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Cross-Border Art Trade: Compliance Challenges

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ABSTRACT

The compliance control of cross-border transactions involving works of art is conventionally executed at the terminal phase of the transactional cycle, when obligational ties are already largely formed and the scope for reversible intervention is constrained, with rule-based screening collapsing at fiduciary chain depths of three or more as a consequence of the multiplicative decay of attributional confidence that no binary check of sanctions-list membership is structurally capable of arresting. The present study proposes a stage-gate finite automaton operating over a typed graph representation of the transaction, in which each successive stage of an eight-phase cycle is protected by a gate whose state is derived deterministically from a quantitatively aggregated evidentiary sufficiency indicator and from accompanying jurisdictional and sanctions signals, while the arrival of disconfirming facts triggers cascading recomputation and forced revocation of previously granted permissions. Empirical verification on a corpus of 1 248 synthetic transactions calibrated against publicly documented restitution proceedings for the period 2015–2023 yields an F1 indicator of 0.914 against 0.598 for the rule-based baseline, shifts the mean stage of first relevant blockage from 5.7 to 2.3, and raises the reproducibility of the causal chain of decisions from 0.612 to 0.968, while the free-port subsample demarcates the lower bound of applicability at recall 0.54.

INTRODUCTION

The established practice of compliance control in the circulation of works of art is organized in such a way that verification of counterparties and transactional grounds is performed at the terminal stage of the cycle, when obligational ties have already largely been formed, and the possibilities for reversible intervention are limited. The documentation of restitution proceedings against reputationally established auction houses demonstrates that objects of questionable origin systematically pass through formally completed control procedures, while the mean depth of the fiduciary chain through which beneficial control is structured exceeds three layers in the segment of transactions above two million euros and reaches four or more in a substantial proportion of cases (Tsirogiannis, 2016). At such depth the cumulative confidence in beneficiary attribution, accumulated from successive links of the chain, collapses multiplicatively, and any threshold-based verification operating on the binary indicator of sanctions-list membership ceases to capture structurally mediated control (Purkey, 2010; Ulph, 2020).

The proposed model constitutes a stage-gate finite automaton over a formalized graph of the transaction, in which each successive phase of the cycle is protected by a gate whose opening is derived deterministically from values of the aggregated evidentiary sufficiency indicator together with accompanying signals, while the arrival of new facts triggers cascading recomputation of the states of all affected gates with forced revocation of previously granted permissions whenever their preconditions no longer hold. Empirical verification on a corpus of 1 248 synthetic transactions, constructed in line with the statistical characteristics of publicly documented cases from restitution proceedings over 2015–2023, demonstrates an increase in the F1 indicator of blocking irreversible executive acts from 0.598 for the rule-based baseline to 0.914 for the proposed architecture on the same sample, with the moment of the first relevant blockage shifting on average from the fifth to the second stage of the transactional path.

LITERATURE REVIEW

The accumulated body of research relevant to the subject of the present study may be systematized through four substantive directions, each of which converges on the same operational gap at fiduciary chain depths of three layers or more, yet rests on different founding assumptions that determine the boundaries within which the solutions proposed in them remain applicable.

The first direction, drawing on the conceptual tradition originating in Merryman's classical work on two approaches to cultural property (Merryman, 1986) and developed in contemporary interpretations of the 1970 standard (Gerstenblith, 2013; Fincham, 2019), treats international conventions and national implementations as autonomous instruments of influence on the market. The epistemological position implicitly adopted within this tradition consists in the assumption that harmonization of substantive norms translates into harmonization of enforcement, an assumption not borne out by the documented divergence between the declared

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1970 standard and the internal provenance research procedures actually applied at major auction houses (Brodie, 2015), where the substantive norm coexists with procedural practices that accept documentary chains of confidence considerably below the threshold the norm would require under mechanical application. The counter-intuitive corollary, defended in the discussion section of the present work, holds that at chain depths of three or more the marginal contribution of further normative elaboration to detection efficacy decays faster than the marginal contribution of formalized evidentiary aggregation.

The second direction, modelling the illicit art market as a network with stable broker positions and neutralization techniques deployed by collectors and dealers (Bowman, 2008; Campbell, 2013; Dietzler, 2013; Yates *et al.*, 2017), commits methodologically to the proposition that the network nature of the market renders effective intervention at the level of an individual transaction impossible. The macro-level orientation that follows from this assumption leaves unspecified the operational procedure for arriving at a decision in a concrete partially documented case, since network models supply the conditions under which risk-bearing configurations emerge without providing the apparatus for quantitatively assessing evidentiary sufficiency in real time.

The third direction, transposing the banking-sector AML toolkit to art transactions without structural adaptation (Purkey, 2010; Ulph, 2020), reproduces threshold heuristics of list-based screening in an environment dominated by opaque fiduciary layers, with the result that binary membership checks systematically miss structured control through holding chains. The architectural limitation of binary firing is preserved under such transposition, and no aggregation rule for multiplicatively decaying confidence in beneficiary attribution is proposed, which explains why the parametric tightening of threshold values does not close the recall gap between the proposed architecture and the baseline on the depth-three-and-above subsample.

The fourth direction, retrospective in analytical orientation and systematizing the results of investigation and prosecution of art crime across various jurisdictions (Manacorda & Chappell, 2011; Chappell & Hufnagel, 2014; Hufnagel & Chappell, 2019), provides a valuable descriptive picture of the typology of violations and the institutional constraints on enforcement; yet, by virtue of the retrospective character of this frame, it is incompatible with the task of blocking a transaction before irreversible legal consequences accrue. The analytical gap occupied by the present work consists in the absence of a preventive procedure capable of translating the descriptive findings of the retrospective tradition into operational constraints on pre-stage permissions, and such a translation requires both a representation tolerant of fact arrival in an open-world regime and a quantitative aggregation function with monotonicity properties suitable for deterministic derivation of gate states.

MATERIALS AND METHODS

At the foundation of the proposed model lies the representation of a transaction as a typed graph whose nodes correspond to the work of art, to natural and legal persons, to fiduciary structures, to documents, events, jurisdictions and restrictions, while directed edges carry a confidence attribute taking values between zero and one and a temporal interval of applicability. The choice of a graph representation is dictated by one persistent empirical characteristic of the corpus: after the contract-signing stage the median transaction acquires approximately two and a half new facts about ownership, while roughly one transaction in seven undergoes retroactive correction of attribution at the upper levels of the fiduciary chain, which makes the closed-world relational semantics a source of silent inconsistency and requires a representation in which facts arrive in an open regime and contradictions among them are recorded as structural objects rather than eliminated at the input.

The confidence value of each edge is derived from a typological table of sources calibrated by the density of independent corroboration. Cumulative confidence in beneficiary attribution is formed by aggregating edge confidences along the chain through a multiplicative scheme under which each additional link of confidence around 0.85 reduces cumulative attributional confidence by approximately fifteen per cent, so that at four homogeneous layers of the fiduciary chain cumulative confidence falls below the value at which the gate transition to the “open” state is admissible under the adopted configuration. The aggregated evidentiary sufficiency indicator is formed as a weighted sum of six components reflecting the continuity of the provenance chain, the coherence of ownership claims, the verification of authority to transfer, the substantiation of export legality, the inverted density of contradictions, and the inverted severity of temporal gaps. Among these components, authority to transfer plays a special role, since its value below a defined level acts as a hard ceiling limiting the final indicator value irrespective of how favourable the remaining signals may be. This construction reflects the doctrinal position concerning the structural primacy of verified authority in the obligational binding of parties (Tsirogiannis, 2016; Gerstenblith, 2013) and at the same time determines the regularity observed below: the sensitivity of the final F1 indicator to perturbations in the weight of authority to transfer noticeably exceeds the sensitivity to perturbations of the remaining weights.

The eight-stage life cycle of the transaction, comprising intake, identity verification, authority verification, agreement of export conditions, contract signing, escrow funding, title transfer and physical relocation, is organized as a finite automaton in which each stage corresponds to a gate with a four-valued set of admissible states: open, conditionally open, closed pending remediation, blocked by mandatory prohibition. The state of each gate is derived deterministically from the subset of indicator components relevant to the given stage, the current

subgraph of sanctions exposure, the aggregated pressure of payment-legality requirements, and the result of a consistency check on the characterization of movement. The arrival of new facts into the graph triggers cascading recomputation of all gates whose preconditions are affected, which eliminates the failure mode in which a gate transitioned once into the open state retains that state after the arrival of disconfirming evidence.

Empirical verification was conducted on a corpus of 1 248 synthetic transactions constructed so as to reproduce the statistical characteristics of publicly documented cases of restitution proceedings over the period 2015–2023 together with the corresponding analytical work on the structure of the illicit art market (Mackenzie *et al.*, 2020). The distribution of fiduciary chain depth is approximately described by a truncated log-normal distribution with mean 3.7 layers and standard deviation 1.4 layers, the median object value is 2.4 million euros, and the type distribution covers antiquities, European painting, and decorative and applied arts in proportions matching the observed segment shares in public auction statistics. Within the corpus three subsamples relevant to the comparative analysis have been demarcated: 742 transactions with fiduciary depth of three or more, on which the principal comparison with the baseline is conducted, 589 transactions in which at least one transit jurisdiction is subject to an active export restriction, and 87 transactions of the free-port subsample described separately below.

The annotation of the corpus was performed by two independent experts in cultural property law, with disagreements resolved by a third arbiter. Precision is defined as the share of correctly blocked acts in the total number of blocked acts, recall as the share of correctly blocked acts in the total number of acts subject to blocking, F1 as their harmonic mean, while the moment of the first relevant blockage is fixed in stages of the normalized eight-stage path. The reproducibility of the causal chain of decisions is assessed as the share of decisions on which two independent auditors achieve complete agreement in reconstructing the chain without access to source code, on a sample of 4 320 decisions stratified by gate type and drawn from 540 transactions selected uniformly at random from the test corpus.

The classical rule-based architecture of sanctions screening with threshold AML heuristics serves as the baseline, operationalized as sequential verification of list membership, the binary politically-exposed-person indicator and a threshold value indicator against the sanctions snapshot of 1 March 2025, executed on the same input fields and within the same computational environment as the proposed system. The applicability boundary of the proposed model is set by the assumption of a streaming order of arrival of graph attributes corresponding to the natural progression of the transactional cycle; the regime of retroactive batch reception of documents is examined separately for the characterization of degradation rather than as a basis for performance claims.

The free-port subsample of 87 transactions was extracted from the main corpus by the criterion of object transit between free-port storage facilities without crossing the customs border of any tax jurisdiction, with the change of control documented through transfer of shares in a top-level holding structure rather than through registration of title transfer over the object itself.

RESULTS AND DISCUSSION

On the full corpus of 1 248 transactions, with a mean fiduciary chain depth of 3.7 layers, the F1 indicator of binary blocking classification for irreversible executive acts reaches 0.914 at precision 0.927 and recall 0.902, which is achieved through recomputation of gate states upon every change in graph attributes and forced revocation of previously granted permissions on the arrival of evidence lowering an indicator component below threshold. On the same corpus and the same sanctions snapshot, the baseline yields F1 equal to 0.598 at precision 0.641 and recall 0.560, while the advantage of 31.6 percentage points on the subsample of depth three and above out of 742 transactions is explained by the multiplicative aggregation of edge confidence along the beneficial-ownership path, which a binary check of list membership is structurally incapable of reproducing. When the coverage of the ownership chain by documented edges falls below 0.55 of the theoretically complete level, F1 drops below 0.72, which sets the degradation boundary as a function of input data completeness rather than of model configuration. The mean stage of the first relevant blockage on the full corpus is 2.3 with a standard deviation of 0.8, with the early triggering achieved through parallel computation of the jurisdictional vector and the sanctions-exposure subgraph at the intake stage without awaiting the completion of provenance verification; the baseline records a mean first-blockage stage of 5.7 with a standard deviation of 1.1, since its assessment is deferred until the assembly of the complete contractual package. On the subsample of 589 transactions containing at least one transit jurisdiction with an active export restriction, the proposed method shifts the first blockage 3.4 stages earlier relative to the baseline. Under retroactive batch reception of attributes after the agreement of export conditions, the earliness gain contracts to 1.1 stages, which appears counter-intuitive given that batch reception delivers more information per arrival event, and is explained by the fact that the batch regime collapses the temporal ordering of facts that the gate recomputation logic relies upon to detect inconsistencies between successive items of evidence.

The local sensitivity of F1 to weights of indicator components, evaluated at a step of 0.05 around the baseline configuration, reaches its maximum on the weight of the authority-to-transfer component: a perturbation of ±0.10 around the baseline value shifts F1 into a range from 0.871 to 0.914, reflecting the ceiling role of this component. Sensitivity to the weights of

the contradiction-density and temporal-gap-severity components turns out to be noticeably lower, which is explained by partial redundancy of these signals on the corpus distribution, where most temporal gaps are accompanied by documented contradictions already captured by the corresponding component. Lowering the gate-passage threshold for contract signing on the authority-to-transfer component from 0.75 to 0.60 shifts the mean first-blockage stage from 2.3 to 1.7 with a drop in precision from 0.927 to 0.864, which establishes a quantitative trade-off between earliness and the precision of authority verification under a single threshold parameter.

On the free-port subsample of 87 transactions, F1 drops to 0.68 at recall 0.54, since the canonical graph representation does not register the change of beneficial control as an event node in the absence of a record of title transfer over the object itself.

Discussion

The advantage of 31.6 percentage points in F1 over the baseline, obtained without any modification of the applicable normative corpus and exclusively through a change in the architecture of permission derivation, requires a reassessment of the relationship between normative harmonization and the operational efficacy of compliance. The position that the gap between the declared norm and its enforcement stems from the absence of an operationalizing infrastructure rather than from the quality of the norm itself (Brodie, 2015) receives empirical confirmation in the present results, while the opposing position defended in the work of Fincham (Fincham, 2019), which attributes the principal lever of reducing illicit circulation to further normative development, does not predict the depth-dependent pattern of the advantage observed here. At chain depths of three or more, the marginal contribution of additional normative detail to detection efficacy decays faster than the marginal contribution of formalized evidentiary aggregation, since the failure mechanism of rule-based systems consists in the multiplicative decay of attributional confidence, which no refinement of substantive norms can overcome in the absence of a quantitative aggregation model.

Network models of the illicit art market (Campbell, 2013; Dietzler, 2013) specify the conditions under which risk-bearing configurations emerge without providing a formal apparatus for decision-making in an individual transaction, and it is precisely this gap that the stage-gate architecture occupies by translating network signals into quantitative preconditions of permissions over individual stages. The recall gap of 0.342 between the proposed architecture and the baseline transposing the banking AML toolkit does not close under tightening of threshold values or expansion of the sanctions list, since the limitation is architectural rather than parametric in character: binary firing admits no operator of aggregation over multiplicatively decaying confidence. The stable broker positions identified by network criminology correspond, in the proposed formalism, to nodes appearing in a disproportionately large number of beneficial-ownership chains, with this structural feature being directly observable during traversal of the graph of an individual transaction and requiring no prior macro-level network reconstruction, which inverts the analytical direction of network criminology and carries the operational consequence that intervention does not require waiting for the accumulation of transactional data sufficient for network reconstruction, since the network signal is computed online from the graph state available at the intake stage of the transaction.

The thesis that the persistence of illicit circulation is localized predominantly in collector-side neutralization techniques (Mackenzie & Yates, 2020) is refuted by an architectural observation: once evidentiary aggregation and cascading gate revocation have been formalized, the subjective rationalization of the participant loses operational purchase, since passage through an irreversible stage becomes a function of the graph state rather than a function of participant interpretation. The mechanistic source of this divergence consists in the fact that neutralization techniques operate in environments where the final decision rests with the participant and lose force in environments where the decision is deterministically derived from quantitative preconditions without an interpretive step, which does not annul the criminological relevance of research on neutralization (Bowman, 2008; Yates *et al.*, 2017) but shifts the lever of practical intervention from participant attitudes to the architecture of the procedure, in consonance with the structural reading of the limits of enforcement in cross-border art proceedings (Manacorda & Chappell, 2011; Hufnagel & Chappell, 2019).

The F1 range from 0.871 to 0.914 under a ± 0.10 perturbation of the authority-to-transfer weight reveals the robustness of the aggregated indicator not as a result of the even contribution of components but as a consequence of the ceiling role of authority to transfer, which renders the model weakly dependent on calibration precision of the remaining weights and accords with the doctrinal position concerning the structural primacy of verified authority in obligational binding (Tsirogiannis, 2016; Gerstenblith, 2013).

The fall of F1 to 0.68 on the free-port subsample demarcates the boundary of applicability and identifies a specific direction of extension: the introduction of event nodes for indirect change of control registered through corporate modifications in holding structures requires integration with registries of corporate beneficial ownership, which lies outside the present implementation while not contradicting its formal architecture, concretizing Mackenzie's observation (Mackenzie, 2011) on the structural opacity of the free-port segment into a quantitatively bounded gap measured by a recall of 0.54 on the corresponding subsample. The differential of 0.348 points of F1 between the principal corpus and

the free-port subsample quantitatively characterizes the limit of a graph representation in which object-centred events serve as the primary triggering mechanism, while extension toward holding-centred event nodes requires no revision of the gate-state derivation function or of the indicator aggregation rule, since the deficit lies in the coverage of input data rather than in the capacity for inference.

CONCLUSION

Deterministic blocking of the irreversible stage of a transaction on the basis of a quantitatively aggregated evidentiary base, recomputed in cascade upon the arrival of disconfirming facts, becomes feasible at fiduciary chain depths from three layers upwards, that is, in the very configuration on which the rule-based baseline yields a recall of 0.560 while the proposed architecture attains a recall of 0.902 under identical testing conditions. What remains open is the formalization of event nodes for indirect control in transactions executed entirely through transfer of shares in top-level holding structures without any record of title transfer over the object itself, that is, in the configuration on which F1 falls to 0.68 at a recall of 0.54 and which sets the lower bound of applicability of the present model pending integration with registries of corporate beneficial ownership of sufficient granularity to register share transfer as a triggering input to the graph.

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