Massachusetts Institute of Technology
Media Lab's Digital Currency Initiative
Sloan School of Management

A Stakeholder Analysis of Agricultural Finance in Ukraine: Prospects for Blockchain-based Warehouse Receipts

Authors: Mark Weber (Graduate Researcher, MIT DCI) and Mykola Yerin (Fellow, MIT Sloan)
Advised by: Nikos Trichakis, Ph.D. (Assistant Professor, MIT Sloan School of Management)

Keywords: b_verify, Blockchain

Blockchain Lab Program
2017-2018 Working Groups Cycle
Taught by N. Narula, G. Gensler, S. Johnson, and M. Casey
Member Company: IADB
Project Group: b_verify

A stakeholder analysis of agricultural finance in Ukraine

Prospects for blockchain-based warehouse receipts

Abstract: A warehouse receipt is a bearer financial instrument asserting the ownership of goods held in a storage facility. In the agricultural sector, especially in emerging markets, warehouse receipts have been found to improve access to credit and pricing power for farmers. But these benefits are stifled by high profile frauds, high transaction costs, and questionable custodianship. We have developed an experimental software protocol called `b_verify`. Its purpose is to provide an improved technical foundation and open-source standard for the issuance, verification, and transaction of warehouse receipts, and eventually other financial instruments and tradable securities. In this paper, we describe our primary and secondary research on Ukraine and evaluate the country as a prospective pilot location for `b_verify`. We describe the process of depositing goods and the issuance of a warehouse receipt, as observed in a full system walkthrough of a major Ukrainian storage facility, and highlight vulnerabilities. We synthesize insights into the agricultural commodities trade based on stakeholder interviews. We conclude by recommending Ukraine as a strong prospect for a pilot of the `b_verify` protocol.

Paper by:

Mark Weber
Graduate Researcher, MIT Digital Currency Initiative
Fellow, Legatum Center for Development & Entrepreneurship

Mykola Yerin
Fellow, MIT Sloan School of Management

Advised by:

Nikos Trichakis, Ph.D.
Assistant Professor, MIT Sloan School of Management

Version date:

May 24, 2018

Table of Contents

Preface: Unlocking "dormant capital"

"Dead capital" is a term coined by the Peruvian economist Hernando De Soto to describe the depressed values and constrained functionality of assets due to dysfunctional property systems. For example, a title record for a parcel of land, if tenuous or untrusted, loses its trade value as well as the ability to be used as collateral for a loan. De Soto's research, which primarily concerns land and prescribes public policy reform, estimates upwards of US$9 trillion of "dead capital" around the world; the exactitude of this figure is uncertain, but the logic of the argument is widely accepted.

We modify De Soto's term to "dormant capital" and extend the argument to other asset classes such as inventories. We hypothesize that, in addition to the legal and policy measures needed, new advancements in blockchain technology and the Internet-of-Things (IoT) can be harnessed for asset records to help unlock billions, if not trillions of dollars in our economies, and contribute to better ecosystems for finance and trade that are at once safer and more transparent, as well as more dynamic and inclusive.

Introduction

The b_verify protocol for blockchain verifiable records

`b_verify` is the name of an applied research project and software protocol we developed at the MIT Digital Currency Initiative at the MIT Media Lab and the MIT Sloan School of Management, with support from the MIT Legatum Center for Development & Entrepreneurship and the Inter-American Development Bank.[1] Its purpose is to provide a new technical foundation and open-source standard for secure, publicly verifiable and transferable records using public blockchain architectures such as those provided by Bitcoin and Ethereum, as well as optional Internet-of-Things (IoT) integrations. The protocol is designed to support the issuance, verification, collateralization, transaction, and retirement of warehouse receipts, and eventually other financial instruments and tradable securities. We provide details on the design parameters for the warehouse receipts use case in the next section.

At a high level, from a computer science and systems engineering standpoint, the `b_verify` protocol is novel in several ways. First, a server (e.g. a cloud server managed by the government) is used as a central repository of information but uses Bitcoin (or another public blockchain of choice), public key cryptography and authenticated data structures to prevent the server from manipulating the information. Second, clients (e.g. farmers, lenders) store their own data and submit proofs to one another to authenticate it; this means client proofs are still valid even if the server goes offline. Third, the protocol is "light-weight," allowing for mobile devices to fully and securely participate.

Whereas many experimental solutions in this space are kept proprietary, we are releasing a "pilot kit" with open-source reference code (Java) for the `b_verify` protocol, template desktop and mobile applications (Android) utilizing the protocol, and associated papers detailing our work as well as considerations for real world experimentation.

[1] "MIT" is the Massachusetts Institute of Technology in the United States. It is widely regarded as the top computer science engineering university in the world, as well as a top five school for business.

Warehouse receipts

Negotiable warehouse receipts or "double warehouse certificates" (hereafter referred to simply as warehouse receipts) are bearer instruments detailing the ownership, origin, quantity, and quality of goods held in a storage facility. They are used for facilitating trade, securing inventory as collateral, and settling futures contracts, especially for agricultural, metallurgical, and mineralogical commodities. In this paper, we focus on agriculture.

Warehousing systems and their corresponding receipts are known to improve access to credit, price discovery, and pricing power for producers, even among the poorest farmers.[2] For example, a USAID program in Tanzania produced a doubling of the prices farmers were able to command for their harvest almost immediately upon the installation of a formalized storage and warehouse receipt program.[3]

Governments and economic development agencies around the world have implemented warehouse systems to strengthen the agricultural sector and to improve national food security and international competitiveness. Since 2011, the Global Warehouse Finance Program under the International Finance Corporation of the World Bank has provided upwards of US$7.5 billion warehouse receipt financing in more than 41 countries in an effort to support small-medium enterprises.[4]

These systems require regulatory coordination between government and industry, including functioning commodity exchanges for price transparency and legislative measures to ensure the legal backing of warehouse receipts themselves, whether in paper or electronic form.[5]

Paper vs. Electronic Warehouse Receipts

Today, warehouse receipts are predominantly paper-based. Of 62 agriculture-based countries surveyed in 2017 by the Enabling Business of Agriculture initiative of the World Bank, 36 reported having paper warehouse receipt laws in place while only 13 have updated their laws to accommodate electronic warehouse receipts (EWR's), Ukraine being among these; the remaining 13 have no reported legislative framework in place.[6] In advanced economies such as the U.S. cotton market, EWR's have become the new standard, rendering paper obsolete.[7]

In recent years, a number of governments have prioritized the EWR legislative reforms as part of their broader national digital strategies. Indeed, our work on warehouse receipts was originally motivated by a 2016 knowledge-partnership with Mexico's ministries of Finance and Economy, which sought to explore blockchain technology as it pursued the legal and technical aspects of warehouse receipt digitization. Our

---

[2] "Warehouse Receipts for Food Security: Benefits and Challenges," USAID 2010.
[3] "Warehouse Receipt System," East Africa Trade Hub, USAID.
[4] Trade Finance and SMEs: Bridging the gaps in provision, World Trade Organization.
[5] "Designing Warehouse Receipts Legislation: Regulatory Options and Recent Trends," FAO 2015.
[6] Enabling the Business of Agriculture, World Bank. Note: to select these 62 agriculture-based countries, the EBA team clustered all countries based on the contribution of agriculture to GDP and employment, then excluded countries Purchasing Power Parity (PPP) of less than US$1 billion unless the population employed in agriculture was more than 100,000 people.
[7] *A Roadmap to Better Understanding the Issuance and Transfer of Negotiable Electronic Warehouse Receipts In the American Cotton Trade*, Ari M. Pozez. Arizona Journal of International and Comparative Law, 2016.

work, including the development of the `b_verify` protocol, has since been informed by stakeholder interviews and warehouse facility visits coordinated for us by the Mexican government.

Problems and solutions

Three main problems prevent warehouse receipts from realizing their full potential for farmers and society: forged documents, high transaction costs, and the potential for disparities between the receipt attestation and the physical goods. We have designed the `b_verify` protocol to help mitigate these problems.

First, high profile frauds involving falsified warehouse receipts, such as a multi-billion dollar warehouse receipt fraud in the Qingdao port of China, have cost banks hundreds of millions of dollars.[8] Such events make banks wary of lending against warehouse receipts and make traders wary of buying them. The `b_verify` protocol addresses this problem by creating signed, digital receipts and publishing cryptographic commitments to set of issued receipts on the Bitcoin blockchain as a secure, public source of record.

Second, assuming the receipts are authentic, the transaction costs involved in verifying and transporting paper records are extremely high, especially in countries with poor infrastructure. To address this, we have developed a new method of updating and transferring ownership records using cryptographic proofs constructed by a designated server, which need not be trusted. To our knowledge, our method is unique among available solutions and reconciles an ongoing debate between public and private blockchain implementations.

Third, again assuming authentic receipts, banks and traders worry about the quality and honesty of warehouse custodianship; perhaps the goods are removed illegally for example. While this problem cannot be completely eliminated by technology, access control measures and Internet of Things (IoT) integrations can combined with the `b_verify` protocol to reduce these risks. For example, outflows of grain from a silo could require authentication via a query of the blockchain record, while digital devices measuring the outflow can independently commit updates to the record without human interference.

An added feature of the `b_verify` protocol is the opportunity for the programmatic enforcement of covenants and contracts (also known as "smart contracts"). For example, using an application servicing the `b_verify` protocol, the pledging of collateral with a warehouse receipt could automate the transfer of the collateral to the lender upon a hard loan default. Covenants such as maximum debt-to-asset ratios or minimum allowed commodity price fluctuations could also be constructed within the `b_verify` system.

The verifiable activities of a given business over time, such as inventory turnover and repayment history, can also provide valuable insight into the health of the business, which is the chief consideration in assessing creditworthiness.

[8] "The biggest warehouse frauds of recent times," Metal Bulletin, 2017..

Lastly, the transparency provided by this publicly accessible and verifiable system of record may contribute to safer, more transparent in asset-backed securities and derivatives markets as these develop in emerging economies.

Thus, we form the following hypothesis: successful implementation of the `b_verify` protocol would 1) reduce transaction friction, 2) improve access to credit, 3) improve price discovery and power, 4) improve supply chain provenance (entire history preserved), 5) improve transparency in asset-backed securities markets. Moreover, these can be achieved using without the need of a trusted server and without using a private-permissioned blockchain.

Ukraine: the breadbasket of Europe

Once known as the "breadbasket of Soviet Union" and now considered "the breadbasket of Europe," Ukraine is one of the world's leading agricultural producers, with exports of $22.6 billion in 2017.[9] Its fertile black soil supports the production of grain, sugar beets, sunflower seeds, and vegetables, as well as beef and milk. Agricultural production constitutes 14% of the county's GDP (2017 estimate) and 5.8% of its labor force, or approximately one million people (2014 estimate).

Despite its agricultural prominence, Ukraine is considered a "Lower middle income" country by the World Bank and ranks low among other agriculture-based nations, as scored on multiple categories by the Enabling the Business of Agriculture initiative. Table 1 displays a sampling of these rankings descending by Finance Ranking.

Table 1: Sampling of Enabling the Business of Agriculture rankings

Economy	WB Income Group	Seed Ranking	Machinery Ranking	Finance Ranking	Markets Ranking	Transport Ranking	Water Ranking	Information Communications Technologies Ranking
Nigeria	Lower middle income	42	16	22	48	43	46	37
Bangladesh	Lower middle income	54	49	23	21	45	56	37
Guatemala	Lower middle income	26	57	24	14	58	58	21
Mozambique	Low income	23	47	25	30	33	21	22
Ukraine	Lower middle income	33	15	26	26	42	29	43
Ethiopia	Low income	39	25	27	51	21	34	62
Malaysia	Upper middle income	45	18	28	40	54	45	22
Thailand	Upper middle income	32	24	29	52	53	60	31
Vietnam	Lower middle income	43	10	30	31	7	27	12
Uganda	Low income	31	31	31	45	18	26	22

Rationale for problem statement evaluation and pilot consideration

As a setting for testing our hypothesis, developing `b_verify`, and evaluating prospective pilot locations, Ukraine is interesting for several reasons.

First, our team has extensive experience in the agricultural and financial sectors in Ukraine. This has proved invaluable in our efforts to analyze a full cross-section of the sector under the neutral, academic banner of MIT.

[9] Ukraine, CIA World Factbook.

Second, Ukraine faces major problems of corruption. It ranks 130 out of 180 countries in Transparency International's 2017 Corruption Perceptions Index; even more concerning is the trend: its score has steadily declined since 2012.[10] This problem was evident in our stakeholder interviews; Ukrainians have become normalized to petty corruption as a part of everyday life, hardly worthy of reprehense. One Ukrainian explained the moral rationale driving the as follows: "If you aren't stealing from your business, you're stealing from your family." The International Monetary Fund (IMF), as Ukraine's single biggest creditor with a US$17.5 billion loan program, is increasingly pressuring both government and industry to prioritize transparency and anti-corruption measures. These priorities align with the problems the `b_verify` protocol is designed to address.

Third, Ukraine is among the few countries in the world that has already implemented laws for both paper and electronic warehouse receipts, and installed state databases for warehouse receipts and pledges of collateral. However, the current "real-world" state of these reforms is unclear.

Our stakeholder interviews indicate the Ukrainian government, under industry pressure, abandoned the enforcement of legal certifications of warehouses in 2014. Warehouse receipts are still legally recognized as bearer instruments, but there is apparently no state auditor certifying and monitoring the storage facilities. Mutual distrust between government and industry is something we have documented elsewhere, but qualitatively in stakeholder interviews in Mexico and quantitatively in our data analyses. For example, in a conjoint analysis of a survey we issued to a small, but influential group of Latin American lenders (see appendix), we found a surprising commonality among respondents highly distrustful of government and those highly distrustful of industry: they both favor open-source systems. Stakeholders in Ukraine, suffering from similar distrust dynamics, may be similarly receptive to the open-source neutrality the `b_verify` protocol calls for.

Fourth, the problem of "dormant capital" is especially acute in Ukraine, with the sale of farmland strictly prohibited by the government despite opposing pressures from the IMF, the agricultural sector, and the international investment community. Following the fall of the Soviet Union, small plots of land averaging 4 acres apiece were granted to Ukrainian citizens.[11] In 2001, the government banned the sale of these lands, effectively disabling the use of these lands as collateral (this ban was renewed in 2017). Many Ukrainians favor the policy, fearing that without, all of Ukraine's lands would fall into the hands of the oligarchs. For proprietors who lease their land instead of farming it, the policy ensures a modest annuity of approximately US$400 (11,500 hryvnia) per leased parcel, bolsterings incomes amidst a tough economic climate. In 2015, the World Bank classified 22% of Ukraine's population as living in "moderate poverty" and 5.8% living under the poverty rate of US$5 in Purchasing Power Parity.[12]

But the extra income for citizens from small-share land leasing comes at a great cost to agricultural productivity and macroeconomic outcomes for the country. With limited access to credit for working capital and investment, small-share farmers are forced to lease their land to or farm on behalf of the biggest companies. Industrial farming of any significant scale involves the negotiation of hundreds of individual leasing agreements with small share proprietors; this process is costly, inefficient, and subject

[10] Corruption Perceptions Index 2017, Transparency International.
[11] "Ukraine's Ban on Selling Farmland Is Choking the Economy," Bloomberg, 2018.
[12] Ukraine Economic Update, April 2017, World Bank.

to political corruption and illicit pressures. These complexities are too difficult for cash-strapped small-medium enterprises (SMEs) to manage, so Ukraine's farmland has become increasingly consolidated (in the form of leasing) by only the biggest corporations.

World Bank leaders estimate the country's land policy is costing the Ukrainian economy billions of dollars per year and suppressing land values to a third of their true value.[13] All of the agricultural stakeholders we interviewed, without exception, cited the land policy as the single greatest barrier to economic growth in the sector.

In the absence of land rights, alternative forms of financing, such as inventory-based lending, and reduced transaction frictions become all the more important for cash-strapped farmers and large agricultural holdings alike. Thus, the impact potential for the `b_verify` protocol is significant in Ukraine.

Stakeholder research

We conducted our stakeholder research in March of 2018. We interviewed commercial banks (Raiffeisen Bank, Crédit Agricole, NBP Paribas, Piraeus), suppliers of inputs to farmers (Syngenta and one of its distributors, international commodity traders (Glencore), agricultural producers (Kernel, Mriya, and Astarta), industry associations (Ukrainian Agribusiness Club, Chamber of Commerce, Agrihub), "agritech" entrepreneurs (GrainTrack, Agroxy, Aliro Trade), warehouse facilities (Astarta), and development institutions (International Finance Corporation, World Bank). These interviews compliment other stakeholder research we have conducted with other governments, multilaterals, and industry stakeholders in Latin America.

In the following sections, we detail our key observations and conclusions from these interviews, beginning with our on-site visit to a warehouse facility.

On-site analysis of agricultural deposits and warehouse receipt issuance

Arrival of goods and inspections

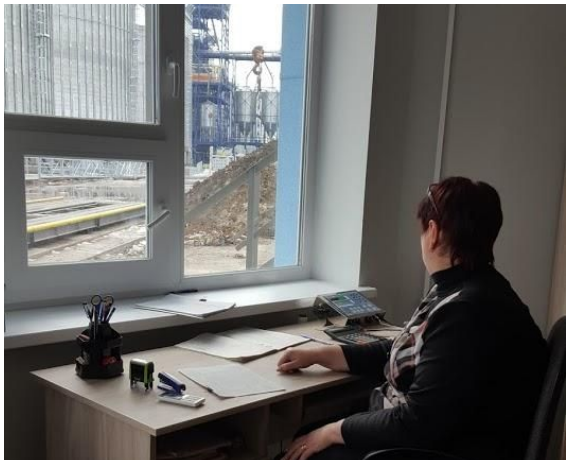
We conducted a full system walkthrough of an agricultural warehouse facility in the rural northeast of Ukraine near the city of Poltava. Owned and operated by a major agricultural holding (a farming company), this facility was undergoing an expansion to increase its storage capacity to 100,000 tons of wheat grain, or any combination of wheat, corn, and soybeans (total storage capacity varies based on product mix as goods vary in density). In addition to providing storage for its parent company, the facility rents storage space to other agricultural producers.

[13] "World Bank: Value of Ukraine's land to triple if farmland sales permitted," Kyiv Post, 2018.

Image 1: Entry gate to warehouse facility

The deposit process begins with a delivery of agricultural goods by truck. To deliver goods to the facility, a driver must first be on-boarded into the system and given a Radio-frequency identification (RFID) access card. Upon arrival at the facility, the driver scans an access card at the gate, then pulls the truck onto a weighing scale. This area is monitored by one or more warehouse employees as well as video cameras. The truck is weighed, the goods are offloaded, the truck is weighed again, and the difference determines the deposit quantity in weight.

Image 2: From a window overlook, a warehouse employee monitors and records the delivery and weighing of goods



Meanwhile, a small sample of the product is sent to a small laboratory for testing. Lab employees use various tools, including advanced electronic devices, to assess quality variables such as moisture, oil levels, and protein content. At the time of this visit, the electronic devices used were stand-alone, meaning the employee must be trusted to write down the correct read-out, but the facility director conveyed interest in eventually connecting these devices with the Enterprise Resource Planning (ERP) system.

Image 3: Laboratory testing of a sample of deposited corn

Employees record all outputs on paper notepads, then populate the results into a computer for sharing with the accountant, whose office is in a different building on site. To mitigate the risk of false entries, lab employees are blinded from the ownership details on lab samples. At this particular facility, those blinds seemed soft as the delivery truck was viewable just a few meters from the lab window.

Inflow of goods

Next is the preparation and deposit of the goods in the silo structure. For grain, as an example, this process takes approximately three to four hours. From a central operations center, an operator[14] uses a software system to orchestrate the flow of grain through a system of hoses to remove additives such as small rocks. The goods are then sent to a large dryer to remove external moisture. These steps may be repeated several times before the grain is sent to temporary storage, weighed again (less additives) to compare to the original weight logged on the delivery truck, then finally deposited in the large silos. Once in the large silos, at which point it is considered a commodity. Grain with more additives tends to fall to the sides, where it is periodically removed and run through the cleaning process again.

Image 4: Facilities and processes map of an agricultural warehouse

[14] At the warehouse we visited, there is only one employee trained to use the software governing the flows of products through the system. The director joked about problems arising if the employee had to take a sick day.

Issuance of a paper warehouse receipt

At this point, the information from the aforementioned processes is consolidated by the accountant on-site, who initializes the issuance of one of two types of warehouse receipts, a non-negotiable warehouse receipt or a negotiable warehouse receipt (also known as a "double warehouse receipt" or *Podviyne Pvidotstvo* in Russian-Ukrainian). These two types of documents have different regulatory controls. Negotiable warehouse receipts, which are the focus of this paper, are to be filed in a state registry, as are all pledges of collateral associated with these receipts in a separate registry of pledges. The accountant populates a digital form with standardized information on the quantity and quality of the good, as well as notes about the geographic origin and company depositing the goods. The receipt is given a unique identification number and printed on special paper standardized at a national level to make counterfeiting difficult. It is then signed and stamped by the silo director and the accountant. The warehouse receipt itself, as a bearer instrument, can only be picked up by the owner, or an agent authorized by the owner via notary.

Image 5: A signed and stamped warehouse receipt provided by the on-site accountant

Outflow of goods

A paper warehouse receipt is required to initiate the outflow of product to a railroad car or vehicle for shipment, at which point, the warehouse receipt is retired. Like the cleaning process, access control for outflows of grain involve an operator using the central software system; all inflows and outflows are to be recorded in the system log.

System vulnerabilities

Two general concerns about warehouse receipts involve custodianship and document integrity. We observed vulnerabilities relevant to both in our on-site analysis.

Among the chief custodianship concerns is that of unauthorized outflows i.e. theft. We observe several vulnerabilities to this threat. First, the periodic cleaning practice supports quality control, but it may also

normalize employees to seeing grain taken out of the sides of the silos. Second, it is unclear how easy or difficult it might be to corrupt the outflows log. Third, the silos have emergency spigots for outflows in case the system goes down.

We observe several key vulnerabilities with regard to document integrity. First, employees must be trusted to document all stages of a given deposit correctly and honestly, but there seem to be only minimal measures in place to ensure this. Second, there seem to be no measures in place to prevent false receipt issuance. This is especially risky when the operator of the warehouse is both a custodian of other owner's goods and a depositor of agricultural goods itself (such was the case for the facility we visited). There is little to stop the warehouse company, which is also an agricultural holding, from issuing itself warehouse receipts for goods that don't exist in order to access better financing. Third, our interviews indicate widespread concern about the reliability of the state registries for warehouse receipts and pledges, respectively.

Trade involving warehouse receipts

International commodity traders are an important element of the agricultural value chain in Ukraine. They source and export crops from medium and large farmers who, for legal, tax or logistic reasons are unable or unwilling to export on their own account.

The main trading agents for such farmers in Ukraine are ADM, Bunge, Cargill, Glencore and Dreyfus. We interviewed Glencore's Ukrainian CFO, the Country General Counsel and the Director of Trading. Glencore experienced a number of fraud and major contract default incidents in the past and now the company follows a strict procurement policy.

Glencore has to compete for farmers to source commodities at best price. To do so it finances forward contract to some farmers. This decision relies mostly on the farmer's reputation. The financing is not collateralized and is provided within the regional quota and individual limits defined by Glencore's headquarters in Rotterdam (US$10 million limit and typically not more than US$1 million per counterparty).

Ukrainian law accounts for three warehouse documents: warehouse confirmation (*Kvitantsiya*), warehouse receipt (*Svidotstvo*) and double warehouse receipt *(Podviyne Pvidotstvo*). Glencore uses warehouse confirmation (*Kvitantsiya*). This document confirms the fact of storage and cannot be used for transferring the title. *Kvitantsiya* cannot be used for pledging the grain as a collateral.

In addition to providing the storage document, the warehouse registrar makes a record in the centralized grain registry, a state database of electronic records. In practice, a digital record is considered worthless because digital records are not thought to be enforceable. Records are not publicly viewable; access to the register can be obtained through signing an agreement with the State Register of Ukraine, a state agency. Amendments of warehouse documents are not allowed. If Glencore wants to sell the portion of stored grain, the original receipt must be retired and a new receipt provided by an in-person process at the warehouse.

Any grain transaction demands the representative of Glencore to be present at the warehouse. Sometimes Glencore's employees have to drive to silos across the country on bad roads to pick up papers. This process is not only costly but also risky. Paper documents are easy to compromise, but the most common issue related to asset misappropriation is that a warehouse may simply sell crops without giving proper notice to Glencore. The judicial procedure is very slow in Ukraine and even when Glencore gets a court decision it struggles and sometimes fails to execute it. Glencore mitigates that risk by working only with carefully selected partner warehouses.

Glencore mentioned that it loses money by failing to get Value-Added Tax (VAT) compensation from the state. Cash transactions between small farmers, trade intermediaries, and warehouses are illegal but prominent. A warehouse does not check the legal status of farmers who bring grain for sell.

It is essential for Glencore to confirm transparent practices for compliance reasons (e.g. *UK Anti Bribery Act*). It is also critical to make sure that input VAT was originated on legit purchase transactions. As the commodity traders sell crops abroad they are eligible for cash reimbursement of the output VAT liability from government. Such tax assets are routinely audited by tax revenue service.

Glencore may be unknowingly exposed to compliance risks cause by (lack of) interoperability across record systems or tax fraud at several layers of counterparties before Glencore in the chain as the authorities may challenge those transactions. Cancellation of such incoming VAT invoices causes cascade effect for subsequent tax documents issued further along the chain.

Summary and conclusions

In summary, we detailed the `b_verify` protocol and the warehouse receipt use case in the context of unlocking "dormant capital" in the economy. We evaluated the agricultural sector of Ukraine, both its challenges and opportunities presented by `b_verify`. We described the processes involved in the deposit and custodianship of goods, and the issuance and retirement of warehouse receipts. We highlighted vulnerabilities observed in these processes. We synthesized our insights from interviews with a major commodities trader in Glencore.

We conclude by recommending Ukraine as a pilot country for the `b_verify` protocol. Ukraine is ripe for technological innovation to unlock its full economic potential. Its fertile soil and vast farmlands are invaluable comparative advantages. While seemingly intractable issues like land rights and corruption should remain reform priorities for the country, Ukraine can make more immediate advancements by utilizing the `b_verify` protocol to improve access to credit, reducing transaction frictions, and improving transparency in agricultural commodities markets.

Appendix

Conjoint survey and analysis

Survey design and data

Farmers' access to finance is a function of lenders' willingness to lend (WTL). To test our hypothesis that b_verify could increase WTL, we issued a survey[15] to Latin American lenders presenting respondents with a six attribute classes for an imagined warehouse system: 1) Blockchain verifiability of warehouse receipt records; 2) Internet-of-Things (IoT) integration; 3) Capacity constraints on warehouse receipt issuance; 4) Depositor detail - high, medium, low; 5) Warehouse detail - basic, advanced; 6) System authority - private, public-private partnership, government, open source. Each of these attributes is first explained to respondents in the survey and respondents are asked to rate their risk factors on a scale of 1-10.

Next is the conjoint part of the survey; respondents are issued a menu of 12 imaginary systems, each with variations across the six attributes, and asked to rank them in order of preference. This design serves as a "Bayesian truth serum" (Prelec, 2004)[16] forcing respondents into tradeoffs that will mathematically reveal their true utilities i.e. preferences for each attribute.

Lastly, respondents are asked demographic questions including job title, years of experience, lending policy-making power, and dollar value of assets under management; these questions indicate the respondents are indeed important stakeholders in this sector.

Eleven respondents produced usable data for analysis.[17] While this sample size is too small to produce scientific results, the expert nature of the respondents allows us to extract good qualitative insights.

Conjoint analysis

To conduct the analysis of the survey data, we utilized an R package called "conjoint."[18] This package requires a fair amount of data wrangling to accommodate its inputs. Once initialized, we proceeded to run a series of functions provided by the package.

First, we analyzed each respondent's preferences one at a time running a simple regression model with dummy variables using `caModel()`. This returns a vector of estimated parameters for the individual respondent for all variables. The coefficients are estimates of the "part-worth" utilities for each attribute. For example, Respondent A's preferences as revealed by linear regression are displayed in Figure 1.

---

[15] This survey was issued in 2018 but the original analysis was insufficient; we conducted a fresh analysis for this project.
[16] A Bayesian truth serum for subjective data.
[17] Some responses are discarded due to suspicious responses; e.g. leaving the rank of the menu untouched.
[18] Conjoint analysis method and its implementation in conjoint R package, Bak and Bartlomowicz.

Figure 1: Linear regression revealing preferences for Respondent A

```
Call:
lm(formula = frml)

Residuals:
      1       2       3       4       5       6       7       8       9      10      11      12
-0.31731  0.58654 -0.52885 -0.16346 -0.05769  0.90385  0.10577 -0.48077  0.16346  0.31731  0.05769 -0.58654

Coefficients:
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                      6.26923    0.31661  19.801  0.00254 **
factor(x$Blockchain)1            2.68750    0.32752   8.206  0.01453 *
factor(x$IoT)1                   0.65865    0.34391   1.915  0.19555
factor(x$Capacity_Constraints)1  1.17308    0.33170   3.537  0.07148 .
factor(x$Depositor_Detail)1     -0.01923    0.44226  -0.043  0.96927
factor(x$Depositor_Detail)2      0.23077    0.44226   0.522  0.65385
factor(x$System.Governance)1     0.14423    0.58870   0.245  0.82930
factor(x$System.Governance)2     0.28846    0.67572   0.427  0.71102
factor(x$System.Governance)3     0.20192    0.56971   0.354  0.75690
factor(x$Warehouse_Detail)1     -0.38462    0.41957  -0.917  0.45607
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.07 on 2 degrees of freedom
Multiple R-squared:  0.9816,    Adjusted R-squared:  0.899
F-statistic: 11.88 on 9 and 2 DF,  p-value: 0.07999
```

Second, we employ a different method in the conjoint package, `caUtilities()`, which produces a similar but more theoretically accurate result which is a vector of utilities for all attribute levels with the intercept on first place. In addition to providing a linear regression output akin to Figure 1 above, this method produces plots visualizing a respondent's preferences - see Figure 2. We repeated this method for each of the eleven respondents to produce.

Figure 2: Bar plot of respondent A's utility preference for blockchain verifiability

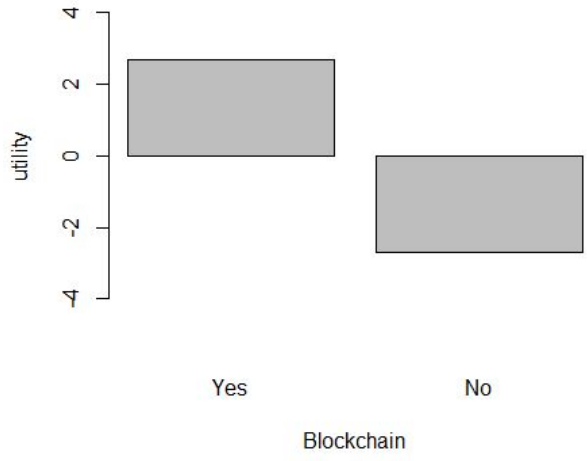


Figure 2 shows that Respondent A prefers blockchain with a part-worth utility of 2.69. With binary attributes, the inverse of this utility will always be mirrored.

Next, we employ the `caPartUtilities()` function to produce a table with all respondent utilities across all attributes. See Figure 3, color coded for readability.

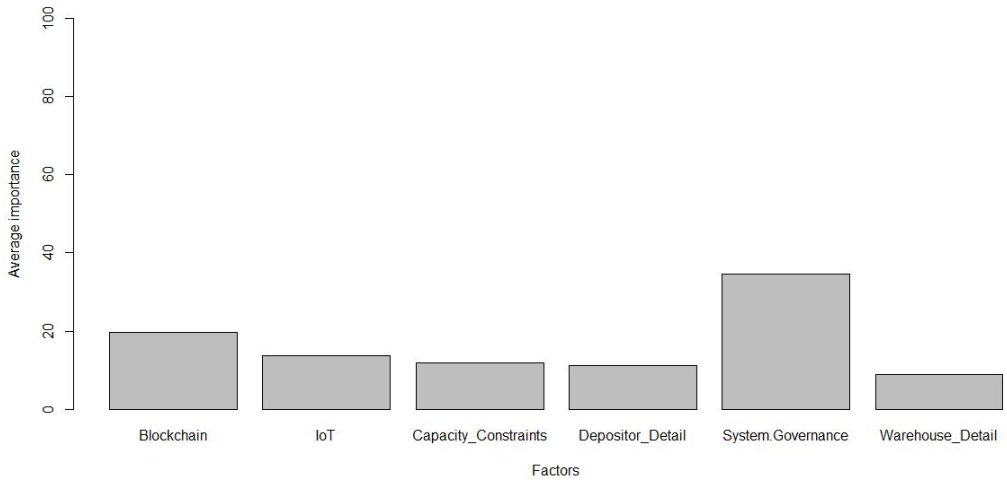
Figure 3: Attribute utilities for respondents

	Blockchain		IoT		Capacity Constraints		Depositor Detail			System Authority				Warehouse Detail	
Respondent	Yes	No	Yes	No	Yes	No	Low	Medium	High	Private	Public-Private	Government	Open-Source	Basic	High
A	2.69	-2.69	0.66	-0.66	1.17	-1.17	-0.02	0.23	-0.21	0.14	0.29	0.20	-0.64	-0.39	0.39
B	0.19	-0.19	-0.41	0.41	-0.02	0.02	1.31	-0.69	-0.62	0.88	-2.05	-2.42	3.59	-0.35	0.35
C	2.13	-2.13	2.11	-2.11	0.37	-0.37	0.32	0.32	-0.64	-1.40	1.19	0.64	-0.42	-0.42	0.42
E	-2.13	2.13	-0.41	0.41	-0.42	0.42	-0.48	0.77	-0.29	1.54	0.52	-3.39	1.32	-1.62	1.62
F	1.94	-1.94	-0.78	0.78	0.67	-0.67	-0.27	-2.27	2.54	1.46	-1.90	1.39	-0.95	0.12	-0.12
G	1.56	-1.56	1.93	-1.93	0.65	-0.65	-0.13	0.37	-0.24	1.52	0.61	0.28	-2.42	-0.73	0.73
H	0.19	-0.19	0.01	-0.01	-1.15	1.15	-0.29	0.46	-0.17	-2.84	-2.42	1.53	3.73	0.23	-0.23
I	1.31	-1.31	-0.47	0.47	-1.83	1.83	-0.02	-0.27	0.29	-2.36	-1.96	1.20	3.12	0.12	-0.12
J	0.56	-0.56	0.87	-0.87	1.65	-1.65	1.12	-0.13	-0.99	-2.54	-0.45	2.85	0.14	0.77	-0.77
K	-0.19	0.19	0.57	-0.57	-0.40	0.40	-0.21	0.80	-0.59	0.10	0.26	-3.91	3.54	1.23	-1.23
L	2.06	-2.06	2.46	-2.46	-0.37	0.37	-0.90	-0.15	1.06	1.03	-1.69	0.24	0.42	0.92	-0.92

A few eyeball observations can be made viewing Figure 3. First, the strongest opinions involve system governance, followed by blockchain and IoT. Second, the respondent pool is generally favorable of blockchain with one strong exception; the other parameters are more mixed. Third, views on system authority are highly polarized; we will look at this more closely in our cluster analysis.

Next, we use the `conjoint()` function to estimate and plot all parameters across all respondents. This produces a number of plots, including the attribute importance summary in Figure 4.

Figure 4: Attribute importance summary



This plot confirms the eyeball observations we made from Figure 3. System governance is most important, followed by blockchain and IoT. Only blockchain and IoT are marked as significant with p-values of 0.00326 and 0.07286 respectively. System governance is clearly significant as well, but because it is so polarized across its four levels, no one level proves significant in this small sample size.

To better understand the importance of system governance, we turn to cluster analysis.

Cluster analysis of conjoint survey data

Using the k-means method employed by the `caSegmentation()` in the `conjoint` package, and selecting for n=3 clusters. This produces the following clusters added to column two and ordered in ascending fashion in Figure 5.

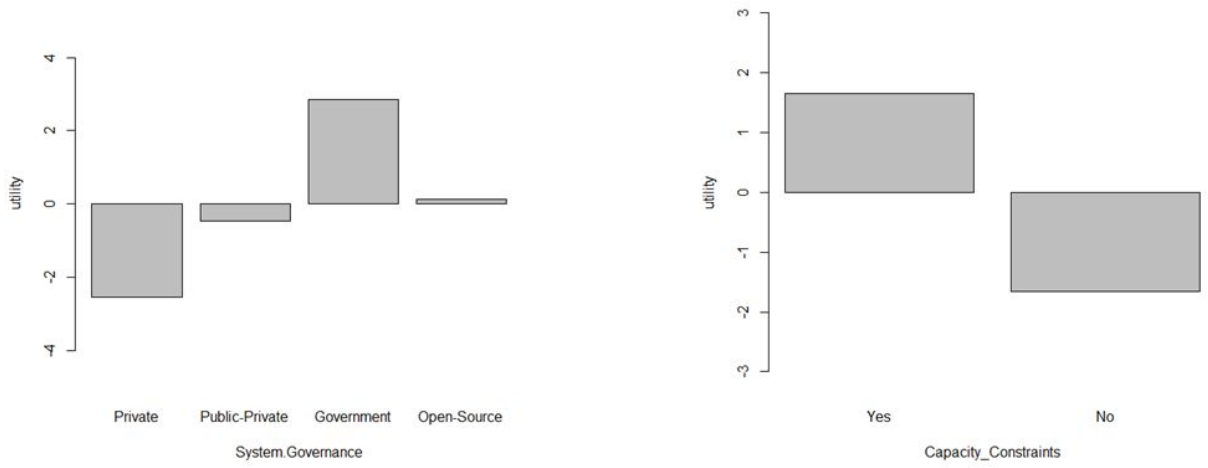
Figure 5: Utilities by cluster

		Blockchain		IoT		Capacity Constraints		Depositor Detail			System Authority				Warehouse Detail	
Respondent	Cluster	Yes	No	Yes	No	Yes	No	Low	Medium	High	Private	Public-Private	Government	Open-Source	Basic	High
F	1	1.94	-1.94	-0.78	0.78	0.67	-0.67	-0.27	-2.27	2.54	1.46	-1.9	1.39	-0.95	0.12	-0.12
J	1	0.56	-0.56	0.87	-0.87	1.65	-1.65	1.12	-0.13	-0.99	-2.54	-0.45	2.85	0.14	0.77	-0.77
B	2	0.19	-0.19	-0.41	0.41	-0.02	0.02	1.31	-0.69	-0.62	0.88	-2.05	-2.42	3.59	-0.35	0.35
E	2	-2.13	2.13	-0.41	0.41	-0.42	0.42	-0.48	0.77	-0.29	1.54	0.52	-3.39	1.32	-1.62	1.62
H	2	0.19	-0.19	0.01	-0.01	-1.15	1.15	-0.29	0.46	-0.17	-2.84	-2.42	1.53	3.73	0.23	-0.23
I	2	1.31	-1.31	-0.47	0.47	-1.83	1.83	-0.02	-0.27	0.29	-2.36	-1.96	1.2	3.12	0.12	-0.12
K	2	-0.19	0.19	0.57	-0.57	-0.4	0.4	-0.21	0.8	-0.59	0.1	0.26	-3.91	3.54	1.23	-1.23
A	3	2.69	-2.69	0.66	-0.66	1.17	-1.17	-0.02	0.23	-0.21	0.14	0.29	0.2	-0.64	-0.39	0.39
C	3	2.13	-2.13	2.11	-2.11	0.37	-0.37	0.32	0.32	-0.64	-1.4	1.19	0.64	-0.42	-0.42	0.42
G	3	1.56	-1.56	1.93	-1.93	0.65	-0.65	-0.13	0.37	-0.24	1.52	0.61	0.28	-2.42	-0.73	0.73
L	3	2.06	-2.06	2.46	-2.46	-0.37	0.37	-0.9	-0.15	1.06	1.03	-1.69	0.24	0.42	0.92	-0.92

Analyzing Figure 5, we name these clusters and divide Cluster 2 into two sub-clusters.

Cluster 1 we name “Pro-government moderates.” These two respondents are open to blockchain and favor government administration. For example, the key utilities for Respondent J are visualized in Figure 6: strong preference for government and preference for capacity constraints above other attributes.

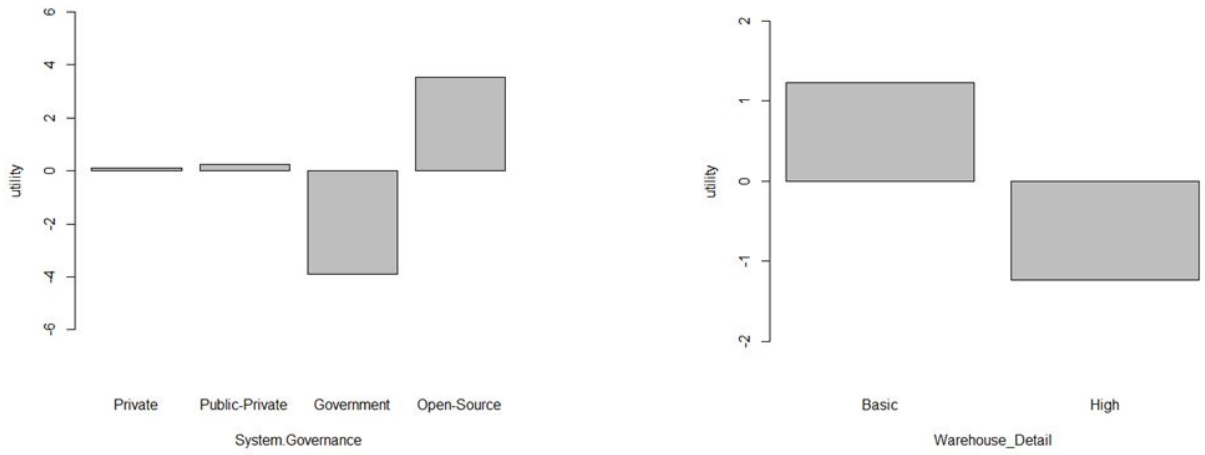
Figure 6: Utilities for Respondent J



Cluster 2 we name “Open-source disciples.” These respondents have a very strong preference for open-source system administration, but for different reasons. Therefore we divide this cluster into two sub-clusters.

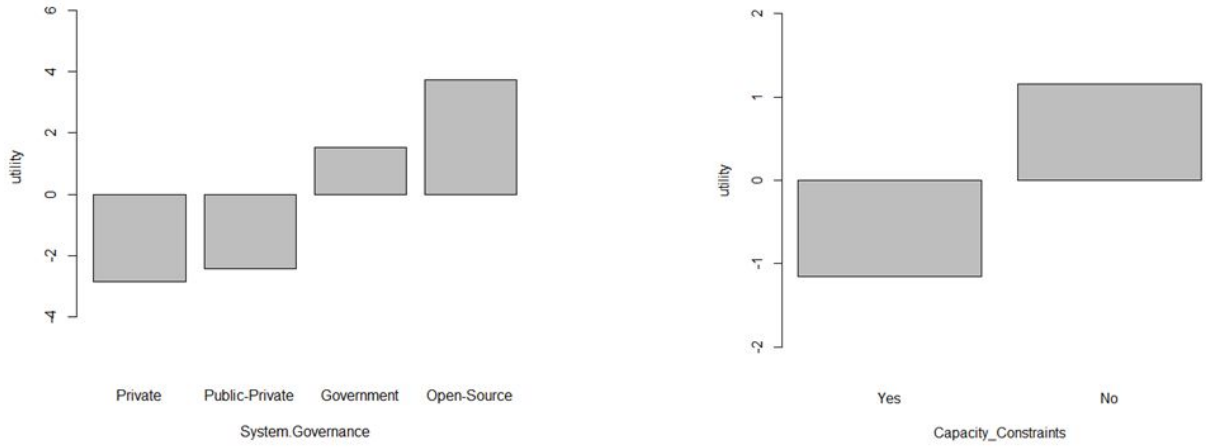
Sub-cluster 2.1 we name “Open-source, anti-government.” This group is comprised of respondents B, E, and K. Figure 7 visualizes the preferences of Respondent K: against government system administration, strongly pro open-source, and strong preference for warehouse transparency.

Figure 7: Utilities for Respondent K



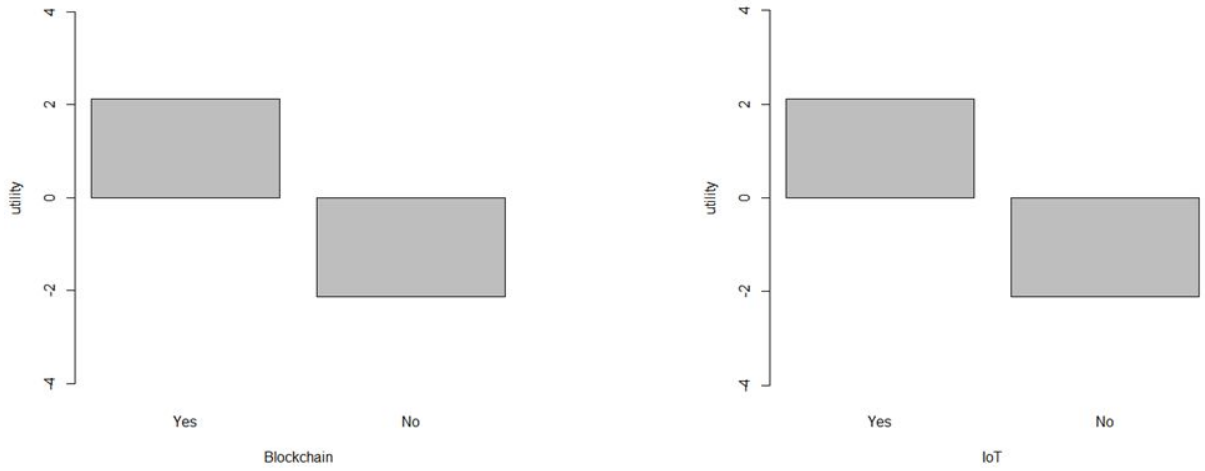
Sub-Cluster 2.2 we name, "Open-source, anti-industry." This group is comprised of respondents H and I. Figure 8 visualizes the preferences of Respondent H: against private sector system administration, strongly pro open-source, and a perplexing negative against capacity constraints (Respondent I also exhibits this).

Figure 8: Utilities for Respondent H



Cluster 3 we name, "All-about-the-tech." This cluster shares strong preferences for blockchain and IoT, but is split on system administration. This group is comprised of respondents A, C, G, and L. Figure 9 visualizes the preferences of Respondent C: strong preference for blockchain and Internet-of-Things, strong preference for public-private system authority.

Figure 9: Utilities for Respondent C



In summary, the conjoint analysis reveals 1) the high importance of system governance and the polarization of views on its assignment, even within what one might think of as a homogeneous stakeholder class, 2) a validation of the hypothesis that blockchain and IoT may improve willingness-to-lend. Since this sample size is small, additional survey data needs to be mined in order to fully validate these results.