RFID APPLICATIONS IN THAILAND'S RETAIL GOLD SUPPLY CHAIN

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Abstract

This research explores the use of RFID in the retail gold supply chain as a means of improving supply chain efficiency and mineral traceability. RFID has value as a tracking and tracing technology to reduce supply chain shrink, improve efficiency, and eliminate conflict minerals. The aim of the research is to investigate the benefits and use of RFID in the retail gold supply chain. The paper tests a conceptual framework of barriers and benefits to RFID implementation in the retail gold supply chain in Thailand. This conceptual framework was tested in a survey of gold retail experts in Thailand (n = 237). Analysis was conducted using structural equation modeling. The findings showed that fragmented supply chains (-), traceability (+), supply chain efficiency (+), shrink and inventory control (+) were significant factors in adoption. However, legal import status of gold and artisan production were not significant. The implication of the study is that RFID does have some significant benefits for gold supply chains, but there are also barriers, especially those related to supply chain fragmentation.

Keywords: RFID, Gold investment, Conflict minerals

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Introduction

Gold is a common retail investment vehicle, with small-scale investors often holding gold in lieu of or as a supplement to other investments (Grynberg & Singogo, 2019; Kumar & Raj, 2019). The supply chain for this investment gold is oblique and sometimes illicit (Finlay, 2020)(Grynberg & Singogo, 2019). Gold can be difficult to trace, in part because of gold mining in conflict regions, including the Democratic Republic of Congo (DRC), where it is extracted and sold illegally to fund military conflict (Finlay, 2020). The conditions of the retail gold supply chain require increased traceability and improved efficiency, which are problems RFID could solve.

RFID in Supply Chain Management

RFID is commonly used in retail supply chain management, from raw materials to retail inventory and stocking (O'Bannion & McMurtrey, 2018). There are many benefits it offers in this domain.

Increased supply chain efficiency.

RFID has retail supply chain benefits under conditions of high supply chain cooperation and coordination (Wang, Hu, Chang, & Ding, 2018). These include supply chain efficiency and reduced management cost, which is strongest for low-volatility demand and long lead times. Deployment of RFID can improve efficiency and avoid bullwhip effects (Wiedenmann & Größler, 2019). However, the range of RFID products and implementations means not all implementation methods deliver the same benefits (Wiedenmann & Größler, 2019). A study of an airplane manufacturing supply chain showed the cost advantages of RFID (Santonino et al., 2018). Several cost reduction points were associated with the supply chain at the producer, distributor, and retailer level. Cost savings could therefore be recognized along the supply chain at different levels. Thus, RFID can improve supply chain efficiency and reduce costs, especially in a coordinated supply chain.

Reduced shrinkage and improved inventory management.

Shrinkage is the rate at which goods acquired for sale are not sold, for example because of theft or damage. Managing the shrinkage rates has high costs, like security monitoring and retail employee costs (Beck, 2018). RFID has the potential to reduce shrinkage, for example through accurate inventory counting, preventing dispatch of incomplete shipments, and increasing stock monitoring (Wang, Hu, Chang, &

Ding, 2018). RFID can also improve inventory management, one of the main reasons for adoption (O'Bannion & McMurtrey, 2018). One study investigated a major retailer in China regarding their willingness to implement RFID technology (Liu et al., 2019). They found that perceptions of reduced shrinkage and increased ability to monitor and control inventory was a factor in the adoption of RFID technology (Liu et al., 2019). Another study in South Korea showed that reduced costs, were a major adoption motivator (Sawng et al., 2018). Thus, the potential for improvement of inventory management costs is a major benefit for RFID adoption.

Goods traceability.

Goods traceability is a verifiable chain of handling or ownership from production to the ultimate owner (Agrawal, Koehl, & Campagne, 2018). Gold's role as a conflict mineral (Finlay, 2020) does introduce an enhanced need for goods traceability, particularly in situations where buyers either have ethical or legal requirements for conflict mineral avoidance (Dickinson, 2013). RFID enables traceability because the tags are cheap and small for application to individual items from extraction (Agrawal et al., 2018). RFID technology can be implemented from end-to-end, enabling a full chain of ownership. This feature has mostly been used in agricultural supply chain for perishability and food safety tracking (Ferrero, Gandino, & Montrucchio, 2018). It can also be used in pharmaceutical and emergency medicine (Saflkhani et al., 2020). Thus, the ability to track and trace specific inventory items is one of the main benefits of RFID technology for gold production.

REID in the Retail Gold Supply Chain

RFID can be used to manage electronic waste and recycling precious metals like gold and platinum (Ullah & Sarkar, 2020). RFID tags may also be used to track ores (Bergquist & Vanhatalo, 2020). However, there is no evidence for RFID in the retail supply chain. This may be because the gold supply chain is fragmented, competitive and reliant on small suppliers (Heidingsfelder, 2019). Furthermore, much gold comes from small-scale artisanal miners in Africa who are working at the livelihood level, although this is beginning to change slowly (Lanzano, 2018). This would prevent the supply chain coordination where RFID works best (Wang et al., 2018).

Conceptual Framework and Hypotheses

RFID can be effective at increasing supply chain efficiency and reducing handling costs (Santonino et al., 2018; Wang et al., 2018; Wiedenmann & Größler, 2019). RFID can also improve the accuracy of data within the supply chain, as well as preventing tampering with data and shipments, which can reduce fraud and transaction costs (Ghode et al., 2020). RFID technology can achieve efficiencies like avoiding stockouts and whiplash effects, resulting in more efficient operation. This has the effect of reducing channel costs, particularly for goods that have a complex, inefficient or loss-prone distribution channel (Li, 2020). Furthermore, (2020) notes, RFID is one of the best understood and least expensive of the smart technologies for supply chains, meaning that these efficiency gains are highly effective compared to others. Thus, our first proposition relates to improved efficiency:

Hypothesis 1: Use of RFID in the retail gold supply chain will increase supply chain efficiency and reduce handling costs.

As a dense, highly valuable material, gold is vulnerable to loss and theft. RFID can reduce shrinkage rates and generally improve retail inventory management practices (Beck, 2018; Ghode et al., 2020; Liu et al., 2019; O'Bannion & McMurtrey, 2018; Sawng et al., 2018). RFID is one of the main inventory management strategies available to the supply chain manager to help control losses in the case of goods that are prone to inventory inaccuracy (Tao et al., 2019). Furthermore, the sharing of RFID tag prices reduces the implementation load on any given implementer, making it particularly helpful for fragmented supply chains. Thus, the second hypothesis is that:

Hypothesis 2: Use of RFID in the retail gold supply chain will reduce shrinkage rates and improve inventory management.

RFID could also offer material traceability and a secure chain of ownership from producer to consumer. A number of studies have established the basic application of RFID technology to traceability for critical applications like food safety, patient and pharmaceutical safety, and tracking and tracing of high-value devices and components (Agrawal et al., 2018; Ferrero et al., 2018; Ghode et al., 2020; Safkhani et al., 2020). These studies allow us to argue as our third hypothesis that:

Hypothesis 3: Use of RFID in the retail gold supply chain will increase material traceability.

There are several potential barriers to RFID adoption in the gold supply chain. There is the problem of supply chain fragmentation and nonlinearity, which could prevent wholesale adoption of any particular technology (Heidingsfelder, 2019; Kumar & Raj, 2019). Furthermore, there is the problem of the relative cost of implementation and distribution of these costs among the actors in the supply chain (Yan et al., 2018). This problem means that in a highly fragmented supply chain it may be difficult to align the interests of the actors to allow for implementation. This fundamental problem relates to our fourth hypothesis:

Hypothesis 4: Fragmented supply chains are a barrier to RFID implementation in the gold supply chain.

There is also problem illegit and illegal gold supply, which may be integrated with legal gold supplies (Finlay, 2020; Kumar & Raj, 2019). This allows is to make the following statement for our fifth hypothesis:

Hypothesis 5: Legal status of gold imports are a barrier to RFID implementation in the gold supply chain.

Finally, there is the problem of dependence on artisan production, particularly in Sub-Saharan Africa, and lack of resources for high-technology solutions (Finlay, 2020; Heidingsfelder, 2019). Thus, our final hypothesis is:

Hypothesis 6: Dependence on artisan production is a barrier to RFID implementation in the gold supply chain.

Conceptual model

The conceptual model of the research (Figure 1) identifies three benefits of RFID technology implementation and three barriers.

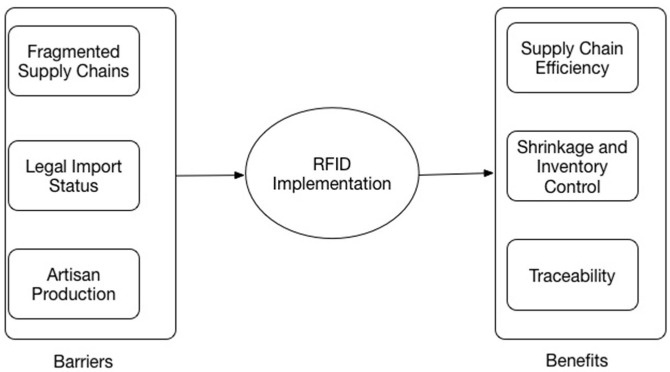

Figure 1 A conceptual model of RFID technology implementation in the gold supply chain

Materials and Methods

Data was collected from a convenience sample of experts in the gold industry in Thailand, including retailers, marketers, and supply chain managers and retail gold purchasers (n = 237). The questionnaire was distributed online, using professional communication sites, email lists and other sources of shared interest and professional practice to recruit participants. The researcher also recruited participants through known professionals in the gold industry, using a snowball sampling technique (Gravetter & Wallnau, 2017) to increase the sample size.

Cronbach's alpha (≥.60) was used to test internal consistency (Kiliç, 2016). As this table shows, all of the subscales of the questionnaire passed the reliability test.

Descriptive statistics and basic reliability tests were conducted first. Confirmatory factor analysis (CFA) was then used to investigate the factor structure (Brown, 2015; Finch & French, 2015). Structural equation modelling (SEM) was used to investigate the proposed conceptual model (Kline, 2016; Gravetter & Wallnau, 2017).

Results

Descriptive Statistics

Descriptive statistics are summarized below (Table 1). Shapiro-Wilk statistics for the scales ($p > .05$) indicated that the scales were in general normally distributed, which is supported by the skewness and kurtosis (<2) (Gravetter & Wallnau, 2017). This confirms the assumption of normal distribution for SEM (Kline, 2016; Schumacker & Lomax, 2017).

Table 1 Descriptive Statistics

	Mean	S.D.	Skewness	Kurtosis	Shapiro-Wilk (p)
FSC	3.99	1.18	-.012	-.795	.812
LIS	2.72	.92	.078	-.877	.294
AP	3.49	1.01	-.006	-.420	.485
SEC	4.19	.74	.014	-1.181	.075
SIC	4.52	.68	-.034	-.101	.096
T	4.32	.99	-.101	-.977	.155
RA	3.38	1.28	-.635	-.636	.682

Measurement Model (CFA)

The measurement model was tested using CFA (Table 2 and Figure 2). The CFA process was used for model testing and reduction, with items with a standardized path estimate of .40 or below considered for removal (Finch & French, 2015). The lowest standardized estimates were for AP1 and AP3, but these items were consistent with the expected scale. Therefore, no items were removed during the CFA process's model reduction stage. A chi-square test for exact fit did not indicate that the model was exactly fitted (χ^2 = 229, p = .001). However, relative goodness of fit tests did pass appropriate thresholds, including CFI (.970, compared to .95 or above threshold), TLI (.963, compared to .95 or above) and RMSEA (.0393, compared to .06 or lower) (Brown, 2015; Finch & French, 2015; Schumacker & Lomax, 2017). Therefore, the measurement model was considered adequately fitted and the SEM process could therefore continue.

Table 2 Confirmatory factor analysis (CFA) results

Factor	Indicator	Estimate	SE	Z	p	Stand. Estimate
FSC	FSC1	0.996	0.1019	9.78	0.000	0.684
	FSC2	1.032	0.1043	9.89	0.000	0.699
	FSC3	1.027	0.1034	9.94	0.000	0.704
LIS	LIS1	1.044	0.0905	11.54	0.000	0.729
	LIS2	1.207	0.0915	13.19	0.000	0.826
	LIS3	1.027	0.0932	11.01	0.000	0.703
AP	AP1	0.688	0.1382	4.98	6.246e-7	0.492
	AP2	0.893	0.1568	5.70	1.229e-8	0.618
	AP3	0.617	0.1306	4.73	2.282e-6	0.430
SEC	SEC1	1.235	0.0769	16.06	0.000	0.856
	SEC2	1.274	0.0751	16.97	0.000	0.888
	SEC3	1.341	0.0754	17.78	0.000	0.915
SIC	SIC1	1.241	0.0730	16.99	0.000	0.900
	SIC2	1.218	0.0775	15.71	0.000	0.853
	SIC3	1.138	0.0745	15.28	0.000	0.837
TI	T1	1.261	0.0707	17.84	0.000	0.914
	T2	1.222	0.0712	17.17	0.000	0.892
	T3	1.206	0.0726	16.62	0.000	0.874
RA	RA1	0.942	0.1085	8.68	0.000	0.659
	RA2	0.962	0.1080	8.91	0.000	0.685
	RA3	0.891	0.1073	8.31	0.000	0.616

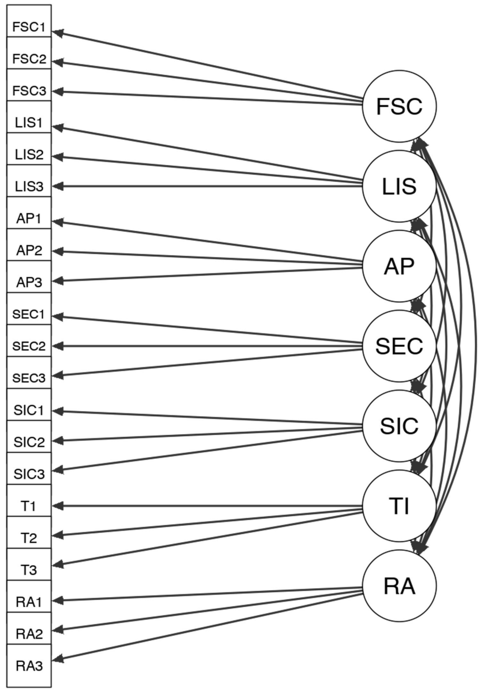

Figure 2 Measurement model

SEM Outcomes

The SEM process was designed to identify the significant factors in RFID Adoption (RA). To begin, an initial assessment of model fit was conducted. The chi-square test (χ^2 = 12.3, p = .196) indicated that the model was well-fitted in exact terms. This was also true for the relative goodness of fit tests (CFI = .965; TLI = .970; RMSEA = .039). Therefore, the model was considered adequately fitted.

Table 3 SEM Coefficients

Predictor	Estimate	t	*p*
FSC	-.311	3.31	.019
LIS	-.106	1.72	.086
AP	-.116	-1.58	.054
SEC	.238	3.54	.016
SIC	.212	4.21	.037
T	.305	9.77	.000

The relationships of the hypotheses were assessed based on the regression coefficients produced within the SEM process. Regression estimates (Table 3) show that the strongest significant factor was FSC (-.311), followed by T (.305), SEC (.238), SIC (.212), and AP (-.116) and LIS (-.106). All of these regression relationships were significant ($p < .05$) except for the LIS→RA ($p = .086$) and AP →RA ($p = .054$) relationships. The standardized coefficients imply that the strongest barrier to RFID adoption was the fragmented supply chain. It implies that the strongest driver of RFID adoption is traceability concerns in the supply chain. Supply chain efficiency and shrinkage and inventory control are also drivers for adoption, but barriers including the legal import status of gold and artisan production were not shown to be a significant reason for adoption of RFID.

Discussions

Based on the findings, research hypotheses H1, H2, and H3, along with H4, could be accepted. The expert survey demonstrated that many of the potential benefits of RFID in the retail gold supply chain were recognized. The strongest barrier was the fragmented nature of the supply chain, which has been identified as a barrier to adoption of any technology in a widespread fashion (Heidingsfelder, 2019; Kumar & Raj, 2019). The strongest positive factor in adoption was traceability of gold supplies. This has been identified in other contexts as one of the biggest benefits of RFID adoption for high-value goods such as pharmaceuticals (Agrawal et al., 2018; Ferrero, et al., 2018; Safkhani et al., 2020). Therefore, it is not surprising that it would be considered to be a factor in RFID adoption. Supply chain efficiency (Santonino et al., 2018; Wang et al., 2018; Wiedenmann & Größler, 2019) was also a concern, although it was less of a concern than either the fragmentation of the gold supply chain or trackability and traceability of gold supplies. The potential for RFID adoption as a way to reduce shrinkage (internal and external loss from theft or damage) (Beck, 2018; Liu, et al., 2019; O'Bannion & McMurtrey, 2018) was also recognized in the model, as one of the potential benefits that could lead to adoption of RFID technology at the retail level.

Hypothesis H5 and H6 were rejected, even though gold supply chains may be contaminated with illicit or grey market imports (Finlay, 2020; Kumar & Raj, 2019). It is possible that gold retailers are either unaware of, or perhaps unwilling to admit to, the scope of illegal imports, which could obscure the importance of legal import status for RFID adoption. It is also possible that retailers are unaware of the role of artisan production (Finlay, 2020; Heidingsfelder, 2019), as they may be separated from the artisan production level. Thus, it is not that these factors are unimportant, but rather that they may be unrecognized at the retail level. These factors may influence the adoption of RFID tracking in the upstream supply chain without retailer knowledge.

The main problem of implementing RFID in the supply chain may be that the supply chains are so fragmented it is difficult to align the interests of different actors (Yan et al., 2018). This could mean that no single actor is willing to pay the cost of RFID implementation, even if all members of the supply chain would benefit. Despite this, the benefits of implementation, especially increased resilience to fraud and shrinkage (Li, 2020), may be important in the long term. This could particularly be true if there is a reduction in gold price that demands increased efficiency.

Conclusions

The aim of this research was to investigate the potential facilitators and barriers to adoption of RFID technology in the retail gold supply chain in Thailand using an expert survey. The expert survey identified several benefits, especially traceability and supply chain efficiency, as positive factors in the adoption of RFID tracing technology in the retail supply chain. However, the only major barrier was the fragmentation of the gold supply chain.

The implication is that industry views support the potential benefits of RFID adoption. It is possible that RFID tracking may soon become a commonplace tool for the gold supply chain in Thailand. Therefore, gold retailers may wish to begin discussion with suppliers about implementing RFID tracking in the supply chain to achieve these benefits. As for academic interest, findings show that RFID is becoming more affordable and commonplace outside of the controlled supply chains of pharmaceutical manufacturers and other integrated firms. Thus, it should be considered as a possible technology for use in other fragmented supply chains.

As for limitations, the study only investigated Thai gold retailers, and did not consider the upstream supply chain. It is also possible that the nature of some of the questions (especially those regarding legal import status of gold and artisan production, commonly associated with trade in conflict minerals) led to some degree of respondent bias in the questions.

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