Global Trade Strategy Forum

Can Blockchain Future-Proof Supply Chains?

A Brexit Case Study

January 2019

Executive Summary

As trade has become increasingly connected, events like Brexit show the fragility of supply chains in the face of disruption. The increase in trade volatility comes at the same time as tremendous innovation in the ways we produce and track goods. But frictions remain in exchanging data across the vast number of entities involved in a trade transaction. By decentralizing data exchange, blockchain introduces tools that can allow each entity to be more flexible in the face of short-term dislocations.

R3's Global Trade Strategy Forum was organized to identify these opportunities, focusing specifically on Brexit-related disruption. Blockchain holds the promise to ease frictions caused by intermediaries, reduce the cost of verification of documentation, and facilitate asset tracking. Because blockchain is novel for regulators and legislators, the group also addressed legal questions surrounding the applicability of blockchain solutions to the trade process.

There are three major sources of disruption that result when a country withdraws from such a union: uncertainty over which border measures will apply, what regulatory regime will prevail, and variability in border processing capacity. We grounded these problem areas in scenarios across the automotive, aviation and aerospace, and perishables supply chains.

Our objective was to understand whether blockchain could help manufacturers to reduce the volatility they experience under trade disruption. Our main conclusion is that blockchain can enable manufacturers to capture data-based insights that will help optimize their performance in ways that are more resilient to trade policy uncertainty. There are three ways in which this can happen:

- Firms can use the additional sources of data that blockchain provides to soften the burden of preparing for an increase in the amount of information required for exports.
- The ability to represent unalterable identities on chain allows regulators to trust, and thus scale, pre-certification programs, which reduce reliance on frequent checks on goods and trading parties.
- By putting their transaction history on blockchain, firms can improve the ability of banks to do due diligence and risk assessment, thus opening the doors to additional financing.

Trade finance is a special topic in that while Brexit is unlikely to impact trade finance, firms are taking second best risk mitigation measures like hoarding inventory because of incorrect expectations about the availability of capital. In this section, we cover how blockchain is being used by financial institutions to avoid future misperceptions.

The final piece of the puzzle is around data security. While the technology is ready today, regulators, legislation and rules around data exchange have some distance to go. Blockchain is a digital technology, but introduces very different data privacy and cybersecurity issues, which we cover in detail from a legal perspective.

This working group, along with the following paper, is the beginning of a journey of exploration into the applicability of blockchain across supply chains. We encourage collaboration on supply chain problems and solutions from the readers of this report. We invite others in the space to use this work to define areas of focus, propel application development, and have productive discussions with regulators.

R3 Global Trade Strategy Forum

This report is the output of the R3 Global Trade Strategy Forum, a working group that assessed the impact of trade uncertainties on situations such as Brexit.

R3 has brought together 27 participants, including banks, law firms, corporates, startups, industry groups and international organizations. The working group included:

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CAN BLOCKCHAIN FUTURE-PROOF SUPPLY CHAINS? A BREXIT CASE STUDY

As trade policy disruption has become more commonplace, so have the calls for blockchain as a solution. But often the reasoning for this link has been unclear. Using the case study of Brexit as a baseline, we map four sources of trade-based uncertainty and explore the extent to which blockchain applications could – when implemented – attenuate supply chain disruption, which has lead to firms taking second best options like reducing investment and switching suppliers. Because the law has not kept pace with technology, the discussion also highlights prominent legal questions raised by blockchain in each instance.

1. INTRODUCTION

As trade has become increasingly connected, events like Brexit show the fragility of supply chains in the face of disruption. The increase in trade volatility comes at the same time as tremendous innovation in the ways we produce and track goods. But frictions remain in exchanging data across the vast number of entities involved in a trade transaction. By decentralizing data exchange, blockchain introduces tools that can allow each entity to be more flexible in the face of short term dislocations.

The genesis of our research was as a response to policymakers' references to blockchain as a "solution" for the trade challenges associated with Brexit.[1] While there is a solid foundation for these suggestions, there has been little substantial work explaining how they relate. This paper uses the Brexit events to anchor a broader discussion around how blockchain can be used to future-proof supply chains against some of the negative impacts of policy volatility.[2]

In this paper, we seek to accomplish two things:

- First, we explore the stages along the trade process where blockchain can be potentially applied to increase resilience to future trade policy uncertainty.
- Second, we highlight key legal questions surrounding blockchain applications in different parts of the trade process.

In order to draw a clear picture about the impact on supply chains, we draw specific examples from three sectors: automotive assembly, aerospace and aviation, and perishables. Each sector illustrates different threats to supply chain management that arises from policy uncertainty, and the extent of the uncertainty can be seen as manufacturers are faced with taking risk mitigation measures without a full understanding of when or how disruption will occur.[3]

[1] The UK Department for Exiting the European Union's July 2018 paper, "The Future Relationship Between the United Kingdom and European Union", received significant backlash for assuming that a 'chain of transactions' was a potential solution without providing reasons or explaining implementation.

[2] The focus of this paper is on the exit of the UK from the EU (Brexit), but the suggestions hold for all of today's sources of trade uncertainty include USMCA, CPTPP, and other sudden renegotiations, withdrawals and changes to existing trade agreements.

[3] We see this in the Brexit case where small suppliers in affected supply chains like aerospace and automotive are being asked to hold inventory that they may not be able to afford. For example, as a consequence of Brexit, Airbus specifically required its suppliers to hold additional inventory (Reuters, 2018). This was done to ensure smooth procurement and continued production even if costs went up or suppliers were themselves constrained in their production.

Additionally, small and medium sized firms that only trade within the EU are a special case that we refer to throughout the paper. This group is among those expected to be most affected if there is a sudden change in customs procedures.

The short story is: blockchain can enable manufacturers to capture data-based insights that will help optimize their performance in ways that are more resilient to trade policy uncertainty. To fully unlock these benefits, legislation and regulation need to adapt to electronic documents, and transition points in the trade process, like ports, terminals, and customs agencies should take steps to become digitally-enabled. These will not only improve supply chain management, but will help the entire trade ecosystem to facilitate frictionless trade.

The organization of the paper follows the trade process. A trade transaction can be thought of as having three categories of interaction - the physical supply chain, the financial supply chain and the supply chain for information. Brexit events have introduced instability into each of these. In the sections that follow, after a brief introduction of blockchain and trade, sections cover logistics, trade finance, and data security.

This paper is a collaborative work by the members of R3's Global Trade Strategy Forum (GTSF). Participants include financial institutions, law firms from R3's Legal Center of Excellence, academics, trade bodies, corporates, and multilateral institutions. Together we explored the issues around Brexit and critically evaluated blockchain as a solution.

2. CONCEPTUAL FRAMEWORK: BLOCKCHAIN AND UNCERTAINTY IN TRADE

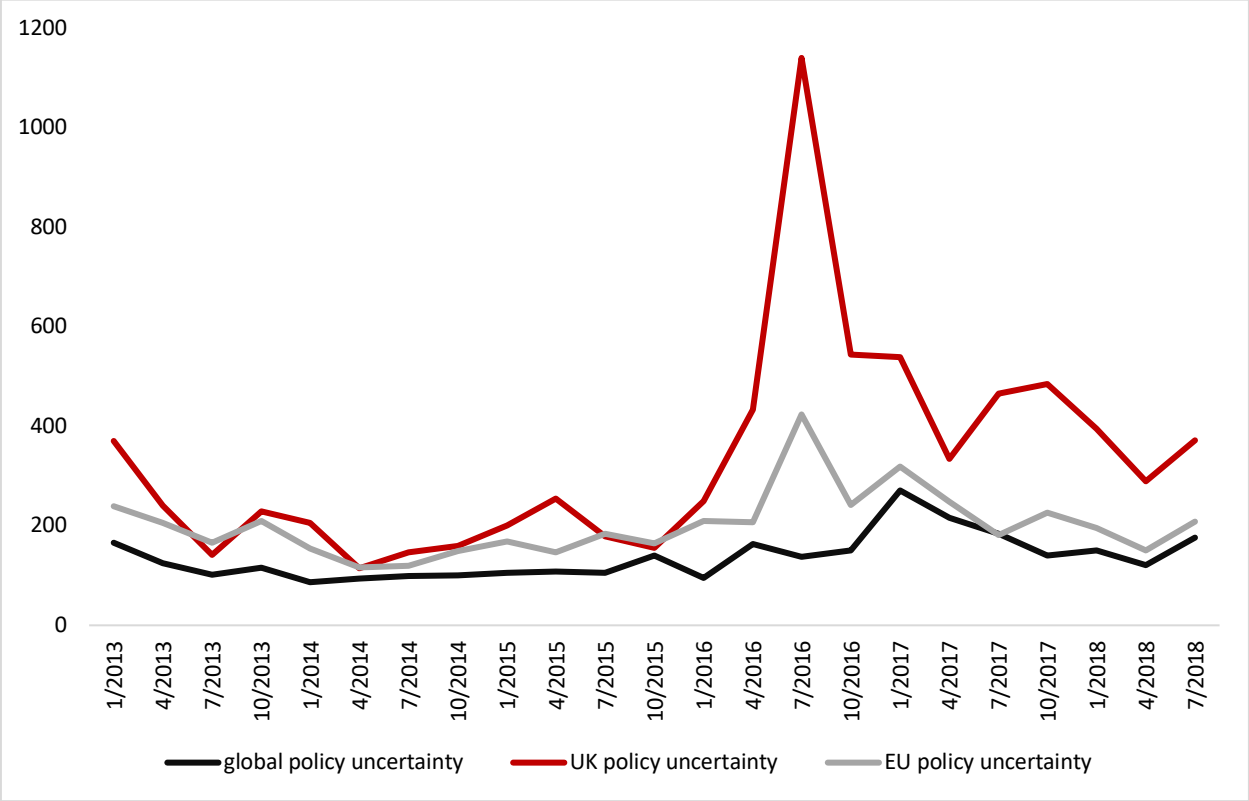
In October 2018, 80% of surveyed companies reported that Brexit had negatively impacted their investment decisions (CBI, 2018).[4] This will come as no surprise as trade policy uncertainty is nothing new. In fact, the desire to reduce volatility is one of the main reasons that governments conclude free trade agreements in the first place (Limao and Maggi, 2015).[5]

Our focus is on Brexit, which is a specialized case of a trade agreement exit. The Brexit event is notable in that it has elevated the aggregate level of uncertainty in the UK following the initial spike caused by its announcement (Figure 1). Because of the role of the UK in EU trade, this has disrupted planning cycles for supply chains across the continent. It has been estimated that only 10% of UK businesses are not exposed internationally. They have exposure abroad, even if they only sell in the UK.

The conceptual model we use is one where a customs union exit introduces uncertainty into cross border supply chains which must then be mitigated. In the four sources of uncertainty we explore, blockchain applications have been piloted in most. We use those pilots for insight into how blockchain might alleviate some sources of uncertainty in the future.

[4] The Office for National Statistics has also illustrated a 22-billion-pound drop-off in investment since the Brexit referendum bill.
[5] The popularity of trade agreements can be traced back to the German Zollverein of 1834. Since 1947, trade agreements have been governed by GATT Article XXIV, and as of May 2018, there are 287 reported trade agreements in force globally.

Figure 1. Policy uncertainty in the UK increasing in recent years (2013-2018)



Source: PolicyUncertainty.com index
Note: Index developed by Baker, Bloom and Davis (2011)

While others have calculated probabilistic risk associated with different Brexit outcomes (e.g. Morgan Stanley, 2016) or evaluated effects on investment opportunities depending on potential outcomes (e.g. Blackrock, 2016), we instead look at the mitigation measures economic actors could take to reduce the impact of such outcomes in the future. Blockchain will not solve Brexit, but application of blockchain in trade can attenuate the negative impacts of future events of trade uncertainty.

2.1 Customs Unions and Blockchain

A customs union involves not only the removal of tariff walls, but also merges customs processes and allows for mutual supervision (Viner, 1950). Thus, when a country withdraws from such a union, we would expect the major sources of disruption to include three areas: border measures, regulatory compliance, and the upcoming lack of border processing capacity. And indeed, the news of Brexit has focused on these issues.

Technology is only a very recent consideration in regional trade agreements. Digital language in cross border policy has been largely limited to e-commerce chapters of regional trade agreements. Accordingly, blockchain is too new a technology to have been written into any trade agreement texts. However, customs agencies, ports systems and other border agencies have begun to explore blockchain pilots as a way to facilitate data exchange.

Blockchain thus in some ways today stands in the same position as ecommerce did 20 years ago. Though the technology had been in use since the 1990s, it wasn't until 2003 that ecommerce was first included in a trade agreement and today they are common (Wu, 2017). Because blockchain is also a fundamentally new way of organizing transactions, its applicability to trade is equally broad and itself disruptive to regulations that did not foresee such application. The history of earlier general-purpose technologies demonstrates that reorganizing the economy around revolutionary technologies generates large long-term benefits despite short-term dislocations. (IMF, 2018).

2.2 Blockchain and Trade Uncertainty

Blockchain technology was not developed for trade. However, it has features that promise to address some of trade's most intractable challenges. These include the friction caused by intermediaries, the cost of verification and checking documentation, and the difficulty of tracking assets from production to retail sale.

The applicability of blockchain to a given trade problem depends on the role of data exchange throughout the production process. Blockchain implementations can introduce more certainty around documentary compliance and production processing. Because of blockchain's focus on data exchange, we use a framework defined by the sources of data that are involved in four types of uncertainty (Table 1).

Table 1. Conceptual mapping of sources of uncertainty to blockchain architecture

Source of trade uncertainty	Data needed	Blockchain characteristics related to this data
Border measures*	• source of inputs • production and transformation • destination • which required documents • updating of documents	• transparency of transaction • no central party holds all the data • sharing of confidential data in a secure way • secure data storage/transfer
Time	• systems to process documents • verification of documentation • all documents • ease of switching between regimes (EU-UK)	• simplification of verification • no need for reconciliation
Regulatory compliance	• auditable production history • regulatory regime • approvals from officials	• each partner owns and has visibility of data • guarantee of verifications • improved data quality (provenance of data) for effective risk management
Working capital	• who are suppliers multiple levels away • inventory stockpiling requests • KYC data	• Transparency of trades • Immutable record keeping • Smart contracts and governance mechanisms, such as consensus before transactions

Source: Author's assessment
Note: this assessment is based on the Corda blockchain which is a permissioned ledger. There are characteristics that do not hold for public blockchains.
**Border measures includes documents involved in tariffs and non-tariff measures (SPS, TBT, ROO, etc)*

Importantly for our discussion, blockchain applications do not need to be applied at the border to reduce border-based frictions. Introducing blockchain into different parts of the production process and by different actors in the financial and physical supply chain can reduce critical trade frictions as well.

Subsequent sections will use this framework to analyze the points at which blockchain can reduce uncertainty in the automotive, aviation and perishables supply chains. We chose these three because they are among the sectors which are expected to be most impacted by trade volatility in the UK case. We turn first to logistics which covers the physical supply chain and the first three sources of uncertainty in the table.

3. LOGISTICS

Logistics is central to any trade transaction. As such, we spend the majority of this paper discussing the disruption in this sector. It is an industry based on intermediaries that verify and coordinate transactions, though each individual logistics company has a limited view into a good's supply chain.

As goods cross a border, they are impacted by both temporal and monetary frictions. These are associated with border measures, regulatory compliance, and trade facilitation measures like whether there is an electronic single window.

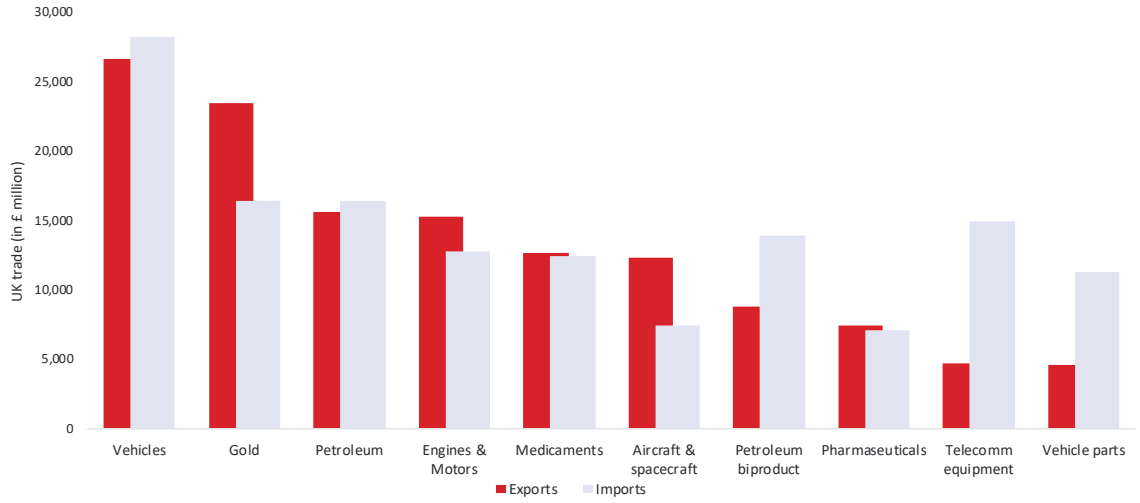
In the UK, while there are a few large intermediaries, such as DHL and DB Schenker, such global firms only control around 10% of the market. The British Chamber of Commerce estimates that the UK has over 5500 customs agents and freight forwarders, 70% of which have less than 5 employees. This illustrates the highly fragmented nature of the logistics process just in the UK. This segment - from carriers, to 3PL operators, to ports systems – is also in the process of exploring blockchain (DHL, 2018).

Our discussion of logistics will focus on seaports. We do this to simplify a complex sector and because this is the logistics point that is expected to have the greatest disruption. Though about 40% of UK's trade by value travels by air, 95% of all UK imports/exports volume cross via ship (UK Department for Transport, 2015).[6]

The most traded manufactured goods across the UK border belong to the automotive and aerospace industries (see Figure 2). Additionally, we will highlight perishables, which are shipped daily via British ports such as Dover and require fast processing times.

[6] This figure includes RORO: freight that arrives at the port already on lorries, which drive straight off the carrier boat once docked.

Figure 2. UK imports and exports (2018)



Source: HMRC

Among the uncertainties that have arisen as a result of the Brexit negotiations, we detail three in this section.[7] These include:

- Border measures
- Regulatory compliance
- Time

This section uses a three-step approach: the cause of the uncertainty, how supply chains are responding, and whether blockchain applications being built in these areas would have reduced uncertainty.

3.1 Border Measures

The process of exiting from a customs union is complex from a documentary and a regulatory perspective. This issue has been exaserbated as the difficulty of ascertaining origin has ramped up with the globalization of trade. For example in countries where neither single windows or electronic data interchanges are in place, customs declarations are submitted in quadruplicate and color coded. Add to this the potential to change documentary requirements and it becomes a core source of risk for firms.

This section looks at two features of border measures: customs declarations and the tariff cost.

The problem with customs documentation is two-fold. First, documents must be compliant with multiple regulatory regimes. This includes national or supranational legislative regimes, as well as local regulatory bodies, such as food safety agencies. Second, there are different types of origin requirements for different agreements.[8] This means that the backup documentation of the certificate of origin will differ depending on where the good is going.

[7] The fourth uncertainty – around working capital – is covered in section 4. While qualified workforce scarcity is also a risk in the case that mobility freedom becomes curtailed, this uncertainty is out of the paper's scope.

[8] As an example, from the US side, NAFTA origin is based on tariff shift and regional value content (RVC), whereas under the unilateral African Growth and Opportunities Act (AGOA) origin is substantial transformation "plus."

This will particularly impact SMEs who have the least capacity to plan for shifts. Brexit will turn firms that currently trade between the UK and EU into exporters overnight, leading to an immediate steep ramp up in customs declarations. Specifically, the British Chambers of Commerce are concerned that the number of customs declarations issued each year could rise from 55 million to 290 million.

SME exporters are most likely to be hit hard. This is due to their small size and potential unfamiliarity with documentation requirements. In addition, the transition from common to separate standards and new rules between the UK and EU27 could increase the number of non-tariff measures (NTMs) related to sanitary and phytosanitary measures (SPS), technical barriers to trade (TBT) and rules of origin (ROO). This could make documentation requirements and regulatory compliance more complicated, resulting in potential barriers for agri-food trade.

Blockchain pilots have been cropping up in a number of ports, which suggests that in the future, changes in trade status may be easier to process. Table 2 looks at some of the types of documentation that has been processed using blockchain over the past year. In many of these cases, the blockchain transaction is done in parallel execution to the paper process because domestic or regional regulations that require paper or physical stamps are more resistant to change.

Table 2. Sample use cases in ports (international)

	use case	*details*
Port of Antwerp	phytosanitary certificates	digital approval from local food safety regulator accompanying goods traded between New Zealand and Belgium
Port of Rotterdam	cargo flows, port logistics and stock financing	paperless integration of physical, financial and informational supply chain
Port of Singapore	track-and-trace	informational record of goods transferred between China and Singapore
Ports of Shanghai and Guangdong	customs clearing and risk control	single window for uploading documentation for customs clearance, augmented by risk analytics
Abu Dhabi Ports	document transfer	exchanging, identifying and acknowledging documents and certificates with the Port of Antwerp
Port of Hamburg	freight container release process	provide a common database for all parties involved in the transfer of high value goods to increase certainty
Port of Valencia	document management	access to documents on IBM & Maersk Tradelens platform, and end-to-end supply chain management with compliance

Source: Author's assesment

USE CASE: Project Voltron

One use case that holds key lessons for customs documentation is trade finance. While trade documentation is just starting to make the switch to digital, in trade finance, blockchain is proving to be the link that enables digital documentation in a secure way. The benefits of digital documentation are clear in situations where paper documentation has to accompany goods. What was missing is a way to ensure that these instruments cannot be altered, are authentic and jointly agreed upon.

Project Voltron is a platform for documentary trade built on Corda. Voltron makes transactions verifiable, and aids in the reconciliation process. Voltron is used to represent letters of credit, a trade finance instrument, on blockchain. The way in which it introduces a more efficient process for maintaining and transferring documents is particularly applicable for customs documentation which also requires back up documents that track goods through the supply chain.

3.1.1 TARIFF APPLICATION

The second angle to border measures and documentation is the need to identify origin for tariff application. In the automotive sector, goods traverse borders multiple times before and after they are finished. This is a particular issue because once the UK is out of the EU, a 4.5% tariff may be applied to all unfinished goods (parts) and a 10% tariff to finished automobiles.

Lack of certainty around applicable tariffs is a key source of risk for firms. These measures ultimately affect the cost of merchandize and are a key concern to importers and exporters operating on thin margins. As a result, their suppliers may no longer be competitive.

Considering automobiles are the largest import and export of the UK, while car engines are one of the largest UK exports (HMRC 2017), tariffs add a significant burden. Baker McKenzie (2017) estimates that the automotive industry is likely to experience the most severe burden with a potential for a 7.9-billion-pound decline in export to the EU.

Additionally, the perishables sector is acutely affected by potential changes to duties due to their reliance on imports. Roughly 30% of the UK's food supply comes from the EU, while another 11% originates from non-EU countries that have free trade agreements (FTA) with the EU28 (House of Lords, 2018). As a result, 41% of the UK food supply is at risk to be traded at most favored nation (MFN) terms, facing significantly higher duties. For example, the average MFN customs duty levied on agricultural goods imported by the UK from the EU-27 would increase to 18.3%. Specifically, tariffs on dairy and meat products would rise to 40% and 22% respectively (Bellora et al., 2017).

USE CASE: deep tier financing

Deep tier financing is an area where blockchain introduces new capabilities that may alleviate uncertainty over increasing cost of foreign goods including those resulting from tariffs. For example, there are a number of supply chain finance applications – like Project Marco Polo – being built on Corda. By providing transparency into the chain of production, these can allow for financing more than a few tiers deep.

Assuming that there are local suppliers for a particular good, providing financing to lower tiers of the supply chain could activate these suppliers. This would relieve manufacturers' reliance on exchanging unfinished goods across borders multiple times throughout the supply chain. Within the automotive supply chain, this would help manufacturers minimize reliance on unfinished goods that will require tariffs.

3.2 Regulatory Compliance

While regulatory compliance is a source of risk in normal times, the risk is exacerbated in a situation where regulators may change. Identity management is a key feature of regulatory compliance. This includes the type of goods being certified, the identities of the trading parties, and the identity of the party submitting associated data. Thus, regulatory compliance involves three inter-related issues: which measures apply, who is pre-certified as trusted operators, and the ability for legacy systems to upgrade.

What regulatory regime will dominate is a problem for regulated industries like aerospace. In the Aerospace sector, companies like Airbus comply with the European Aviation Safety Agency (EASA) in their production standards. Today there are harmonized rules between the UK Civil Aviation Authority (CAA) and the European Aviation Safety Agency. If EASA no longer applies, the CAA may need to take on more responsibilities.[9] Conversely, it is unclear if certificates previously issued by the CAA will continue to be accepted under the EASA system. Finally, services and leasing are equally affected in that it's unclear what safety regulation will prevail.[10]

Within aviation, the Brexit related issues center on the maintenance, repair and overhaul (MRO) of airplanes, a highly regulated process arranged by the airlines and carried out by independent contractors. EASA approval is needed for major repairs.[11] The key issue with MRO process is updating and keeping track of the logbook, which records servicing for a given airplane. Mistakes bear high costs, since regulations dictate that if the logbook is lost, the plane must be scrapped. This is an acute issue since planes are often bought and sold multiple times in their lifetimes, and servicing can occur in any country.

[9] Including approvals for UK designed aeronautical products, approvals for third country organizations and validation of EU Part-FCL pilots licenses for UK operated aircrafts (UK Department of Transport). EU operators would become foreign carriers under the UK regulatory regime, requiring them to register as a third country operator (Part-TCO) and maintain a 'foreign carrier permit.'

[10] Currently, to lease an airplane (with crew included) from another country, an airline needs to satisfy legal requirements.

[11] There are three main complications in the process. First is the decision flow to determine if the aviation authority should be involved - while minor repairs are recorded in the maintenance log, major repairs must get EASA approval. Second, the operator or airline is dependent on receiving a certificate of release from the MRO. Finally, there are many interactions between the maintenance company, aircraft operator and regulator, who must maintain an EASA worthiness certificate.

The ability to get pre-certified is an important global program to facilitate trade. Eighty countries have an Authorized Economic Operator (AEO) program, which is a unique regulatory innovation that allow firms to obtain preferential status. AEOs are entities recognized by national customs authories as adhering to a set of WCO standards based on the SAFE Framework of Standards. AEOs provide a level of security for supply chains that are recorded digitally. In order to be certified as an AEO, the firm is required to maintain four processes: pure customs processes, security and safety processes, international operational processes, and outsourced processes.

One of the challenges of AEOs is the recognition of AEO programs between countries. In order to do this, countries enter into bilateral agreements and exchange spreadsheets. These often become outdated quickly. In July 2018, the Pacific Alliance signed the first plurilateral mutual recognition agreement. Mexico, Peru and Costa Rica are piloting blockchain as a way to exchange and maintain common logs of certified AEOs.

Legacy architecture upgrades is an important issue related to our discussion around blockchain. Can customs windows interface with a blockchain solution? In the past few decades, governments, along with intergovernmental agencies, have made efforts to digitize the customs clearing process. In the UK, one of the first IT innovations for customs processing was The Customs Handling of Import and Export Freight (CHIEF) system, for trade between maritime ports. The system - which is still used today - was rolled out in the early 90's, accommodating the UK's entry into the EU, and was designed to handle five customs declarations per second.

Unrelated to Brexit, HMRC is replacing the CHIEF system with a more modern IT solution, called the Customs Declaration Service (CDS), which is intended to increase the amount of declarations that customs can handle, along with scaling taxation and compliance efforts to handle the annual 34 billion collected at the border (World Customs Organization, 2016). It remains to be seen if this will be blockchain enabled.

USE CASE: self-sovereign identity

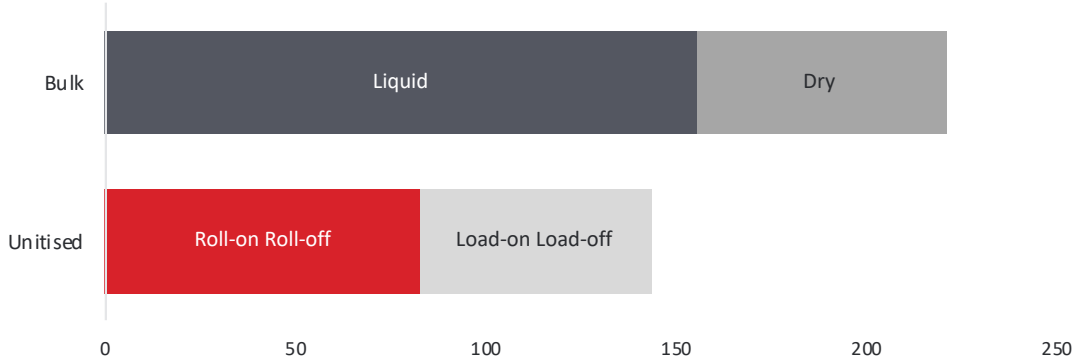
Customs documentation has been a use case for a number of different blockchain solutions. In particular, blockchain could enable importers to share digital certificates pertaining to the goods they carry with customs officials. A project run by Evernym shows that documents – or any fact verified by a government agency or trusted third party – can be used to prove identity.

The application connects Corda with the Sovrin network, a "self-sovereign" identity network on which individual or corporate users are able to make attestations about their information. The same framework could apply to other shared attestations relating to origin or SPS. Additionally, a blockchain based identity layer can help regulators scale programs such as AEO by granting verifications to traders that can be recognized and trusted by other regulatory regimes.

3.3 TIME

Border crossing time uncertainty is a new problem that stems from potential Brexit changes. It is associated with questions surrounding qualified staff, availability of computer systems to process new types of documentation, and the potential for congestion in ports like Dover which have traditionally been RORO and are not equipped for customs processing (Figure 3).

Figure 3. UK port freight by type of cargo and country (2018)



Source: UK Port Statistics 2017

All sectors are affected by border crossing times, though some will be more than others. For goods that travel short distances, the time delays will be felt more strongly than goods that travel long distances where arrival times are approximate.

Perishables in particular will be potentially negatively impacted due to their temporary nature and shipping method. Perishables are primarily imported into the UK through roll-on roll-off (RORO) ports (Zangrando et. al, 2017). Though 82.8 million tons of goods enter the UK via RORO in 2017 (Figure 3), ports currently have very limited infrastructure for RORO customs checks.[12] If the expected massive delays at Dover materialize, perishables trapped at the border will spoil.

Additionally, in the automotive sector, companies like Nissan, which has a major facility in the UK, use manufacturing techniques that are responsive to consumer demand, and thus do not store goods in warehouses. This makes their supply chain extremely responsive, but also sensitive to parts deliveries. For example, Nissan's UK factory uses the common just-in-sequence (JIS) delivery assertion combined with just-in-time (JIT) manufacturing process, keeping only 50% of a day's worth of materials in inventory, so the facility is reliant on frequent restocking. The automotive industry has already made some steps in adopting blockchain technology[13] and exploring standards.

The aerospace industry has also been vocal about the changes they require of their suppliers as a result of uncertainty about the cost and ease of movement for aircraft parts. For example, the Airbus A350 wing production may face Brexit uncertainty because making each wing requires multiple border crossings. The process starts in Spain and Germany, where Beluga air transport planes carry the lower and upper wing skins to Broughton from the Madrid and Hamburg factories, respectively. In Broughton, the wing skins are attached to the base of the wing, made of UK sourced composite spars. The wing must then be loaded back on the transport plane and sent to Bremen (Germany), where the trailing-edge flap is attached. Finally, the wing is flown to Toulouse (France), where it can be connected to the rest of the aircraft (Seattle Times, 2016). This type of high technology production requires both certainty and flexibility as technologies continue to change.

[12] RORO ships carry wheeled cargo that can be driven straight off the ship once at port.
[13] For example, Porsche has run a project using blockchain to lock and unlock the vehicle via an app, and give temporary access authorizations, enabling new business models based on encrypted data logging. The car becomes part of the blockchain, making a direct offline connection possible – that is, without diversion through a server.

In the aerospace industry, delays or shortages at the very lowest levels of the supply chain perambulate through the system, directly affecting the production of finished goods. For example, earlier this year, Spirit AeroSystems, an aerostructure manufacturer, was featured in newspapers because of their failure to deliver fuselages (main body of the airplane) to Boeing for use in the flagship Boeing 737 plane. The primary cause of the issue was delays from some of Spirit's 600 components parts distributors (Seattle Times, 2018). Delays are particularly costly in the aerospace industry because production requires the interplay of many complicated production steps and finished goods have relatively high values.

USE CASE: shipping container tracking

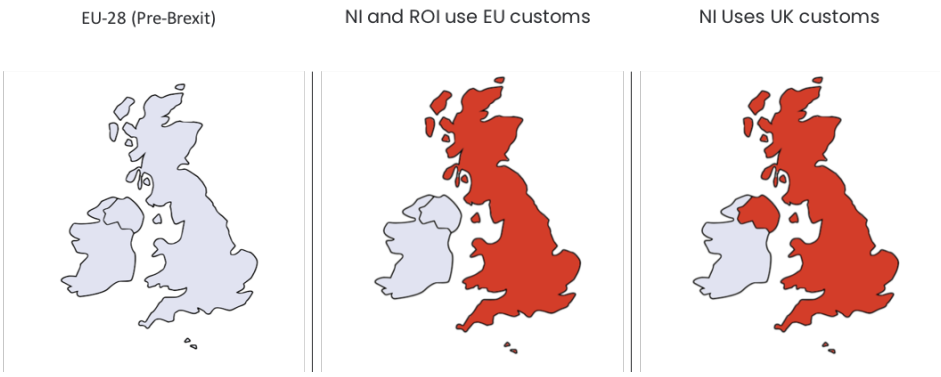
While blockchain cannot make customs officials move faster, creating better representations of goods being shipped may lead to less delays by reducing the risk profile of exports and imports and enabling quicker checking.

Blockchain may enable more certainty over delivery times through applications that provide logistics tracking. For example, the Port of Rotterdam is building a pilot program to track shipping containers, which will be linked to Corda. Especially in cases where cargo is accompanied by IoT sensors, blockchain provides a shared data layer that provides transparency throughout supply chains, which are currently are highly fragmented and lack central parties with visibility over the entire process.

3.3.1 The Irish Border Questions

There is an additional consideration in the question around border crossings, that is: the border between Britain, Northern Ireland (NI) and the Republic of Ireland (ROI). There are 270 public road crossings along the 500km border between NI and ROI. Since no physical infrastructure exists between NI and ROI, it is unclear how customs between these areas will be enforced. Further, potential unique agreements between UK, NI and ROI that have yet to be finalized introduce further uncertainty over how these nations will trade with mainland EU.

Figure 4. Potential outcomes of Irish borders under Brexit options



Source: Author

Firms operating in Ireland face the same uncertainties as in the rest of the UK with added questions around where the border would be. In the case of the UK, border crossing points are clear, however they simply may not be ready for trade. But without any border infrastructure between NI and ROI, customs transfer points are an additional uncertainty at the Irish border. This can potentially cause delays in border crossing, which will be detrimental to some industries as we mentioned earlier. The issue of grounded flights has also been raised in the news, but we do not treat it here.

While there is no direct applicability for blockchain, the trade issues raised around the Irish border highlight the potential for this disruptive situation to stir some creative thinking around how to resolve issues raised by shifting borders.

USE CASE: HM Land Registry

Border disputes are a physical problem, which limits the applicability of blockchain as a solution. Blockchain is about data exchange. However, there is one feature of land questions around which increasing blockchain thinking has occurred.

Blockchain-based land registries have been implemented in a number of different countries. Most applicable for this paper is the HMLR which is developing a blockchain registry on Corda. This creates an immutable record of ownership to different plots of land. And given that land disputes are often the most dangerous parts of a country split, having such a record may ease the transition in these cases.

4. TRADE FINANCE

The impact of Brexit on trade finance is an interesting story. In contrast to the disruption that is happening throughout the physical supply chain, the impact of Brexit policy changes on the financial supply chain is expected to fall in the range of: limited to none. But Brexit will at the least be a shock to firms that they should diversify their trading partners beyond Europe, and may need trade finance for the first time.

So why cover it in so much depth? For two reasons. The first is that firms expect trade finance to be disrupted. And expectations sometimes matter more than reality. The memories of the Global Financial Crisis remain. When trade finance availability plunged in 2008, credit rationing led to the collapse of global trade. This will not happen this time, but if firms expect limitations in finance for trade, they will begin to undertake second-best risk mitigation techniques today. We are seeing evidence of this already.

The second reason is that trade finance stands apart in the supply chain as the segment in which blockchain has found its most substantial use cases and its strongest impact. 2019 will be the year that blockchain trade finance applications go into production. This provides us with a counterpoint to logistics where blockchain is largely in the pilot stage due to outdated legislation. In trade finance we can get a sense of the extent of disruption and how much the world will change.

4.1 Sources of Expectations around Working Capital

Trade finance comprises credit and risk mitigation instruments that financial institutions offer to firms to facilitate global commerce.[14] It is a particularly low-risk form of finance due to its short tenor and the fact that its backed by physical goods. The ICC trade register gives it a 0.02% risk of default globally, and most of those defaults are collected on.

When disruptions occur to trade finance supply, it is associated with liquidity.[15] The fear of credit rationing - which is a process whereby banks transfer liquidity shocks to their borrowers (Agur, 2012) - is thus unlikely in the case of Brexit because the drivers of uncertainty are unrelated to liquidity. UK banks are well-positioned from a funding and liquidity perspective (Fitch Ratings, 2018). Although even as global liquidity is high, yields are low in trade finance which puts pressure on banks to focus on high value relationships which may impact SMEs.

Yet, finance for trade is reported as a source of confusion and uncertainty by firms. What is the reason for this misalignment of expectations? Uncertainty around working capital appears to stem from two sources: firms' uncertainty who their suppliers are, and the need for additional capital due to buyer requests to hold inventory. Both of these is a valid concern.

The first source of uncertainty stems from the lack of clarity over one's suppliers. Supply chains are deep and complex, and firms may only have insight a few tiers deep into their suppliers. For banks, this affects risk assessment and KYC. Banks, however, report that any changes to risk assessment will be minor and unlikely to affect clients. Since small enterprises may not be fully aware of how their bank assesses risk, they may have incorrect concerns about how the process will change.

The second uncertainty is more immediate. Some large buyers are requesting their suppliers to hold additional inventory so that manufacturing can continue in the event of delays or disruptions in the supply chain due to customs and logistics issues. Firms that hold inventory will demand more working capital in order to keep the rest of the business running. Firms have already reported reduced wage increases as they hold capital (FSB, 2017). This is not a bank liquidity issue, but rather one where firms make inventory and procurement decisions today without full information about the future.

The referendum itself has already created uncertainty, which has caused corporates to reconsider looking to the UK for products. Suppliers are being told to strengthen their cash positions and make new contracts flexible. Some EU companies are reported reluctant to use British firms in their supply chains because they still do not know which tariffs or regulations will apply, so they cannot estimate time to cross border or final cost of product (CIPS, 2017).

[14] Conceptually, it consists of four elements: payments, financing, risk mitigation, and information (Malaket, 2014). In practical terms, it involves loans and guarantees from banks that underpin imports and exports. It supports cross-border trade by either directly providing funding or through unfunded guarantees on behalf of the importer to the exporter.

[15] And it is true that rationed populations tend to be more risky firms (Stiglitz and Weiss, 1981) or where relationships have a shorter history (Biais and Gollier, 1997) or in financially vulnerable industries (Chor and Manova, 2012). While it is unlikely that banks will see any liquidity impact, the churn associated with buyer learning that their suppliers are now "foreign" is already impacting demand for finance.

4.2 Blockchain's Thorough Disruption of Trade Finance

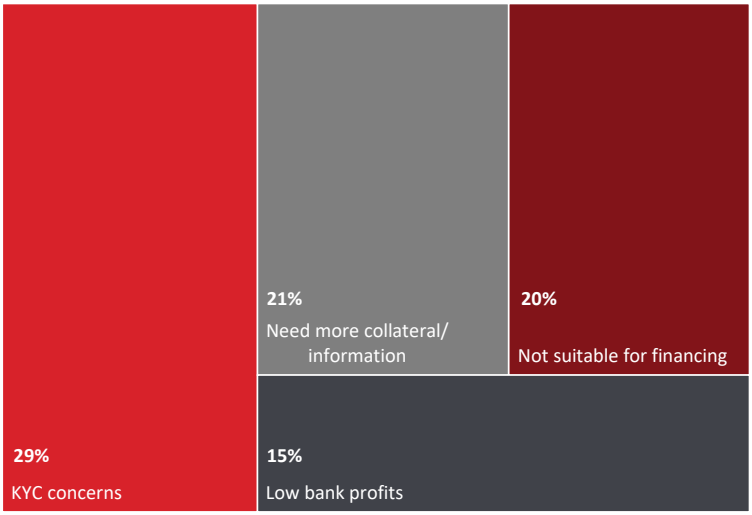
The path that blockchain has taken in trade finance is informative for our discussions about supply chain applications. While other parts of the supply chain have been studying and testing blockchain technology, trade finance has embraced it and propelled it toward production. This provides us with some insight into whether blockchain can in fact introduce certainty into a process that has historically relied on intermediaries, paper documents, and multi-layered risk mitigation to facilitate trade.

Since small and medium sized enterprises are among those most likely to face disruption under Brexit, we will focus on these firms in this section. Our objective is to answer the question - does the use of blockchain in trade finance modify any of the existing challenges trade finance faces in servicing small and medium sized enterprises?

It's not easy for small traders. Cross-border trade can be risky business. Traders doing cross-border trade tend to experience longer delays between production and payment than with domestic sales. Banks also screen exporters and importers with greater precision than domestic buyers and sellers (Ahn et al., 2011). Firms that export incur additional expenditures compared to firms that only handle domestic sales due to the cost of learning about foreign markets, foreign regulatory compliance, and product customization (Foley and Manova, 2015). Furthermore, these additional expenses are factored into risk assessment by banks. As a result, the costs of credit can be higher with cross border commerce. Particular groups – for example, small firms, and traders in high-risk countries - are more dependent on credit to support their exports than others.

The reasons that SMEs struggle to access trade finance are related to 3 issues: lack of information, lack of profit (in the financial transaction), and KYC concerns (Figure 5). Each of these causes can be attenuated by architectural features of blockchain (DiCaprio and Jessel, 2018). And if we look into the applications that are built on blockchain, the story becomes even more powerful.

Figure 5. Reasons financial institutions rejected trade finance applications (2017)



Source: ADB. 2017 Trade Finance Gaps, Growth, and Jobs Survey.

In both Project Voltron (documentary credits) and Project Marco Polo (open account), blockchain-based applications can limit the negative features of trade finance and promise to expand the market to a greater number of SMEs.

The need for additional information is related to the lack of transparency into the SMEs suppliers or transactions. This issue has been raised in the Brexit context where the BCC reported that small firms were least likely to have prepared for Brexit and may be caught unaware when they learn that they are actually importers (Bloomberg, 2018). When multiple transactions are placed on blockchain, the history is tamper resistant. This will facilitate the information gathering process for both banks and firms.

Thin profit margins are another reason for the rejection of trade finance. For this, blockchain can make processes quicker and more cost efficient. We've seen this in the case of the Project Voltron pilots where the time to settlement is reduced considerably. A major cost factor in trade transactions is the passing back and forth of the same documents multiple times. A single truth layer, or digital shared access to a confirmed and verified document or a piece of information, can eliminate the costly process of passing the same documents back and forth multiple times.

Regarding KYC concerns, the use of smart contracts and the need for consensus before transactions are committed to the blockchain can introduce additional certainty into the process.

In 2019, blockchain applications in trade finance are going into production. These applications have introduced changes in the sector that are long overdue - updated regulations and legislation for example. These applications were able to move so quickly because the parties in a trade finance transaction are limited, and contracts can be used where existing legislation is outdated. For this paper, the trade finance experience introduces both new opportunities for finance and a wider pool of eligible firms. This can help firms using blockchain to guard against some of the more unstable features of trade finance - rejection due to lack of information - for example.

4.3 Legal Considerations written by Cassels Brock & Blackwell LLP (Alison Manzer)

Are digital forms of contracts and signatures accepted under UK law for trade finance and is that consistent with EU standards?

Trade finance documentation is, in general, based on contractual agreements that are free of statutory interference or requirements, they have no grounding in statute at all, other than that terms are imported into negotiable instruments to favor ease of trade in those negotiable instruments.

Digital contracts and signatures - A digital form of contract and signature is now well established in the EU and UK, most recently with the 2016 enactment into law of the EU regulation. That regulation created consistency as to the basis for legal acceptance of the digital form of documents in trade finance and legislated interstate acceptance of home state protocols and standards for the electronic representation of documents.

Although the EU regulation is worded as providing recognition and acceptance among "member states," there is no reason to believe that the acceptance of the standards in the UK by EU members and vice versa will not stand, at least at first instance.

The regulation in the EU and the corresponding legislation in the UK accepted a set of standards. That recognition standard is not grounded in inter-member acceptance, but rather acceptance of the concepts and standards of existing technology in each jurisdiction. The courts in each country are most likely to continue to accept that recognition and acceptance, at least in part because the technology and standards are sufficiently consistent among the member states and the UK that to refuse to accept one from the other of the EU and UK would amount to refusal to accept their own legislated standards.

The legal recognition of digital agreements and signatures with the current standards is guaranteed to remain in place the EU and UK allowing the documentation now being used in electronic form to continue on an accepted legal base. As the standards and technology for electronic forms of contract and signature become increasing harmonized globally it is difficult to conceive a reason why the EU or UK would differ from that global approach and not allow for mutual recognition of these digital contract arrangements and further keep pace with evolving methods and standards over time.

Negotiable instruments – There is one type of documentation that may require some additional consideration - that of negotiable instruments. The statute law (to supplement general contract law) regarding negotiable instruments was put in place to allow ease and speed of trading in the instruments as a payment form at a time when paper instruments were the only available basis for trade and the physical passing of the instrument from hand to hand the only effective means of transacting. That process was rife with the risk of fraud and alteration meaning the ultimate recipient could not rely on the instrument received to convey the obligation to pay through the chain of holding.

The solution was to have a statute deeming the chain of obligation to remain in place, unaltered and free of defenses, where the instrument was presented, free on the face of alteration or fraud.

Viewing the digital form of negotiable instruments from that perspective, blockchain delivers the assurances that Bills of Exchange legislation was required to deliver for paper instruments of a negotiable instrument**.** A blockchain based digital negotiable instrument by the very functionality of the blockchain eliminates the need for such a statue, the application of which (in requiring "writing") provides legal scholars with troublesome conceptual issues as to what is a writing. There is no need to examine the requirement for a written instrument because the very legal concerns that underlay that requirement are resolved by the characteristics of the blockchain.

How does the possible Brexit loss of the EU regulation affect blockchain-based trade finance instruments?

As discussed above, the loss of member state status for the EU regulation on a Brexit for the UK does not really affect either the use of digital contracts, or the use of negotiable instruments in trade finance.

There are two aspects of the blockchain solution to the inability to rely on Bills of Exchange legislation that need to be considered because they are not inherently solved by blockchain.

Endorsers - The first is the legal responsibility of "endorsers" through the chain, which I suggest is readily and easily resolved by the terms of use when the instruments are on chain. That leaves the issue of the ability to interrupt the chain with legal claims such as garnishment or other legal seizure.

Garnishment or legal seizure - Although untested as of yet as to blockchain functionality, legal seizures will still need to follow the usual process and would require legal ability to seize in an open, notified manner both as to legal process and as to possession of the seized item (in this case, the instrument). There is no concept in law of stealth garnishment and therefore to be effective, the seizure would have to be both possible in the blockchain and notified to the chain. The rights to garnish are not unbounded and have to follow due process. Which means, in the same manner as the garnishment or other seizure of a written paper negotiable instrument, a garnished instrument is only lost to the process if it does not reach the end of the chain, otherwise it has not "opening and with notice" been seized. If it has reached the end of the chain, it has not been validly seized. It does not seem that the concern of mid-chain seizure has a legal basis. Therefore again the blockchain itself - with a simple rule regarding endorsers - resolves the need for negotiable instrument legislative assistance.

What happens when a transaction goes off chain?

Finally on chain – off chain considerations need to be added, as it is quite possible that in many instances trade finance agreements, including negotiable instruments will move on and off chain. For instruments other than negotiable instruments, this should present no legal issues. The only documents requiring special considerations would be negotiable instruments if the blockchain is being used to substitute for the Bills of Exchange legislated protections.

Entering the chain - If the chain rules require that the instrument enters the chain as a negotiable instrument, the fact that it is part way through a series or chain of transfer is irrelevant because the law relating to negotiable instruments brings it in-chain in a state that effectively mirrors the assurances of the chain and the blockchain then carries it forward as per above.

Exiting the chain - If the instrument is exiting the chain, it does so with the assurances of the chain and at that stage would have to be transmuted into an instrument acceptable for trade finance and therefore likely will need to have the characteristics of a negotiable instrument. But it enters that state with the assurances of the blockchain practical protections to that stage. While this is clearly not an issue for blockchain application, it would seem that an instrument exiting the chain does so with the assurance of the chain and that occurs after proceeds from the base of having the characteristics intended for a negotiable instrument.

5. DATA SECURITY

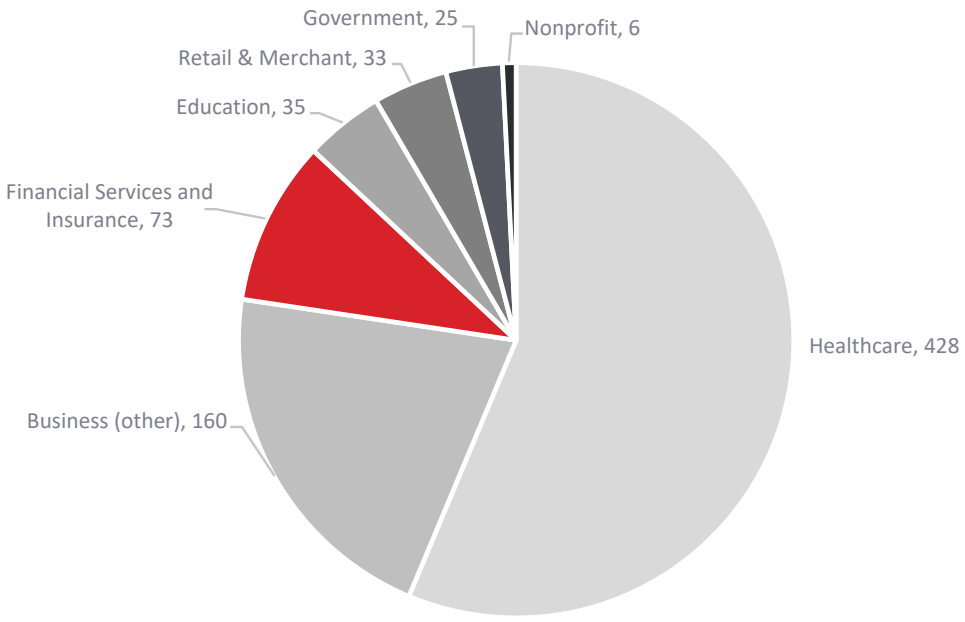
Previous sections have identified blockchain as a solution to some of the challenges posed to supply chain management in times of uncertainty. Yet the legal sections note that blockchain does not fit neatly into existing legal and standards regimes. In other words, while data security is not uniquely a Brexit problem, it is essential to consider data security when evaluating technological solutions to the aforementioned frictions across global trade.

This section is broken up into two sections, cybersecurity and data pricacy. While related, they solve distinct problems. While the fundamental question for cybersecurity is *do* I have access to data, the relevant question regarding data privacy is *should* I have access to data.

5.1 Cybersecurity

One of the key problems with digital solutions is that centralization creates a focus for hackers. This becomes a particular problem with confidential data, although it can have repercussions well beyond this. Take the example of the central electrical grid in Ukraine. It was hacked in 2015 and much of the country went dark. In a separate event, the US Internal Revenue Service was compromised, giving hackers access to over 700,000 accounts.

Figure 6. Data breaches by type of organization (2017)



Source: privacy rights clearing house

Blockchain has considerable benefits over centralized systems in the area of cybersecurity. This is why it is being widely piloted in regulated industries like aerospace and defense. These sectors operate under a level of security typically used by financial institutions. In part this is why companies like Airbus are looking at blockchain applications that are private ecosystems. This makes it both easier to determine the applicable law and also limit the nodes in the network. Blockchains are resilient as the data stored on the blockchain can survive, even if a node on the network fails or is corrupted, as such data can be recovered from other participating nodes.

Closely related to resilience, and also following from the decentralized and distributed nature along with the use of cryptographic techniques, is blockchain's tamper-resistant character. Because blockchains are an 'append-only' mechanism once data is hashed onto the chain, it is very difficult to subsequently alter or delete this data.

However, blockchains are not the silver bullet for all cybersecurity problems. Where the resilience and immutability of blockchain technology is vested in the strength of the underlying cryptography, cryptography is a constantly moving field. What is considered as state-of-the-art cryptography today may well be caught up by the potential drastic increase in computational powers brought along the technological advancements made, for example, in the field of quantum computing.

A second major vulnerability again lies not in the network, but at the ends of the network. More specifically, the user interfaces used to communicate with the blockchain layer of a transaction are often the target of hacking attempts, as these often lack in security, or – more plausibly – are not updated frequently enough.

Blockchain 'hacks' tend to be caused by either an insecure vendor or a bug in the programs that run on the blockchain (e.g. a rogue smart contract protocol). For example, Mt. Gox was a bitcoin exchange that by 2014 handled over 70% of all bitcoin transactions. In February 2014, the company revealed that 750,000 bitcoins were lost, which made up around 7% of the digital currency's total supply, resulting in a crash of the price of bitcoin. On April 30 2016, a program called The DAO was launched on the Ethereum blockchain, for which investors could purchase tokens using ether. On June 17, a hacker found a vulnerability in that smart contract that allowed the user to withdraw 3.6 million ether (roughly a third of the money held by the DAO) into a separate account. The hack sparked disputes in the community, ultimately resulting in a hard fork of Ether into two separate networks. Both the Mt. Gox and DAO hacks generated massive amounts of attention towards the risks associated with digital currencies like Bitcoin and Ether respectively. However, cases were the fault of the infrastructure around the blockchains – not the blockchains themselves.

Here, the hacking tactics that are used are no different than the ones used in traditional computing mechanisms. Via phishing or social engineering, hackers gain access to the private keys that in turn give access to the corresponding data on the blockchain network. For example, Target suffered a data breach exposing the credit cards of over 41 million customers. Investigations revealed that the hacker gained access to a customer service database using security credentials from one of Target's third party sellers.

The main challenges for blockchain in terms of systemic security lie not in the blockchain itself, but the smart contracts that run on, or the user interfaces that interact with the blockchain. While the only public examples are related to cryptocurrency, these reveal some potential issues about the technology that we should consider. [16]

All supply chains are impacted by cybersecurity issues since supply chains involve transportation, vendor management, procurement and various other functions. As blockchain systems are designed, issues that we need to consider are what cybersecurity aspects should be taken into account by different design roles (ie, designers, governors or operators of business networks) versus infrastructure providers and users.

[16] Public permissionless blockchains introduce a separate concern surrounding settlement finality. The ethereum classic 51% attack (January 2019) highlights the very real threat of transactions on public chains being reversed..

5.2 Data Privacy (GDPR)

The General Data Protection Regulation (GDPR) is a European-wide data protection legislation with extraterritorial effects that is directly applicable in all EU Member States, i.e. including the UK, since May 2018.

While after Brexit the GDPR will no longer be directly applicable to all organizations based in the UK, the UK's new Data Protection Bill has been drafted in line with GDPR principles, and the current regulatory data protection framework is set up to operate in line with GDPR requirements. Therefore, the UK is very likely to be considered as a country that ensures an adequate level of data protection, which will not only facilitate data transfers between the EU and the post-Brexit UK, but which will also require a continuous focus on GDPR compliance. Additionally, it cannot be denied that the GDPR is becoming the new global standard for data protection compliance. For this section on compliance with data privacy requirements we will therefore specifically focus on compliance with GDPR requirements.

In order to ensure compliance with GDPR requirements, as for any other software a blockchain-based solution needs to be designed in line with the so-called "Data Protection by Design"-approach.

This section focuses on private blockchains since public blockchains seem conceptually irreconcilable with the accountability requirements of the GDPR. R3 has spent a great deal of time considering how Corda can comply with data privacy regulations. For example, methods that make it impossible to re-identify an individual on Corda would fall under the anonymization exemption of the right to be forgotten.

One area where Brexit does impose challenges is where various standards apply to the question of data – particularly eIDAS (portable digital identity), OWASP (visibility into security of software) and ENISA (cyber security best practices). For example, eIDAS – which serves the purpouse of a single window for digital signatures, digital identity and other trust services – is not applicable to non-EU or non-EEA states. The UK equivalent standard, offered via Gov.uk Verify, has yet to be fully accepted in eIDAS.

5.3 Legal Considerations written by Crowell & Moring (Maarten Stassen & Louis Vanderdonckt)

What is considered personal data, and what techniques must be adhered to in order to ensure that it is sufficiently private?

The GDPR regulates the processing of personal data, which refers to any type of information relating to an identified or identifiable living individual. This means that using encryption or proxy identifiers is not sufficient to stay out of scope of the GDPR.

Given the above, there are three main ways in which personal data can be processed in the context of a blockchain: on-chain, off-chain, and as part of both public and private cryptographic keys that contain information related to the owners of the corresponding keys.

The first step of the Data Protection by Design approach is to assess and document - by means of a Data Protection Impact Assessment (DPIA) - how the blockchain-based solution can comply with the GDPR and how the rights of individuals (aka data subjects) in question can be optimally protected. Following, we list out the 8 features of a DPIA that must be considered in detail for a blockchain-based application. We go into detail about whether there are specific considerations a blockchain application will need to consider that are different from any other digital supply chain solution.

Lawfulness & Fairness – The processing of personal data in the context of a blockchain-based solution will only be lawful when it is based on specific legal ground. While consent might be the most discussed basis for processing, it is certainly not the only one.

Transparency – It is crucial to look for the best way to ensure that the use of personal data is in line with the individuals' expectations. First, the content of the communication will need to describe all the aspects of the intended use, with a special focus on the blockchain-specific aspects such as its distributed and immutable aspects. Second, the transparency will need to be effective, i.e. the responsible parties need to ensure that the information is duly communicated to the individuals in question.

Data subject rights – As part of the aforementioned transparency requirement, which data protection-related rights apply and how they can be exercised in an effective and efficient manner must be considered.

Purpose and storage limitation – While these are two clearly separated GDPR principles, in a blockchain environment it makes sense to combine both purpose and storage limitation principles. The reason being that one of the purposes of any blockchain solution is the blockchain itself or, more specifically, its inherent distributed and immutable aspects.

Data minimization – It should be carefully assessed whether personal data should be collected in the first place and if so, whether such collection and any further use is proportionate with the purpose(s) for which they are collected, whether the risk exposure cannot be reduced by off-chain storage or additional technical and organizational measures, etc.

Accuracy – While the secure character of the blockchain ensures that personal data cannot be tampered with, the information is only as accurate as its initial input (the "garbage in, garbage out" principle). Inaccurate data might therefore indeed reside permanently on a blockchain, but there are several ways to limit the effects of their future use.

Integrity & confidentiality – For GDPR compliance, Security ("Is there access to data?") and Privacy ("Should there be access to data?") go hand in hand. Established security considerations demand that a system exhibits confidentiality, integrity and availability (the C.I.A. principles). Whereas blockchain technology inherently scores high on integrity and availability, a breach of confidentiality is a risk that cannot be ignored, as all the nodes on a blockchain store data on the chain (though the data stored differs among the different blockchain implementations). Therefore, appropriate technical (e.g. encryption techniques) and organizational (e.g. identity and access management) measures should be taken.

International data transfers – Under the GDPR, data transfers outside the European Economic Area are only allowed under certain specific circumstances. Given the borderless concept of a blockchain, a compliant data transfer mechanism should be put in place. Several options could be considered depending on the set-up of the permissioned blockchain solution in question. These include things like codes of conduct, certification mechanisms or binding corporate rules to standardized opt-in contractual clauses approved by a competent supervisory authority.

It should be noted that a DPIA is not a one-off-exercise. As blockchains are operating in a fast-changing ecosystem, it is required to continuously monitor and, where required, adapt the technical and organizational measures to cope with a changing risk profile.

Who is responsible for data processing and potential issues that result? Is there case law or regulatory guidance on these issues?

As a result of its decentralized nature, there are a multitude of actors in a blockchain ecosystem, and their GDPR-specific roles and responsibilities depend on their involvement in the processing of personal data.

Developers - A developer who only writes the software code without being involved in the further use of the blockchain does not have to comply with the GDPR. In this paper we will not elaborate further on the many relevant and rightful debates about the ethical consequences of this situation.

If, however, the developer does have an even minimal role in the further use of the technology, they will have a GDPR-specific role, and as for the other actors in the blockchain ecosystem, it will be of utmost importance to clearly describe and allocate their roles and responsibilities.

Controllers - Organizations that decide to put personal data on a blockchain are responsible and accountable for such use as "controllers." This means that they will have to assess how they can comply with the corresponding GDPR obligations.

The fact that these organizations do not manage the nuts and bolts of the technology does not make them less responsible or accountable, which is not different than for any other technology that they use (unless, of course, they have developed it themselves).

This reasoning is in line with how the Court of Justice of the European Union recently ruled on an entity that uses a website on a social media platform. As a result of the mere fact of using the latter's infrastructure as a technical basis of its website, the entity can be held responsible in the event of an infringement of data protection legislation.

Other actors such as miners who process personal data on behalf of the controllers are called "processors." The GDPR requires them to receive specific instructions and to have a number of aspects formalized in a contract or other legal act. How to do this in an efficient manner depends on the specificities of the blockchain solution in question.

The contractual aspect is indeed one of the questions that the French data protection authority Commission Nationale de l'Informatique et des Libertés has left unanswered in its clear and timely guidance of September 2018, encouraging actors in the blockchain space to come up with innovative but compliant solutions.

After Brexit, what happens if some data centers are in the UK while others are in the EU? If they contain personal data, what new uncertainties emerge?

While the GDPR will no longer directly be applicable in the UK, the GDPR might still apply to processing operations outside the European Union as a result of its extraterritorial scope, or the GDPR might still be relevant in a different way, as described above.

Therefore, both compliance with the GDPR as a whole, and compliance with its international data transfer obligations, should be taken into account when designing any blockchain solution.

6. CONCLUSION

This paper used the challenges of trade policy uncertainty to highlight the benefits of blockchain in supply chain management. By introducing transparency into the production process and reducing errors from verification, regulatory and documentary compliance can become faster and less burdensome to exporters and SMEs.

Unfortunately, the time to implement new technologies means that these solutions will not impact the businesses, banks and public sector entities faced with trade uncertainty under Brexit. But the exercise of mapping blockchain applications to trade volatility produced insights that can guide governments and firms in their future planning of how to use technology to produce the most benefits and opportunities.

Ultimately, we found that blockchain-based supply chain solutions could mitigate disruption across a variety of processes that were identified as Brexit problem areas. The thread that connects all of them is transparency and identification of both the operator and the goods themselves. These include:

- **Facilitate regulatory compliance.** The need to assess risk differently for exports is expected to be a cause of border delays. The friction is in gathering additional or different data on the goods. With greater transparency, the data needed to address any shift in risk assessment would be already available.
- **Scale pre-certification of authorized operators.** By having immutable and certified data on chain, the pre-certification process that has been used but is still difficult, could be scaled regionally and globally. This could include an efficient implementation of Mutual Recognition Arrangements (bilateral agreements) with the exchange AEO master data in seamless and secure manner.
- **Reduce uncertainty about trade finance relationships**. SMEs have limited banking relationships which makes the application process uncertain and difficult. But as data about their transactions and existing trading relationships is on blockchain, due diligence can become faster and cheaper.

The reader will notice that the solutions we covered here do not involve every part of the transaction being on blockchain. This is a key benefit of this technology. It can connect different existing systems rather than replacing them. Importantly, these benefits do not require government implementation. Rather, applications can benefit supply chain management by smoothing frictions that exist in various parts of supply chain management.

There are other sources of uncertainty associated with Brexit and supply chains that we do not cover in this paper. For example, one key issue is the movement of labor. The need for skilled workers and customs officials is critical, but will not be solved or mitigated by blockchain in its current iteration.

While this paper specifically focuses on uncertainties deriving from Brexit, the solutions are applicable to trade regardless of circumstance. The added benefits of blockchain – such as transparency, facilitation of deep tier financing and scalable regulatory compliance – ring true across industries and geopolitical situations.

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R3 is an enterprise blockchain software firm working with an ecosystem of hundreds of members and partners across multiple industries from both the private and public sectors to develop on Corda. R3 helps its partners move applications into technical implementation and production with ease and low operational cost. R3's international team is supported by technology, financial, and legal experts drawn from its member base.

Corda is an open source blockchain platform to record, manage and synchronize agreements, designed for business from the start. Only Corda allows you to build interoperable blockchain networks that transact directly, in strict privacy.

It delivers on the promise of blockchain for business: enabling parties who don't fully trust each other to form and maintain consensus about the existence, status and evolution of a set of shared agreements.