

A Conceptual Model of Digital Ecosystem-Based Circular Economy for Craft Industries Utilizing Renewable Natural Resources

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ABSTRACT

The handicraft sector utilizing renewable natural resources plays a pivotal role in rural economic development and cultural preservation. However, conventional linear production models face severe market frictions, including upstream resource depletion, information asymmetry, and unaccounted ecological externalities. Grounded in environmental resource economics, microeconomic value theory, and digital platform architecture, this study proposes a conceptual framework that integrates circular economy principles into a digital ecosystem. Using an integrative conceptual synthesis methodology, this study models the structural interactions among four core dimensions: closed-loop input stewardship, smart platform verification, consumer willingness-to-pay internalisation, and community-level economic governance. The model introduces four key theoretical propositions explaining how distributed digital ledgers and eco-labeling mitigate moral hazard, transform positive environmental externalities into producer surplus, and optimize resource renewal rates. Ultimately, the conceptual architecture demonstrates that digital enablement does not merely digitize commercial transactions, but recalibrates resource governance, fostering regenerative rural craft clusters and long-term socio-ecological sustainability.

Keywords: Circular Economy; Digital Ecosystem; Environmental Economics; Local Wisdom; Natural Resource Craft

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INTRODUCTION

Rural craft enterprises reliant on natural raw materials—such as bamboo, rattan, natural dyes, and pandanus—serve as the economic and cultural backbone of traditional communities in developing economies (Hendriyana et al, 2025). Traditionally, these production networks embody indigenous knowledge and local conservation ethics. Nevertheless, modern commercial pressures have increasingly driven these artisanal clusters toward a linear "take-make-waste" paradigm. Artisans face acute resource constraints, volatile raw material prices, degradation of regional wild flora, and a disproportionate extraction of economic rents by intermediary traders who exploit informational advantages (Stahl et al, 2026).

From a microeconomic perspective, the degradation of communal renewable resources represents a classic market failure rooted in uninternalized environmental externalities and open-access inefficiencies. While global markets exhibit an escalating willingness to pay (WTP) for green and heritage products, local producers struggle to signal genuine ecological stewardship due to pervasive information asymmetry in conventional supply chains. Consumers frequently encounter credible verification deficits regarding whether products originate from sustainably harvested natural capital or employ non-toxic processing methods (Alnuqaydan, 2024).

Previous literature has extensively documented the benefits of the circular economy (CE) in industrial manufacturing and urban environments (Geissdoerfer et al., 2026). Concurrently, digital business scholars have examined e-commerce adoption and platform mechanics among micro, small, and medium enterprises (MSMEs). However, a critical theoretical gap remains: existing research tends to treat digital business models merely as transactional conduits for market access, rather than institutional coordinating mechanisms that can govern regenerative resource cycles in resource-dependent rural clusters.

To bridge this divergence, this study develops an integrative conceptual model synthesizing natural resource economics, microeconomic pricing and incentive theory, and digital platform ecosystems. The objectives of this research are threefold:

1. To conceptualize a closed-loop framework tailored to traditional craft production utilizing renewable biomass;
2. To delineate how digital platform components (such as digital product passports, localized eco-labeling, and decentralized data ledgers) reduce transaction costs and mitigate adverse selection;
3. To formulate theoretical propositions illustrating the transition from open-loop extraction to a regenerative, welfare-maximizing circular equilibrium in rural economies.

METHODS OF RESEARCH

This study employs an integrative conceptual research methodology (Jaakkola, 2020). Rather than relying on primary empirical field testing, conceptual synthesis is the established scientific approach when integrating theoretical concepts across previously siloed domains—specifically environmental resource economics, digital business ecosystem design, and rural enterprise development.

The analytical procedure consists of three sequential phases:

1. **Domain Literature Delineation**

Analyzing seminal and contemporary literature (2016–2026) covering circular business model typologies (cradle-to-cradle, regenerative design), microeconomic information asymmetry (signaling theory, incentive structures, market failure), and smart ecosystem architectures (platform

cooperativism, digital trace verification).

2. Component Mapping and Theoretical Synthesis

Identifying structural bottlenecks in traditional craft supply chains and mapping them against digital governance interventions across four lifecycle stages: material regeneration, production design, digital verification/distribution, and biological cascade recycling.

3. Model Construction and Proposition Development

Formulating an interrelated conceptual framework represented through systemic structural diagrams, supplemented by formal theoretical propositions that yield testable hypotheses for future empirical and field research.

RESULT AND DISCUSSION

1) Structural Bottlenecks in Traditional Natural-Resource Crafts

Traditional craft industries operating on renewable materials generally experience three interlocking economic inefficiencies.

a. Upstream Degradation & Resource Insecurity

Traditional craft industries utilizing renewable raw materials depend intrinsically on the ecological carrying capacity and biophysical stability of local rural landscapes. When global and urban market demand surges without coordinated extraction governance, the harvesting of indigenous materials—such as bamboo, rattan, pandanus, and natural dye plants—inevitably outpaces natural regeneration cycles. Persistent commercial pressure compels harvesters to extract immature biomass or clear natural stands indiscriminately, disrupting multi-generational biological succession cycles that customary communal institutions historically preserved.

Through the lens of natural resource microeconomics, this process demonstrates classic market failure stemming from the common-pool nature of rural renewable resources. In the absence of secure property rights or enforceable customary (adat) conservation mandates, harvesters operate within a tragedy of the commons dilemma, where individual actors are economically incentivized to maximize short-term biomass extraction before competitors preempt them. Consequently, the external costs of resource depletion are completely excluded from private extraction decisions, driving harvest rates far beyond socially optimal bioeconomic equilibrium.

The exhaustion of local natural capital directly shifts the private marginal cost curve upward and outward across upstream production units. Harvesters and village artisans encounter localized resource scarcity, forcing them to venture deeper into remote ecological buffers or purchase lower-grade inputs imported from external regions at inflated logistics expenses. This outward cost shift reduces rural labor productivity significantly, as an increasing proportion of artisanal labor and operating time is consumed merely by sourcing increasingly scarce, degraded natural inputs.

Raw material supply instability triggers pronounced price volatility for rural micro-enterprises that lack liquid financial reserves. During seasonal shortages intensified by habitat degradation, craft producers possess insufficient working capital buffers to absorb acute input price spikes. As a result, small-scale workshop operations experience frequent operational disruptions, production lead times become highly erratic, and rural enterprise clusters struggle to reliably fulfill high-volume, standardized commercial contracts.

Over the long term, upstream degradation compromises the socio-ecological resilience of rural communities at a fundamental level. Biodiversity erosion diminishes raw material diversity while gradually extinguishing specialized craft techniques inherently tethered to unique regional plant species. This structural dependency on a degrading natural resource base creates an economic poverty trap, where declining biological yields compel rural producers to adopt increasingly extractive harvesting methods simply to maintain subsistence income levels.

b. Information Asymmetry in Distribution

Traditional craft supply chains exhibit severe information deficits between rural upstream producers and downstream urban or export consumers. Primary artisans hold extensive private information regarding the authentic, sustainable attributes of their goods, including low-impact harvesting methods, biodegradable processing cycles, and non-toxic botanical dyeing practices. However, multi-layered conventional distribution channels sever this qualitative narrative, flattening culturally embedded, environmentally restorative crafts into undifferentiated physical commodities in wholesale exchanges.

From the standpoint of signaling theory, the absence of low-cost, credible verification mechanisms prevents rural producers from effectively transmitting unobservable quality signals to the market. While environmentally conscious consumer segments demonstrate an increasing willingness-to-pay for ethically crafted, regenerative goods, they cannot independently verify ecological stewardship claims prior to purchase. This dynamic generates pervasive informational uncertainty, leaving credence attributes regarding resource renewal indistinguishable from unsubstantiated corporate greenwashing.

This pronounced information asymmetry triggers adverse selection, mirroring the dynamics of Akerlof's classic lemons problem. Because end-consumers cannot reliably verify genuine organic sourcing or fair-labor harvesting, market clearing prices gravitate toward the average quality level of mass-manufactured, conventional alternatives. Consequently, authentic artisans who absorb higher private production costs to maintain non-extractive harvesting methods are economically undercut by synthetic, machine-made imitations or unsustainably extracted substitutes.

The homogenization of product value by conventional intermediaries progressively erodes incentives for circular innovation at the workshop level. Intermediaries prioritize volume consistency, uniform aesthetics, and minimized unit costs, systematically ignoring the fact that natural material processing requires flexible curing times and yields organic stylistic variations. When circular stewardship is unrewarded by a distinct wholesale price premium, artisans face compounding economic disincentives to sustain labor-intensive, regenerative handling methods.

Ultimately, this communication failure prevents the emergence of an efficient green market equilibrium for heritage goods. High-value, ecologically restorative crafts remain trapped in low-margin regional commodity markets, while affluent consumers willing to support circular initiatives shift toward certified industrial alternatives. Without decentralized, tamper-proof digital traceability architectures to verify provenance at near-zero transaction costs, informational opacity will continue to trap authentic rural crafts in destructive price-competition spirals.

c. Depleted Producer Surplus

The most debilitating structural defect within traditional craft value chains lies in the pronounced distortion of value-added distribution. Rural artisans routinely confront monopsonistic or oligopsonistic local market structures, where commercial access is controlled by a tightly knit network of intermediary

traders and collectors. Severe geographical isolation, high search costs, and a lack of local warehousing infrastructure leave primary producers with virtually zero bargaining power, forcing them to accept price levels dictated entirely by rent-extracting middlemen.

Intermediaries leverage their concentrated market power to capture substantial economic rents across the distribution pipeline. In downstream retail centers, eco-ethnic handicrafts command significant price markups predicated on the marketing of indigenous heritage, sustainable authenticity, and rural aesthetics. Yet, this consumer surplus premium is absorbed almost entirely by distributive gatekeepers, while farmgate purchase prices offered to rural artisans remain anchored near or even below the true marginal cost of labor and resource extraction.

The severe erosion of producer surplus depresses artisan household income to bare subsistence returns, preventing real capital accumulation in rural clusters. Operating on razor-thin operating margins, micro-enterprises possess no discretionary capital reserves to reinvest in modern tooling, circular production improvements, or digital capability development. Deprived of investable surplus, workshop infrastructure remains technologically stagnant, fragile to supply shocks, and incapable of capturing higher value-added transformation stages.

Critically, the depletion of producer surplus obliterates the financial capacity of rural communities to fund natural resource replenishment. Cultivating regenerative nursery stocks, managing controlled secondary growth cycles, and implementing circular biological composting require dedicated upfront capital and uncompensated labor hours. When primary producers are systematically trapped in chronic cash-flow deficits, undertaking long-term ecological conservation projects becomes an economically unviable burden that threatens basic household survival.

From a rural macroeconomic perspective, this skewed rent distribution triggers a catastrophic labor drain within local creative economies. Younger generations observe handicraft production as an economically precarious, undercompensated occupation characterized by low social mobility, prompting accelerating out-migration toward urban industrial informal sectors. The steady loss of primary producer surplus not only threatens the survival of renewable craft clusters, but systematically dismantles the foundational pillars of self-reliant, equitable rural economic development.

Table 1. Structural Comparison between Linear and Digitally Enabled Circular Craft Models

Analytical Dimension	Linear Craft Industry Model	Digitally Enabled Circular Model	Theoretical Economic Mechanism
Resource Input Paradigm	Depletive harvest; linear throughput	Controlled regenerative harvesting; biological cascade	Bioeconomic optimal yield management
Information Governance	Opaque supply chain; high asymmetry	Transparent digital audit trail / Digital Product Passport	Information signaling; mitigation of adverse selection
Value Distribution	Intermediary-dominated; low rural capture	Direct platform aggregation; transparent premium capture	Producer surplus retention; rent redistribution
Waste Stewardship	Open disposal; organic scrap underutilized	Secondary biological upcycling; local composting loops	Internalization of negative production externalities

(Source: Conceptual synthesis, 2026)

2) Conceptual Model Architecture: The Digitally Enabled Circular Loop

The proposed model coordinates four dynamic components across the enterprise lifecycle, creating a closed-loop bioeconomic system.

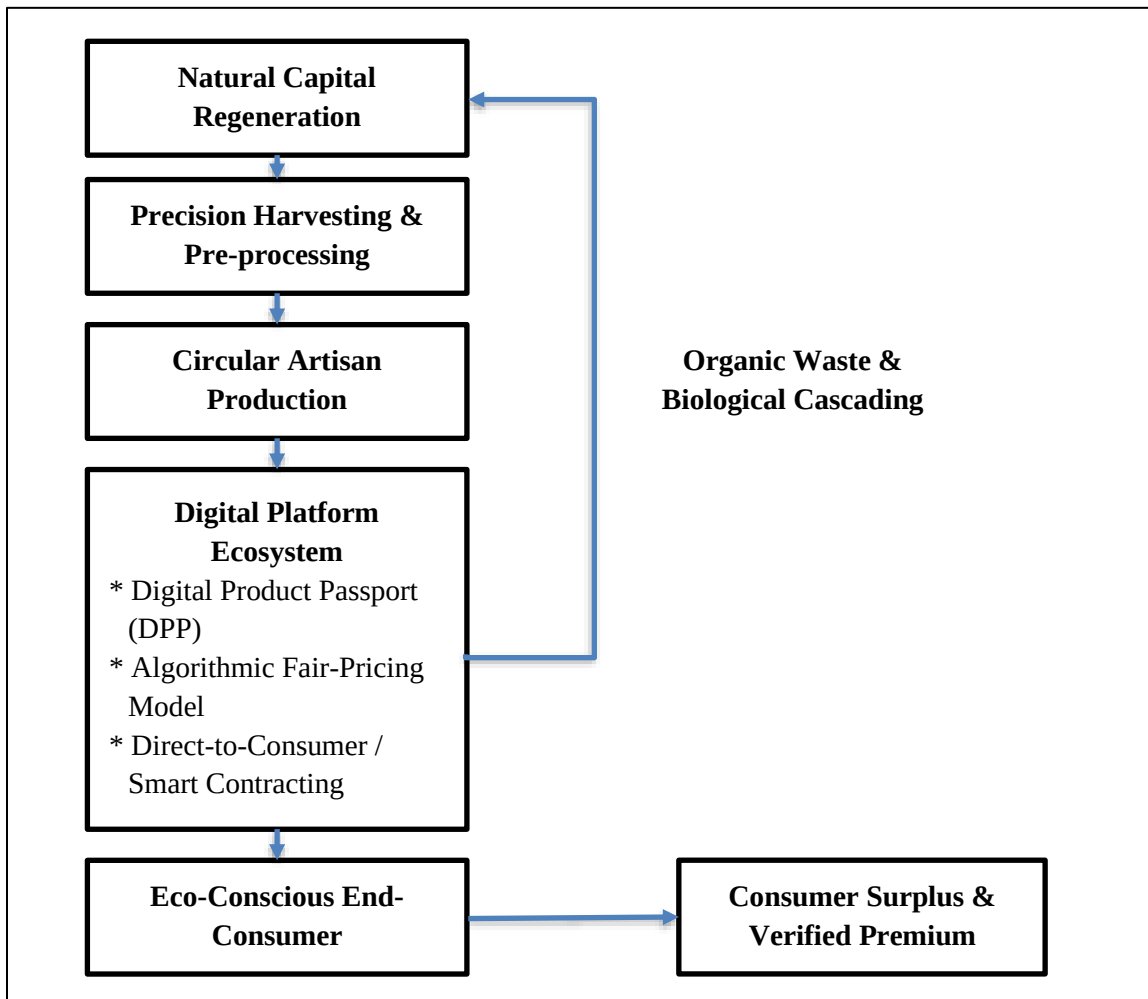


Figure 1. Conceptual Model Architecture
(Source: Author, 2026)

The core engines of this architecture are defined as follows:

a. Regenerative Bio-Resource Management

Regenerative bio-resource management is rooted in an integrative synthesis between indigenous local wisdom (*kearifan lokal*) and modern bioeconomic principles. Historically, rural communities practiced customary governance mechanisms—such as temporary no-harvest zones, selective harvesting based on maturity indicators, and rotational fallow cycles—to preserve native flora like bamboo, pandanus, rattan, and natural dye plants. The proposed framework revitalizes these communal norms into structured operational parameters, ensuring that aggregate biomass extraction remains strictly within the ecological threshold of maximum sustainable yield.

Operationally, biological resource harvesting is governed by a dynamic bioeconomic condition where harvesting volume in any period must remain below or equal to the natural regeneration growth rate ($h_t \leq g(S_t)$). To operationalize this constraint without burdening rural artisans with cumbersome administrative red tape, extraction data is recorded locally at the farming cluster or workshop level using intuitive smart rural data-logging interfaces. Every batch of natural biomass entering the production facility is timestamped and documented according to harvest parcel

location, raw volume, and designated fallow schedules, directly preventing over-extraction in buffer zones.

This bioeconomic alignment transforms rural natural capital from an exhaustible, depletive asset into a continuously replenished circular stock. Ensuring raw material sustainability mitigates supply chain volatility for artisanal clusters, shielding micro-enterprises from severe input price fluctuations and seasonal resource scarcity. Simultaneously, this regenerative commitment preserves rural landscape biodiversity and protects indigenous cultural raw materials for future artisanal generations without breaching local ecological carrying capacities.

b. Decentralized Digital Audit and Identity

A critical institutional bottleneck preventing rural micro-enterprises from accessing green markets is the cost-prohibitive nature and administrative rigidity of conventional third-party ecological certifications. The decentralized digital audit and identity engine overcomes this barrier by deploying an affordable, transparent, and inclusive communal verification system. Through a localized digital platform, the entire material journey—from sustainable biomass harvesting sites and manual weaving techniques to non-toxic plant dye applications—is collectively verified and endorsed by peer artisanal clusters and trusted customary validators.

This architecture is operationalized through a Digital Product Passport (DPP) embedded directly onto physical craft artifacts via QR codes or lightweight distributed ledger NFC metadata tags. When scanned by prospective buyers, the digital passport reveals an immutable provenance trail displaying artisan identity, community-certified organic material compositions, minimal process carbon footprints, and direct socio-economic impact metrics. This digital transparency eliminates the chronic information asymmetry that has historically obscured the authenticity and true craftsmanship value of traditional rural goods.

By establishing a low-cost, credible quality signaling device, rural artisans are no longer marginalized by capital-intensive industrial certification standards. This verifiable digital identity protects craft producers from unfair price competition against synthetic mass-manufactured imitations or extractive, uncertified commodities. Consequently, decentralized verification builds a direct, high-trust market bridge linking upstream indigenous custodians with ethically conscious downstream consumer segments.

c. Microeconomic Incentive Alignment

The microeconomic incentive alignment engine reorganizes downstream market structures that have traditionally kept primary craft producers in subordinate, price-taking positions due to intermediary monopsony power. By utilizing digital platforms to bypass speculative wholesale channels, circular-certified heritage crafts directly access downstream markets populated by environmentally conscious, ethical consumers. This disintermediation mechanism effectively captures consumer willingness-to-pay (WTP) for verified ecological and cultural authenticity, translating consumer premiums into fair farmgate prices.

Theoretically, this mechanism induces an equitable shift in economic welfare directly toward rural production communities. The green price premium paid by conscious consumers is no longer captured as economic rent by speculative intermediaries; instead, it expands rural producer surplus while eliminating deadweight market losses. Simultaneously, consumers realize enhanced utility from verified product provenance and the transparent assurance that their purchase directly supports rural ecological conservation and socio-economic equity.

This equitable rent distribution creates rational economic incentives for artisans to consistently adhere to circular production standards. Raising artisan income above mere subsistence margins provides micro-enterprises with the discretionary working capital needed to invest in ergonomic workshop improvements, advanced design experimentation, and biological raw material nurseries. The model demonstrates that ecological sustainability need not impose an economic penalty on rural creators; rather, it serves as a direct catalyst for microeconomic profitability and local capital accumulation.

d. Biological Cascading and Secondary Cycles

The biological cascading and secondary cycles engine implements a *cradle-to-cradle* circular bioeconomy framework, ensuring that production scrap is treated as valuable biological feedstock rather than discarded waste. Traditional craft processing generates substantial plant biomass residues, including cellulose shavings, fibrous scrap, bark trimmings, and organic dye residues. Instead of disposing of these biological by-products in open landfills or through open-air burning that generates emissions, the framework routes all organic scrap into localized secondary value loops.

Applying rural industrial symbiosis principles, fibrous cellulose and woody trimmings are diverted into secondary production streams, such as clean-burning biomass briquettes, organic mushroom cultivation substrates, or agricultural moisture-retention mulch. Concurrently, nutrient-rich plant cuttings and non-toxic dye residues undergo monitored community fermentation and composting, producing high-grade bio-organic fertilizers. This cascading mechanism completely internalizes biological waste flows within the rural production landscape without introducing persistent environmental contaminants.

The economic returns from this cascading loop materialize as dual cost efficiencies within the craft cluster. Artisans eliminate solid waste handling costs while establishing auxiliary revenue streams through the commercialization of bio-briquettes and organic compost. Furthermore, the resulting compost is reintroduced at subsidized rates to local harvesters to enrich communal agroforestry plots and raw material reserves. This closed-loop bio-cycle harmoniously reconnects the creative handicraft sector with natural ecological metabolisms.

3) Theoretical Propositions

To provide a rigorous analytical foundation for the conceptual model, four deductive propositions are articulated below. Each proposition establishes the microeconomic rationale, theoretical linkages, and operational transmission channels that govern the proposed circular digital ecosystem.

- a) **Proposition 1:** *The implementation of localized digital verification mechanisms significantly attenuates market failure caused by information asymmetry, allowing sustainable natural craft products to capture a premium price that reflects true ecological costs.*

In traditional commodity craft markets, environmental stewardship remains an unobservable credence attribute. Under George Akerlof's adverse selection framework, consumers cannot distinguish authentic, regenerative handicrafts from synthetic or unsustainably harvested imitations. This inability to verify claims collapses consumer willingness-to-pay (WTP) to an undifferentiated baseline price (P_{avg}), leaving artisans who absorb higher private extraction costs to preserve biodiversity financially penalized.

The deployment of a tamper-evident Digital Product Passport (DPP)—anchored by lightweight

distributed ledger entries and localized community endorsement—acts as a credible, low-cost signaling mechanism. The immutable audit trail explicitly communicates provenance, harvesting rotation compliance, and chemical-free material processing.

By eliminating asymmetric information, the signaling cost barrier is overcome, shifting the demand curve outward for certified regenerative goods (D_{green}). Consequently, the market clears at a premium price ($P_{green} > P_{avg}$), where $P_{green} = MPC + MEC$ (Marginal Private Cost + Marginal External Conservation Cost). The positive ecological externality is thus fully internalized into the market transaction rather than neglected as an uncompensated public good.

- b) **Proposition 2:** *As the proportion of direct platform transactions increases, the share of total economic surplus retained by rural primary artisans rises, thereby strengthening the financial capacity of community clusters to maintain renewable resource replenishment programs.*

Conventional rural craft value chains exhibit extreme vertical market power asymmetries characterized by oligopsonistic or monopsonistic intermediary networks. Middlemen exploit geographic friction and market-access barriers to capture up to 60–80% of final retail margins, depressing farmgate compensation down to bare subsistence wages ($W \approx MC_{labor}$). This leaves primary production workshops with zero retained economic surplus or investable free cash flow.

A decentralized, community-facing digital platform functions as a direct-to-consumer (D2C) aggregation corridor that disintermediates rent-seeking brokerage tiers. The platform automates price discovery and settles transactions via transparent escrow protocols, reallocating economic rent across the value chain.

Removing intermediary distortions shrinks deadweight loss and converts captured middleman rents into expanded producer surplus (PS). With household incomes lifted above subsistence thresholds, craft clusters generate dedicated communal conservation funds. A predictable portion of this retained surplus is deployed toward upfront ecological investments—such as establishing botanical seedling nurseries, fencing young bamboo groves, and funding seasonal fallow wages—directly enhancing the biological carrying capacity of the community's resource commons.

- c) **Proposition 3:** *Integrating closed-loop biological cascading into rural craft clusters reduces private production input costs over time by substituting purchased inputs with recycled agricultural and craft by-products.*

Under linear operating conditions, trimming scrap, organic dyes, cellulose shavings, and botanical residues are treated as negative-utility waste, incurring disposal labor costs or creating environmental degradation via open-air combustion. Simultaneously, rural workshops incur explicit operational expenditures ($OPEX$) to purchase secondary inputs, such as external fuel briquettes, soil enhancers for home gardens, packaging fillers, and chemical cultivation fertilizers. Applying the *cradle-to-cradle* circular bioeconomy framework establishes a localized industrial symbiosis network. Organic biomass residues are systematically collected and classified into secondary valorization streams: fibrous trimmings become compost substrates or packaging padding, while dense lignin and cellulose residues undergo densification into clean-burning biomass fuel briquettes.

The marginal cost curve (MC) of the craft workshop shifts downward over time. Purchasing expenses for external thermal energy, synthetic soil inputs, and commercial packaging are replaced by internal circular transfers. What was historically categorized as uncompensated production scrap transforms into auxiliary factor endowments ($Q_{secondary}$), reducing average total production costs

(ATC) while eliminating solid waste management externalities within the local ecosystem.

- d) **Proposition 4:** *A community-governed digital business platform serves as an institutional anchor that reinforces traditional customary conservation norms by providing transparent economic rewards for adherence to sustainable harvesting quotas.*

Communal natural resources are perpetually vulnerable to Ostrom's common-pool resource dilemmas and free-rider behaviors, particularly when traditional customary (*adat*) enforcement mechanisms erode under modern commercial incentives. Without transparent monitoring and immediate feedback, individual artisans face short-run microeconomic incentives to cheat and over-harvest local raw materials before their peers do.

The digital ecosystem couples decentralized monitoring tools with customary tenure governance. Harvester quotas, designated rotational plots, and maximum sustainable yield thresholds ($h_t \leq g(S_t)$) are codified transparently within the digital platform's producer registry. When harvesters log biomass inputs that conform to verified seasonal quotas and maturity criteria, the system validates their standing through smart platform incentives, such as preferential algorithmic product ranking, communal dividend bonuses, or reduced platform commission fees.

This institutional coupling aligns individual profit-maximizing behavior with long-term collective ecological survival. Moral hazard is actively deterred through peer-visible, transparent data logs rather than punitive state policing. Traditional ecological wisdom is codified into a digital institutional architecture, transforming informal social capital into tangible economic security and ensuring strict adherence to regenerative resource equilibrium across generations.

CONCLUSION

This study presents a multidimensional conceptual model that integrates circular economy principles into natural resource-based rural craft enterprises via a digital platform ecosystem. By examining the structural interactions among renewable natural capital, microeconomic incentive structures, and digital verification mechanisms, the model demonstrates that digital transformation in rural settings can transcend transactional e-commerce. When properly configured, digital platforms function as institutional coordinating architectures that eliminate information asymmetries, distribute surplus equitably to rural artisans, and reinforce sustainable biological cycles. For local policymakers and rural enterprise developers, this framework underscores the importance of investing in rural digital literacy, shared community digital assets, and localized green labeling. Future research should empirically validate the proposed model through structural equation modeling across varied artisanal clusters and assess consumer price elasticities for digitally verified regenerative crafts.

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