage risk while creating value.

Sustainable Supply Chain Finance (SSCF) has the potential to be a strategic tool that can increase financial performance while promoting environmental and social objectives. It combines elements of financial practice with sustainability, improving liquidity, risk management and stakeholder engagement [1, 2]. Empirical research shows SSCF can create long-term value through responsible sourcing, ethical procurement and more nuanced supplier relationships [3, 4].

Digitalization is also appearing as a key enabler for SSCF because it provides improved transparency and operational efficiencies. When organizations identify and implement technologies, such as blockchain, AI and digital platforms that enhance data availability, data sharing in real time, data traceability and that reduce costs, there is a corresponding change in the return on investment (ROI) [5, 6]. Digital technologies are increasingly important in managing complex global supply chains [7].

Macroeconomic variables, such as inflation, have also been identified as playing an implicit role in SSCF outcomes. For example, high inflation can raise input costs for goods and services and shrink margins [8]. GDP growth can create a positive economic environment and could, subsequently, produce higher returns in businesses as compared to contractions [9]. Complexity, when managed for resilience, can become a competitive advantage enabling adaptability within the supply chain [10].

While SSCF is becoming more prevalent as investors and policymakers focus on more sustainable practices, research still lags behind in critically engaging with SSCF, particularly its impact in terms of financial benefits to organizations, under various economic conditions. This study provides an opportunity to start to address this gap using a Markov-Switching model to understand how SSCF drivers impact ROI in various economic regimes.

2 Methods

2.1 Data and Variables

The analysis is based on a panel of time series data from 1991–2024 that includes simulated firm-level and macro data relevant to SSCF. The dependent variable is the Return on Investment (ROI) in log (logROI) form. The exploratory variables include:

log_Digitalization_Level_SCFinance – A proxy for digital finance infrastructure in the supply chain
log_Inflation_Rate – Capturing the instability of prices in the macroeconomy
log_GDP_Growth – Economic growth
log_Net_Income_Companies – Corporate profitability
Supply_Chain_Complexity – A categorical variable measuring logistical and operational complexities in supply chains

Continuous variables were log transformed, where relevant, to normalize distributions to better interpret estimated coefficients in elasticity terms.

2.2 Model Specification

In order to model structural changes over time, the study utilizes a Markov-Switching regression model that allows for regime shifts in both the intercept and the regression coefficients. This is particularly suited to account for time-varying effectiveness of SSCF when macroeconomic or corporate conditions differ (e.g., financial crisis versus stable growth periods).

The general specification of the MS model is:

$$logROI_t = \alpha_{S_t} + \beta_{1,S_t} \log\left(\text{Digitalization}_{\text{Level}_{\text{SCFinancet}_t}}\right) + \beta_{2,S_t} \log\left(\text{Inflation}_{\text{Rate}_t}\right) + \beta_{3,S_t} \log\left(\text{GDP}_{\text{Growth}_t}\right) + \beta_{4,S_t} \log\left(\text{Net}_{\text{Income}_{\text{Companies}_t}}\right) + \beta_{5,S_t} \text{Supply_Chain_Complexity}_t + \epsilon_t \quad (1)$$

Where:

$S_t \in \{1,2\}$ is unobserved regime (e.g., low-growth vs. high-growth period) following a first-order Markow process
α_{S_t} and β_{k,S_t} are regime-specific intercepts and coefficients
ϵ_t is error term

Estimation and Diagnostics. The model will be estimated using the MSwM package in R using maximum likelihood estimation. Regime transition probabilities P(St|St−1) will be estimated with the coefficients. Key diagnostics include:

Log-likelihood and AIC/BIC measures of model fit
Smoothed regime probabilities to understand changes over time
Significance levels for all coefficients conditional on the different regimes
Residual plots and the standardized errors for understood goodness-of-fit

2.3 Rationale for Using Model

The Markov-Switching framework is preferred because we suspect that the association between SSCF indicators and ROI is not constant over time but changes across economic or operational conditions. For instance, while digitalization may raise ROI during a 'normal' period, that effect may weaken, or even become negative, during inflationary shocks periods. Similarly, all of the SSCF indicators positively increase ROI but that may shift to a negative effect depending on the regime.

This approach builds upon a broader body of empirical work that has applied advanced econometric techniques to related financial and economic phenomena. A group of scientists have effectively used ARIMA models, VAR models, SEM models, LS models, and other models in their scientific work on issues of bank transformation, digitalization of retail banking services, currency risk, risk management, econometric analysis of population deposits and factors affecting them, and various forecasts [11, 12, 13, 14, 15]. Another group of scientists conducted their research on energy risk assessment, green hydrogen expansion, energy diversification, renewable energy development, financial stress and energy-related factors, effectively using Linear

regression, Polynomial regression, Fixed effects, Functional-coefficient models, Globalization, Linear functional, Linear functionals, Quantile regression, spatiotemporal analysis models and analysis methods [16, 17, 18, 19, 20, 21, 22].

3 Results and Discussion

The Markov-Switching Model divided the return on investment (logROI) into two regimes. Regime 1 defines a stable SSCF environment, whereas Regime 2 identifies periods of volatility or where higher responsiveness is noted. The regime classification plot delineates these changes in time.

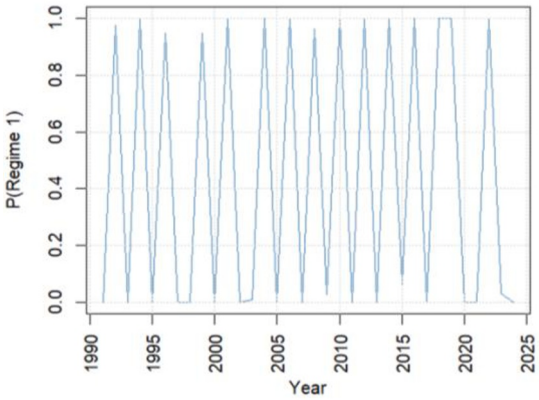

Figure. 1. Smoothed Probability of Regime 1 Over Time

The regression smoothed probability distribution from 1991 to 2024, clearly shows cyclic regime switching, oscillating values between 0 and 1. We deduce that high probabilities suggest essentially pure Regime 1, while low values suggest we are in Regime 2. There is a notable shift just before the year 2020 that indicates a structural break or change. Due care should be exercised in interpreting that shift, but it could be hypothesized that it relates to a macroeconomic phenomenon, a spasm of different policy, or due to new technologies that affected the process itself.

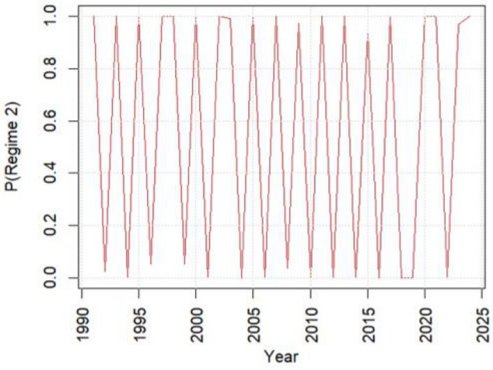

Figure. 2. Smoothed Probability of Regime 2 Over Time

The smoothed probability plot for Regime 2 (1991–2024) provides evidence of cyclical shifts back and forth between regimes with periods at or near to one that show a strong presence of Regime 2. The fluctuations do encourage some consideration of whether we can detect structural changes in the changes in economic process. The spike after 2020 might reflect a longer-term shift only relative to external shocks or change in the policy environment.

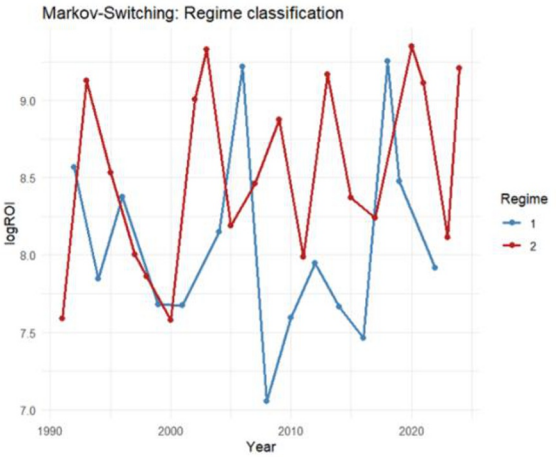

Figure. 3. Markov-Switching Regime Classification of ROI

The regime plot of the Markov-Switching model reveals clear transitions between two different regimes over the course of time in logROI activity. Regime 1 (blue) is generally characterized by low or mixed returns, while Regime 2 (red) is characterized by high logROI values. Transitions are structural breaks or economic regime shifts where each regime does not continue indefinitely. Interestingly, post-2020 figures are mostly classified under Regime 2, showing either enhanced ROI performance or a more stable economic environment in recent years.

Table 1. Comparison of OLS and Regime-Specific Coefficients from the Markov-Switching Model.

Variable	OLS Coef.	OLS Sig.	Regime 1 Coef.	Regime 1 Sig.	Regime 2 Coef.	Regime 2 Sig.
log_Digitalization_Level _SCFinance	0.78620	***	0.9506	***	0.7096	***
log_Inflation_Rate	-0.68085	***	-1.0248	***	-0.5654	***
log_GDP_Growth	0.50296	***	0.1211		0.2381	***
log_Net_Income_Companies	0.95348	***	0.8988	***	1.0919	***
Supply_Chain_Complexity	0.46558	***	0.3317	***	0.5919	***

Source: Authors' work

Companies in the Regime 2 show extremely high ROI performance, all the factors have significant effects on ROI. When digitalization increases by 1% that increases ROI by 0.71%, this is a good factor of efficiency and transparency. Inflation is a negative factor affecting ROI, where a 1% increase of inflation decreases ROI by 0.57%, supporting inflation as a risk factor. GDP growth shows a positive effect on ROI (0.24%), indicating that there are macroeconomic benefits. The effect of net income is the most significant; in this case a 1% increase of net income, would increase ROI by 1.09%, emphasizing profitability. Complexity has a positive effect on ROI (0.59%), demonstrating that complexity when managed well is a positive strength affecting ROI under stable conditions.

Through our Markov-Switching analysis we see the emergence of two paths towards ROI, the moderate (Regime 1) path and the high (Regime 2) path. These paths are shaped by high-level external influencers, such as digitalization, inflation and evolving policy changing public and private sector practices on the environmental sustainability aspect of ROI. Digitalization consistently supports ROI, in both Regimes, more dramatically in Regime 2, especially, during moments of uncertainty. Inflation impacts ROI statistically more negatively in Regime 1, signaling the necessity to have measures to manage inflation risk for sustainability purposes. Our due diligence identified a strong positive association between net income and complexity of the supply chain impacting ROI across the two regimes. GDP growth statistically benefits ROI primarily in Regime 2. Taken together, these findings speak to the role SSCF plays in embedding resilience and flexibility in organizations during an evolving economic climate.

4 Conclusion

Though our findings suggest SSCF incorporate focus on digitalization, profitability and complexity management in enhancing ROI across two diverse economic characteristics; inflation risk can precipitate negative ROI, particularly in weak or anxious Regime 1 and comparatively, macroeconomic growth in GDP only supported ROI in a strong performance Regime 2. SSCF supports their firms' short- and long-term adaptation of their financial strategies to manage the risk return profile according to the economic landscape.

Policy implications:

- Enhance digital investment in supply chains through incentives.
- Support organizations in utilizing sustainable finance tools such as ESG-linked loan products.
- Encourage inflation risk plans.
- Enhance capacity for public-private management of complexity.
- Integrate SSCF into institutional governance, with direct linkage to ESG criteria and board oversight.

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