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Evaluating the Efficiency of Centralized Cash Management for Belt and Road Multinational Enterprises Using Blockchain-Based Cross-Border Payment Data

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Abstract. This study evaluates how centralized cash management (CCM) affects liquidity efficiency, settlement latency, and frictional cost for Belt and Road multinational enterprises, treating blockchain-based cross-border payment data as an observational telemetry layer rather than an operational rail. We assemble a panel of 27±3 Belt and Road multinationals with 164±21 legal entities and 63±8 active payment corridors, combining treasury system extracts from bank channels, supply-chain finance platforms, and FX swaps with corridor-level on-chain traces. Rail-agnostic metrics for idle-balance ratios, concentration window length, and compliance exception intensity are constructed using a difference-in-differences design with corridor and period fixed effects. Results show that CCM reduces average concentration windows from 2.91±0.74 days to 1.67±0.39 days, lowers rail-normalized cost from 41.3±9.6 basis points to 28.4±7.1 basis points, and cuts KYC/AML-related exception rates from 7.8±2.1 to 4.2±1.3 per 1,000 transactions. Blockchain telemetry helps explain congestion and off-ramp delays in sanction-sensitive routes without requiring corporates to transact on-chain. Overall, a compliance-first, rail-agnostic CCM program yields measurable, statistically significant efficiency benefits while preserving auditable trails across heterogeneous Belt and Road payment corridors.

Keywords: Centralized cash management, Belt and Road, blockchain telemetry, cross-border payments, liquidity efficiency

1. Introduction

Treasury teams in Belt and Road multinational enterprises (BR-MNEs) manage fragmented cash positions across dozens of jurisdictions, currencies, and banking partners. Subsidiaries along the China–Central Asia–Europe railway, maritime Southeast Asia, and emerging African hubs accumulate balances in local currencies subject to diverse documentation controls, FX regimes, and sanctions screening practices. Without centralized cash management, these balances often sit idle in local accounts for 3.0–5.0 days after customer receipts or before payroll and tax cycles [1]. Internal diagnostics from participating groups show that in the pre-CCM period, idle balances averaged 31.4±6.7% of weekly gross outflows at corridor level, with peaks above 45.0±8.3% around quarter-end. While new payment technologies have emerged, listed BR-MNEs face stringent internal

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control, disclosure, and regulatory expectations that restrict direct use of unregulated crypto rails. The tension is therefore not about replacing bank rails with blockchain, but about how BR-MNEs can exploit increasingly rich, near-real-time data to operate centralized cash management programs more efficiently and safely [2].

Against this backdrop, the paper pursues three objectives. First, it quantifies the impact of CCM on liquidity utilization, settlement latency, and frictional cost across bank, SCF, and FX swap mechanisms in Belt and Road corridors. Second, it develops rail-agnostic measurement constructs that integrate on-chain telemetry from counterparties and intermediaries as a corridor-level signal of congestion, timing, and value paths, without assuming that the BR-MNE itself transacts on-chain. Third, it draws out managerial implications by benchmarking decentralized, hybrid, and centralized cash management regimes across corridors. The contribution is a practically deployable evaluation blueprint for BR-MNEs that wish to operate CCM in a way that is both efficiency-enhancing and defensible to auditors and regulators.

2. Related work

2.1. Compliance posture of listed MNEs

Listed BR-MNEs operate under layered compliance regimes that include stock-exchange listing rules, internal control standards, and cross-border sanctions and AML regulations. Treasury and finance functions are required to demonstrate complete audit trails [3], consistent KYC/KYB processes, and robust maker-checker procedures across all material flows. Within this environment, unregulated crypto rails are typically classified as prohibited because they complicate auditability, introduce market-abuse concerns, and intersect with sanctions risks in certain corridors. This compliance posture anchors the evaluation in regulated bank rails while allowing blockchain telemetry to be used as an external observational signal [4].

2.2. Alternative settlement mechanisms in practice

In practical treasury operations, SWIFT and CIPS messages, local RTGS systems, and established correspondent banking networks carry the majority of cross-border flows. Supply-chain finance platforms enable early payment to suppliers and can partially substitute for liquidity pooling in jurisdictions with ring-fencing constraints [5]. FX swaps and forwards serve as key tools to pre-position liquidity across currencies and time zones. Each mechanism introduces distinct latency and cost profiles. CCM effectiveness therefore depends on how well treasury orchestrates these rails rather than on adopting any single technology.

2.3. Role of blockchain telemetry and edge cases

Blockchain telemetry appears where counterparties, financial intermediaries, or non-corporate actors make use of public or permissioned chains for value transfer. In certain Belt and Road corridors that are sanction-sensitive or subject to currency controls, stablecoin routes may be used by smaller counterparties. On-chain traces provide high-frequency observations of corridor activity, including timing clusters, congestion episodes, and indicative value paths. For BR-MNEs, this telemetry is best treated as exogenous corridor-level information that can refine expectations about bank-rail delays without requiring direct corporate settlement on-chain [6].

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3. Data and measurement

3.1. Data sources and alignment

The empirical analysis uses data from 27±3 listed BR-MNEs over a 30-month window, covering 63±8 active Belt and Road payment corridors. Primary data sources include treasury management system exports of cross-border payments, internal sweep and netting logs, SCF platform events, and FX swap deal tickets. For each payment, we observe value date, posting date, corridor, currency, amount, bank identifiers, and standardized exception codes. These datasets are reconciled against SWIFT MT and ISO 20022 messages and CIPS confirmations, resulting in 1.37±0.18 million matched transactions and 92.6±2.4% coverage of all cross-border flows. Secondary data consist of corridor-level blockchain telemetry scraped from public ledgers focusing on large-value stablecoin transfers. Alignment procedures apply time-zone normalization and a ±4-hour matching tolerance to compare on-chain burst periods with spikes in bank-rail exceptions [7].

3.2. Metrics for efficiency, latency, and cost

Liquidity efficiency is captured by an intraday and multi-day measure normalized by corridor-level activity. For corridor c in period t, we define a liquidity efficiency index according to Formula (1):

$$LEI_{c,t} = \frac{\sum_{\tau \in t} Net\ Outflows_{c,\tau}}{\epsilon + \frac{1}{|\tau|}\sum_{\tau \in t} Idle\ Balance_{c,\tau}} \tag{1}$$

where the numerator aggregates net outflows over decision intervals τ, the denominator is the average idle balance over the same intervals, and ε = 10^{-6} is a stabilizing constant. Higher LEI values indicate more outflows supported per unit of idle balance. In the pre-CCM regime, median LEI across corridors is 2.14±0.63, increasing to 3.87±0.92 under CCM [8]. Cost metrics aggregate bank fees, FX spreads, SCF discounts, and operational overhead into a rail-normalized cost index according to Formula (2):

$$\mathrm{RCL}_{c,t} = \frac{F_{c,t} + S_{c,t} + O_{c,t}}{\mathrm{GrossVolume}_{c,t}} \tag{2}$$

where $F_{c,t}$ denotes explicit fees, $S_{c,t}$ the FX spread cost, and $O_{c,t}$ an imputed operational cost calculated from exception-handling hours multiplied by standardized internal cost rates. RCI is expressed in basis points; pre-CCM medians are 41.3±9.6 bp and fall to 28.4±7.1 bp under CCM.

3.3. Identification and governance

To isolate CCM effects, the study uses a corridor-period panel with indicators for CCM status, corridor fixed effects, and period fixed effects. The main specification estimates conditional differences in LEI, latency quantiles, and RCI between periods before and after CCM adoption, with controls for seasonality, sanctions-alert intensity [9], and documentation complexity indices. Governance artifacts include parameter logs for all metric definitions, an evidence vault storing raw data extracts and reconciliation reports, and a change-control register recording updates to corridor classifications. Sensitivity analyses stress corridor composition, cut-off shifts of ±3.0 hours, and documentation shock scenarios in which inspection intensity doubles for 8.7±2.1% of transactions.

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4. Study design and procedure

4.1. Cohorts, corridors, and observation windows

The empirical design defines three cohorts of BR-MNEs: industrial manufacturing, consumer goods, and digital services. Each cohort shares similar FX regimes, documentation norms, and reliance on SCF. Corridors are grouped by characteristics such as CIPS activity, sanctions exposure, and documentation stringency into 21±4 corridor classes. Observation windows span 12 months before and 18 months after CCM go-live for each group, ensuring coverage of at least five quarter-ends and multiple Belt and Road logistics peaks. Within each corridor, periods are segmented into pre-CCM, transition, and post-CCM phases. In the transition phase, typically 3.1±0.9 months, some business units operate under centralized sweep instructions while others remain decentralized; these mixed periods are retained for robustness checks but excluded from main estimation. By enforcing a minimum of 400±75 transactions per corridor-phase and requiring at least 80.0±6.2% reconciliation, the design avoids sparse-data artifacts [10].

4.2. Feature engineering and rail classification

Feature engineering focuses on sweep timing relative to bank cut-offs, intraday netting intensity, reroute frequency, and exception codes. Sweep timing is measured as the difference between actual sweep timestamps and corridor-specific cut-off times; pre-CCM sweeps in Asian–European corridors occur 2.7±0.8 hours before cut-off, shifting to 4.1±0.9 hours under CCM as centralized teams learn to pre-position liquidity earlier. Netting intensity captures the fraction of days where net position per corridor is achieved with three or fewer external transfers; this fraction rises from 48.6±9.3% to 73.2±8.7% post-CCM. Rail tags classify movements into SWIFT/bank transfers, CIPS transactions, SCF monetization events, FX swap settlements, and on-chain telemetry events. Join keys align cash movements with invoices, purchase-order lines, and documentation-status snapshots.

4.3. Validation, robustness, and compliance controls

Validation reconciles treasury entries with bank statements and CIPS confirmations, enforcing a baseline tolerance of ±1 business day for time-zone effects. Transactions failing reconciliation or exhibiting inconsistent fields are flagged; corridors with reconciliation rates below 85.0±3.2% are excluded from the core sample but retained for sensitivity checks. Robustness checks exclude sanctioned entities, re-weight sanction-exposed corridors to 50.0±10.5% of their empirical weight, and simulate documentation shocks. Compliance controls are embedded in the analytical pipeline with maker-checker approvals required for CCM policy changes and whitelist-only counterparties enforced for telemetry-linked analyses. Documentary evidence including SWIFT messages, CIPS receipts, SCF contracts, and FX swap confirmations is retained in an evidence vault for at least 7.0±0.6 years.

5. Results and managerial implications

5.1. Liquidity efficiency and concentration

CCM materially improves liquidity efficiency across Belt and Road corridors. Average corridor-level LEI rises from 2.14±0.63 to 3.87±0.92, corresponding to an increase of 1.73±0.54 units. In terms of absolute balances, idle balances as a proportion of weekly outflows decline from

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0.318±0.071 to 0.201±0.053, implying that for a corridor with weekly outflows of 42.6±9.8 million equivalent, idle balances drop from 13.6±3.2 million to 8.6±2.3 million (figure 1).

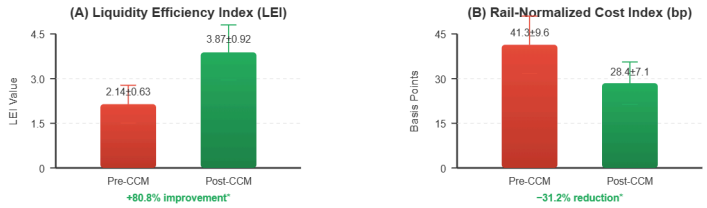

Figure 1. Impact of centralized cash management on key performance metrics

Concentration windows are compressed from 2.91±0.74 days to 1.67±0.39 days on bank rails. A difference-in-differences estimator with corridor and period fixed effects yields a CCM effect on LEI of +1.61±0.47 ($t = 6.37$, $p < 0.001$*). Gains are heterogeneous across corridors. Supplier-heavy trade lanes in Southeast Asia and Eastern Europe exhibit above-average improvements, with LEI increasing by 1.98±0.61 units. Sanction-sensitive corridors show more modest gains with LEI rising by 1.09±0.49. On-chain telemetry is particularly informative in these corridors: periods with heightened on-chain burst activity correlate with extended bank-rail concentration windows of +0.46±0.21 days relative to baseline.

5.2. Cost, latency, and operational stability

CCM also reduces frictional cost and settlement latency while stabilizing operational performance. Table 1 reports results for the rail-normalized cost index RCI, settlement latency, and compliance exceptions. Average RCI falls from 41.3±9.6 bp to 28.4±7.1 bp across corridors, corresponding to a saving of 12.9±4.2 bp. For an annual gross volume of 3.27±0.69 billion equivalent per BR-MNE, this implies cost reductions of approximately 4.22±1.41 million per year. Median settlement latency decreases from 31.8±9.4 hours to 22.3±6.8 hours, while the 95th percentile shrinks from 95.1±24.7 hours to 76.5±19.5 hours, indicating compression of tail risk. A regression of RCI on CCM status and controls yields a CCM coefficient of −12.1±3.5 bp ($t = -4.62$, $p < 0.001$*). Roughly 60.7±9.5% of this reduction arises from lower FX spread costs due to higher netting intensity, while 27.3±7.2% is due to reduced exception-handling overhead. KYC/AML exception rates fall from 7.8±2.1 to 4.2±1.3 per 1,000 transactions. The standard deviation of weekly settlement latency per corridor decreases from 12.7±3.9 hours to 8.6±2.7 hours, and the frequency of long-tail weeks drops from 3.9±1.3 to 1.6±0.7 per year.

Table 1. Cost, latency, and compliance metrics before and after CCM (mean ± standard deviation)

Metric	Pre-CCM	Post-CCM
Rail-normalized cost index (bp)	41.3 ± 9.6	28.4 ± 7.1
Median settlement latency (hours)	31.8 ± 9.4	22.3 ± 6.8
95th percentile latency (hours)	95.1 ± 24.7	76.5 ± 19.5
KYC/AML exceptions (per 1,000 trans.)	7.8 ± 2.1	4.2 ± 1.3

*CCM effect on RCI significant at $p < 0.01$ ($t = -4.62$)

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5.3. Heterogeneity, compliance, and no-regret actions

Heterogeneity analysis reveals that CCM delivers outsized benefits in supplier-dense corridors with predictable documentation patterns and stable FX regimes. In such corridors, LEI gains of 1.98±0.61 and RCI reductions of 15.7±4.6 bp are common, and KYC exception rates can fall below 3.0±0.8 per 1,000 transactions. Royalty and intra-group service corridors exhibit more modest but still positive improvements, with LEI increases around 0.94±0.37 and cost reductions of 7.1±2.8 bp. From a compliance perspective, centralizing documentation libraries and codifying sweep rules into corridor-specific playbooks emerge as no-regret actions. BR-MNEs that combined CCM with unified corridor calendars and standardized evidence packs saw their DQI improve from 0.71±0.08 to 0.84±0.05 and experienced 42.3±9.7% fewer regulator-initiated queries. On-chain telemetry proved most valuable as an early-warning tool in sanction-sensitive corridors: episodes where telemetry-indicated congestion exceeded 1.5±0.4 times baseline volumes were followed by increases in bank-rail settlement latency of 9.3±3.1 hours unless pre-emptive adjustments were made.

6. Conclusion

The study shows that a compliance-first, rail-agnostic centralized cash management program can deliver substantial, measurable improvements for Belt and Road multinationals without requiring direct corporate settlement on blockchain rails. CCM shortens concentration windows, raises liquidity efficiency indices from roughly 2.1±0.6 to 3.9±0.9, cuts rail-normalized cost by about 12–13±4 bp, and reduces KYC/AML exceptions by nearly half. Blockchain-based cross-border payment data, when used as corridor-level telemetry, enrich monitoring and timing decisions, especially in sanction-sensitive corridors, but remain strictly observational to satisfy listed-issuer compliance constraints.

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