PANIC, INFORMATION AND QUANTITY ASSURANCE IN A PANDEMIC

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Abstract.

During a pandemic or other disaster, public visibility of the supply chain can be useful for controlling the symptoms of coordination failure, such as panic and hoarding, that arise from the desire for quantity assurance by various sectors of the economy. It is also important for efficient coordination of the logistics required to tackle the disaster itself, with vital information flows to centralized agencies leading the response as well as to decentralized agents upstream and downstream in a supply chain. Publicly visible information about the supply chain at the time of a crisis needs to be secure, timely, possibly selective in terms of access and the nature of information, and often anonymous. Recent advances in distributed ledger technology allow for these characteristics to be met. Building digital infrastructure that permits visibility of the supply chain when needed (even if dormant during normal times) is essential for economies to be more resilient to black swan events.

Keywords: Pandemic; panic; hoarding; information; supply chain; coordination; quantity assurance

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Fear is the mind-killer. Fear is the little-death that brings total obliteration… And when it has gone past I will turn the inner eye to see its path. Frank Herbert, *Dune*.

1. Introduction

Disasters and crises, especially those that can qualify as near-black swan or black-swan events (Taleb, 2007), typically come with short, medium and long-term economic and societal repercussions. The COVID-19 pandemic qualifies as a "black swan" insofar it emerges as a surprise, unpredictable event with major effect. One of the most immediate economic consequences of the COVID-19 pandemic was the apparent supply shortages across a range of products from household consumables (most prominently toilet paper) to personal protective equipment (PPE) for medical workers (such as face masks), caused by sudden, unanticipated spikes in demand. Toilet paper shortages were first reported in Hong Kong and Japan in February 2020 - causing retailers to ration supply and led to the spontaneous creation of secondary markets in toilet paper - before spreading to much of the rest of the world. Shortages of medical grade face masks, particularly in countries that did not have a history of the widespread public use of face masks, remained a persistent problem during the pandemic.

The main focus of this paper is to discuss the role that public visibility of private information about the supply chain at times of need can have in alleviating symptoms of coordination failure such as panic and hoarding, and to examine the how new advances in distributed ledger technology (DLT) can help build a digital infrastructure necessary to tackle this and other black swan events. In doing so, we emphasize the importance of combining both centralized and decentralized responses for managing disasters. Given the enormity of the COVID-19 pandemic, many of the stylized features that we seek to examine here will draw from this particular black swan event. However, the analysis of the problem and prescribed solutions may well extend other disasters such as floods and famines, as well as financial crises and wars.

The impact of disasters depends to a large extent on the responses of various agents in the economy including firms, households and the government. Once a disaster has occurred, at a very broad level, there are multiple dimensions along which disaster management processes may need to proceed. First and foremost is the management of the emergency response. Second, there may be significant economic consequences that need to be addressed, especially in the medium and long-term. Third, there may be ancillary problems that arise during the course of the disaster

management cycle (e.g. in the response, recovery and mitigation phases). In the case of the COVID-19 pandemic, for example, the primary problem is the control of the disease through the actions of number of agents: health care institutions, providers, and professionals; firms that supply medical equipment; households and social care organisations that need to cooperate in following medical advice; and, the different levels of government (local, regional, national, supranational). The economic problem following the pandemic is monumental involving, as it does, the cessation of cross-border movements of labour, disruptions in travel and transport, and the shutting down of all non-essential services to curb the spread of disease. All this has significant short and long-term impact for the health of the economy. In addition to these issues, there exist a host of short-term ancillary problems as well: panic buying and hoarding of essential retail items by consumers that has led to empty grocery stores for a significant amount of time and the shortages of essential medical supplies like masks and protective equipment for health workers. These ancillary problems either prevent effective disaster management or attract valuable resources that could be better utilized elsewhere.

In responding to these problems, the role of data and information is vital. Disaster management in the digital era has typically become a data-intensive process (Poblet et al., 2013, 2018). Specifically, there are two distinct decision-making environments here that are conditioned by the nature of information available. In some instances, such as an epidemiologist attempting to understand the nature of contagion or an economist forecasting the impact on the economy, the decision-making process is driven by uncertainty. To put this slightly differently, the moves made by nature during a disaster event and the impact it can have on the economy are unknown to all agents in that economy, and information across agents is relatively symmetric. In other situations, decisions are taken under asymmetric information. A retail store, for example, may know more about its supply chain than consumers, or the supplier of masks may know more about its production schedule than the hospital that procures its masks, or a hospital may know more about its stock than the government. The focus of this paper is on the challenges posed by private information during disasters and how recent advances in digital decentralized technologies can mitigate its adverse impact. To that end, examining the repercussions of asymmetric information in the third set of ancillary problems including panic buying and localized shortages of medical equipment is particularly instructive.

The standard literature on asymmetric information that deals with adverse selection and moral hazard assumes a vital ingredient that makes the problem "interesting": conflict of interest between entities classified as either a principal or an agent, depending on who has the *ex ante* bargaining power while offering a contract. In the context of disasters such as pandemics, there is not

necessarily any conflict of interest between agents with greater information and those with less; for example, it is in the interests of both supermarkets and households that a panic run on household staples ends, and in the interest of suppliers of PPE, the public, the government and hospitals that hoarding of medical equipment ceases. Rather, the conflict of interest arises between agents having the same level of information due to the desire for quantity assurance, that is, to secure one's share in a dwindling stock of particular goods, which essentially boils down to a coordination problem.

In this environment, we argue that there is a need to harness information regarding the supply chain that is held privately by a distributed set of agents. The fact that supply chain and logistic considerations are important during a crisis is certainly not novel (see, for example, Dasaklis et al, 2012 for a review of the main issues and the literature). However, the literature has paid little attention to the issue of how to use supply chain information to control panic and hoarding during a disaster, or why that may be desirable. As such, there are three main issues that we seek to highlight here for creating a system resilient to *force majeure* shocks such as pandemics: first, that dispersed private information about the supply chain needs to be made public to a contextually specific set of agents in order to end a cycle of panic and coordination failures; second, that the technologies already exist to do this in a manner that can ensure selective release of information about a firm's supply chain; and third, rather than an exclusive top-down, one-way information flow, disaster management requires a mix of centralized and decentralized responses to rapidly emerging information.

2. Quantity assurance in the large and small

2.1 Panic! at the supermarket

Panic buying of staples and medicines by consumers during a disaster is not an unknown phenomenon. During the SARS outbreak in 2003, for example, China witnessed the panic buying of vinegar, masks, salt rice and vegetable oil (Ding, 2014). Panic after the Fukushima nuclear plant radiation leakage in 2011 resulted in shops being stripped of salt, followed by a panic buy of soy sauce as salt supplies in stores ran out.[2] The anticipation of Hurricane Sandy in 2012 in the Washington D.C area led to a run on bottled water, batteries, flashlights, alcohol and – incredibly enough – potato chips.[3] During the COVID-19 pandemic, stores ran out of essential staple items in multiple cities throughout the world.

When such panic reactions of consumers do occur, even when there are no unusual disruptions

[2] See https://www.chinadaily.com.cn/cndy/2011-03/18/content_12189705.htm
[3] See https://www.theguardian.com/world/2012/oct/29/washington-dc-shutdown-hurricane-sandy

in the supply chain, assurances by firms and the government do little to contain the spread of panic. In situations such as this, the communication by firms and governments to instil confidence in the workings of the supply chain is essentially perceived as cheap-talk, since these assurances are not verifiable. The effects obtained might be opposed to those initially intended, putting supply chains under further strain. The only observable variables here are empty shelves that signal quantity availability disruptions to consumers, which in addition rapidly propagates through social media sites.[4] This points to a significant way in which consumer perceptions change during a crisis. In normal periods, much of consumer trust revolves around *quality* assurance: is a product of high or low quality, or what are the ingredients in a food item, or what is the provenance of sea-food, and so on. During a panic buy, the focus of the consumer trust is predominantly on *quantity* assurance: whether items available in quantities that can satisfy the surge in demand following the onset of a disaster.

Given the fact that one-way communication by governments and firms regarding the state of the supply chain are often ignored by consumers due to lack of verifiability, one would expect that the re-stocking of shelves would reduce panic buying. While this may well be true (all panic buys ultimately come to an end), there are other subtle informational problems that can manifest even then. During the SARS epidemic, for example, the control of social side effects such as panic buying, overpricing and rumours was converted by official rhetoric to evidence that anti-SARS measures were working, thereby implying that the SARS epidemic itself was being brought under control. In reality, however, the epidemic continued to spread even after these side effects were contained (Ding, 2014). As Ding (2014) states:

One key difference between the SARS outbreak and its social side effects was their differing degrees of visibility. Whereas mass panic and overpricing were highly visible because of their direct impact on people's daily lives, the actual development of the epidemic was far less visible: the public was only granted limited access to medical and epidemiological information. In addition, it was difficult for anyone but medical care workers and SARS patients and their families to sense its immediate impact. Therefore, although it is impossible to hide mass panic and overpricing from the public, information blackout can easily though temporarily prevent the public from realizing the actual existence and development of epidemics.

While this evidence is anecdotal, it points to the subtle ways in which asymmetric information can be manipulated during a crisis. If information is manipulated often enough, trust in official communication erodes and can ultimately be lost.

[4] See, for example: https://www.canberratimes.com.au/story/6686297/we-do-not-have-a-supply-issue-woolworths-boss-calms-panic-shoppers/; https://www.abc.net.au/news/2020-03-21/farmers-call-for-calm-amid-coronavirus-panic-buying/12076764; https://www.abc.net.au/news/2020-03-18/coronavirus-panic-buying-pm-tells-people-to-stop-hoarding/12066082

To summarize, there are a number of stylized features that follow from the above discussion. First, when there is the possibility of contagion of the disaster, as in the case of epidemics, there exists the potential for contagion of the panic as well, from country to country and from locality to locality within a country. Thus, the panic purchase of household staples is often not limited idiosyncratically to a single store or to a single firm's output; the problem can be systemic and widespread. Second, even when there are no disruptions to the supply chain, quantity assurance is vital during a crisis to dissuade panic purchase. Third, official one-way communication from the government and by executives of firms is not verifiable, and consequently may not be effective in controlling panic buys. Finally, when panic buys do end, its cessation can be conflated with the control of the emergency itself, which in situations such as epidemics, can lead to households abandoning health precautions (irrespective of whether the conflation is manipulated by official channels or not), and can cause households to lose trust in official communication over time.

So, if statements by government officials and the chief executive officers of firms are unlikely to provide consumers with the quantity assurance needed to contain panic buys during disasters, how is one to tackle this problem? To answer this, one can perhaps look to other instances of panic in the economy, and examine the solutions put forward there. As such, another instance of panic in markets that bears some resemblance to the problem at hand is a bank run.

While the literature on bank runs is vast, there are essentially two aspects to the problem that are relevant here. First, as put forward by Diamond and Dybvig (1983), bank runs occur as a self-fulfilling prophecy. Enough agents withdrawing money from a bank will result in its liquidation; thus, if an agent perceives that others will withdraw, so will the given agent in order to claim funds before liquidation. This problem exists in panic buys during disasters as well: if enough consumers purchase household staples, shops will run out of supply; if this is expected to occur, the only way to procure goods is to beat others to it, which results in panic buys by a large number of consumers and the store indeed running out of stock. Historically, the traditional response of banks to a bank run is the suspension of convertibility from deposits to cash. Such responses occur in panic buys as well, with stores temporarily rationing goods to consumers. Diamond and Dybvig (idem) also examine other schemes: deposit insurance and lender-of-last-resort. It is not clear what parallels exist in goods markets; possibly the closest is the maintenance of a buffer stock by the government of some developing countries that assist in times of flood or famine, though these are seldom utilized to control panic buying.

The second strand of the bank run literature (for example, Chari and Jagannathan, 1988) focuses on information problems: bank runs occur because depositors do not have information about the solvency of banks. Park (1991) examines historical bank panics in the US and shows that

governments and banks stopped the contagion of panic withdrawal from banks primarily by providing financial information on the solvency of banks.

The analysis of the bank run literature, therefore, suggests the possibility of both a coordination failure (all consumers purchasing at the same time) and an information failure (consumers unaware of the supply chain and believing temporary shortages may be prolonged). A mechanism that *credibly* informs consumers of the state of the supply chain and the fact that goods are not in short supply can remove the coordination failure and provide quantity assurance. Such a mechanism must provide consumers with trusted data and information about the supply chain, rather than merely relying on unsupported claims.

2.2 Shortages of vital medical equipment

Another aspect of quantity assurance during emergencies and disasters relates to shortages of vital equipment and medicines required. During the COVID-19 pandemic, for example, according to the World Health Organization (WHO) shortages in personal protective equipment (PPE) occurred due to "rising demand, panic buying, hording and misuse", which led the WHO to issue a call for governments and industry to increase manufacturing of PPE.[5] The shortages in PPE are mimicked by shortages in machines such as ventilators and key medicines as well.[6] So, like the retail context, this situation can have the same elements: rising demand, panic buying, hoarding and localized shortages as the supply chain struggles to cope.

In spite of the resemblance to retail panic buying of consumer goods, however, the problem here is more intricate and complex. In the retail good case the desire for quantity assurance occurs in only one sector of the economy: the household sector seeking assurance over availability of staple items. With medical equipment and medicines, the quantity assurance may be sought not only by households who purchase equipment such as masks for their protection, but also by hospitals who compete for increasingly scarce medical resources.[7] Given that scarce medical resources are vital to end a pandemic, the end result can be a scramble for equipment and supplies by hospitals in a locality, by localities and states in a nation, and between nations themselves, thereby dragging the government sector (at various levels) and the external sector into the race for quantity assurance as well. Thus, we find, during the COVID-19 pandemic, governors of various

[5] See https://www.who.int/news-room/detail/03-03-2020-shortage-of-personal-protective-equipment-endangering-health-workers-worldwide.
[6] See https://www.statnews.com/pharmalot/2020/03/31/a-new-covid-19-problem-shortages-of-medicines-needed-for-placing-patients-on-ventilators/.
[7] In addition, medical equipment and medicines also have to satisfy stringent quality requirements, which can hinder the supply chain response. See, for example, https://www.bbc.com/news/world-europe-52092395.

states in the US engaging in a race for supplies from the federal government[8]. Given that a pandemic encompasses the entire globe, it is perhaps not surprising that the matters are further complicated by governments entering the race to assure supply of medical equipment for their country. In the COVID-19 pandemic, the Chinese government started stockpiling PPE and other medical supplies initially, followed by European countries as the virus spread geographically (The Economist, 2020).[9] The logic of panic inevitably leads to hoarding by the governments of countries in *anticipation* of the pandemic reaching their geographic borders.[10] Consequently, the evidence suggests that panic during a pandemic is, in a sense, fractal: the patterns of panic that occur in a neighbourhood replicate themselves in consecutively larger scales as well, very much like rumours and disinformation in the absence of factual knowledge (Faye 2020).

In the case of the panic buying of staples by households, the response by retailers is typically to ration goods to consumers; we argued in Section 2.1 that this mimics the response by banks in a run that cease convertibility of deposits to cash. The reaction by governments is similar with nations limiting exports of medical equipment and other supplies. By March 11, 2020, roughly three months into the COVD-19 pandemic, 24 countries had restricted exports of medical supplies, with many more doing so in the following days (The Economist, 2020; Bown, 2020).[11] In addition to a more complex scale of panic, with shortages in medical supplies during a pandemic, there can be supply side problems as well as major producers of medical equipment deal with the pandemic within their own borders, thereby reducing global supply.[12] This is the most visible aspect of the medical equipment shortage: a massive global quest for quantity assurance, leading to a coordination failure in terms of getting supplies to where they are the most useful, which generates

[8] See https://www.washingtonpost.com/politics/governors-plead-for-medical-equipment-from-federal-stockpile-plagued-by-shortages-and-confusion/2020/03/31/18aadda0-728d-11ea-87da-77a8136c1a6d_story.html. As quoted in that article, the governor of New York, Andrew Cuomo, stated described the process of coordinating vital supplies with the federal government as "being on eBay with 50 other states, bidding on a ventilator". Elsewhere, the governor states: "I'll contract with a company for 1,000 masks. They'll call back 20 minutes later and say, 'The price just went up,' because they had a better offer. I understand that. Other states who are desperate for these goods literally offer more money than we were paying. It's a race that's raising prices higher and higher"; the quote appears in:
https://www.usatoday.com/story/news/nation/2020/03/22/coronavirus-n-95-mask-shortage-us-fema-donald-trump/2895344001/.

[9] Preliminary reporting on the matter suggests that governments are sourcing supplies internationally in open markets, driving prices up in these markets and displacing private importers who cannot compete in terms of acquiring funding. See:
https://www.theage.com.au/lifestyle/health-and-wellness/call-for-national-response-to-ensure-medical-supplies-20200328-p54esr.html.

[10] See, for example, https://www.aljazeera.com/news/2020/03/covid-19-panic-india-health-workers-ppe-shortages-200331075627594.html.

[11] See also https://edition.cnn.com/2020/03/27/business/medical-supplies-export-ban/index.html.

[12] See, for example, https://www.infectioncontroltoday.com/mask-respirators/survey-us-hospitals-brace-severe-ppe-shortage.

further panic and a continuing cycle of coordination problems and panic.

But hidden behind these visible symptoms, as with the retail panic case, there are informational problems lurking in the background. The WHO has explicitly noted the importance of a coordinated effort in distributing medical equipment to the areas that most need it.[13] The result has been the creation of agencies such as the Pandemic Supply Chain Network (PSCN), whose mission is to "create and manage a market network allowing for WHO and private sector partners to access any supply chain functionality and asset from end-to-end anywhere in the world at any scale"; and, in achieving this mission, "the PSCN requires *visibility of the supply chain market* as an overall system in the context of a pandemic which includes understanding the capacity and risks associated with delivering critical the commodities and supplies to the those areas in most need." [emphasis added][14] The problem here is again one of asymmetric information with supply chain nodes having information that another entity requires, and the prescribed solution, as before with retail panic buys and bank runs, is greater visibility of the supply chain. However, the arguments put forward by the WHO for making the supply chain visible relates to the *ex post* issue of how coordinate efforts to get medical equipment to the areas that need it the most. While this is certainly needed, the insight offered in this paper that there is an *ex ante* value to making the supply chain visible due to the impact it can have in reducing panic and hoarding, which reduces the chances of localized shortages to begin with.

So, to briefly summarize, with shortages of medical equipment during a pandemic one observes elements similar to panic buys of retail staples, but on an increased scale and with greater complexity due to the involvement of virtually all sectors in an economy in a global competition over medical items. Here, again, there are coordination problems with multiple entities unable to coordinate their strategies in terms of distributing supply as entities scramble for quantity assurance. These coordination problems are visible and often help to intensify the panic. Like retail panic buys, informational issues are at the center of equipment shortages. In many ways, resolving these information problems are the key to mitigating panic, and for breaking a cycle of panic and coordination problems that reinforce each other during a crisis.

[13] See the link in footnote 4, which states: "WHO is working with governments, industry and the Pandemic Supply Chain Network to boost production and secure allocations for critically affected and at-risk countries."
[14] See https://www.weforum.org/projects/pandemic-supply-chain-network-pscn. For an overview of COVID Action Platform, see also https://www.weforum.org/platforms/covid-action-platform.

3. Information, decision-making and new technology

When disasters strike, crisis management procedures are usually overseen by various layers of the government. The responsible agencies can be spread across sub-national jurisdictions and by specialisation, but are usually subject to national executive level coordination (such as Australia's COVID-19 national cabinet and the United State's COVID-19 White House Taskforce) that presents a centralised response. In a global pandemic such as COVID-19, Section 2 highlighted the possibility of involvement of virtually all sectors of an economy and, indeed, all countries in the world engaged in seeking assurance over supply of vital goods at virtually every level – households, hospitals, suburbs, cities, states and nations. In such a fragmented and chaotic process, centralized responses are hard because the information required to take centralized decisions is widely dispersed and not readily available. Economists are familiar with this critique of centralized decision making, especially Hayek's (1945) observations on the informational problems with a centrally planned economy. In addition, when it comes to coordinating the response of nations during a pandemic, there is no clear central planner, with international agencies such as WHO having only an advisory role.

Suppose a government agency is seeking to understand the state of the supply chain in terms of medical equipment, so that it can ensure allocative efficiency – sending the equipment to the area that needs it the most. How would the government collect this supply chain information? The obvious answer is that it would contact various firms. Thus, we find the Australian government, for example, issuing a "request for information" over PPE production capabilities in a supply-mapping exercise.[15] The request was released on 15th March 2020, giving firms *three days* till 18th March 2020 to respond. Moreover, data collection is just the beginning of the decision-making process – it must be compiled and assessed, and non-responding firms followed up with. In a pandemic where new infections virtually double every two to three days, this timeframe is remarkably slow.

A centralized crisis response management often requires not only information on supply, but also, in order to ensure allocative efficiency over limited supply, information on demand as well. A government, for example, may need to know which hospitals are facing severe shortage of PPE; movement of information from a local hospital to state government to the federal government that ultimately procures and distributes supply can, like the supply-mapping exercise, be too slow.

Previous examples from crowdsourced crisis mapping show that it is possible to coordinate

[15] See https://www.canberratimes.com.au/story/6679660/australian-government-mapping-domestic-supply-chains-for-masks-and-gowns-amid-global-shortage/.

information on demand horizontally. Digital platforms such as Ushahidi or Sahana have been used by volunteer groups and aid organisations in the aftermath of earthquakes, hurricanes, floods or bushfires (Poblet et al. 2018). Crowdsourced crisis mapping typically leverages social media contents to collect information on urgent needs, a task that requires deploying curation and verification processes to make this information actionable. Nevertheless, if not augmented with additional, trusted data from aid and response organisations, there is a risk that social media information per se does not completely reflect demand at any given time. Again, a combination of different information flows seems best suited to capture a more comprehensive state of demand.

Apart from information flowing to the government, its transmission to industry can also be vital during a crisis because it allows for a decentralized response to supply shortages as well. In a now famous example of rapid response to a shortage of valves in a hospital in the Lombardy region in Italy, an engineering start-up designed a 3D-printed prototype valve in less than *three hours*. In this particular instance, the demand for valves by the hospital was made known to the Italian firm through a journalist.[16] But the message behind this anecdote is clear: the flow of information allows for industry to adapt to changing requirements *rapidly*, fostering innovative and decentralized solutions that assist in the centralized management of a crisis. In a pandemic, therefore, the information has to flow in all directions of a supply chain (upstream, downstream, and sideways) and be visible *simultaneously* to multiple agents to ensure speed and efficacy of response.

There are a number of issues that arise relating to this: first, how is such informational sharing to be organized; second, who has the ability to control the flow of information; third, how is confidential information regarding a firm's supply chain to be protected,[17] even if it is valuable information for a government agency coordinating a pandemic response; fourth, can this information be updated and disseminated rapidly; and fifth, what happens when the pandemic is over?

Before tackling these questions, however, it is worthwhile reiterating the mix of centralization and decentralization that exists in crisis management. The response to a pandemic is overseen centrally, specifically by the government (federal, state and local) in different countries. However, supply chain information is distributed, and localized shortages are often best handled by decentralized responses. Information, therefore, needs to be made available both to central and decentralized agents, while at the same time ensuring that the providers of information have discretion (to the extent permitted by regulation) over who the information is released to;

[16] See https://www.bbc.com/news/technology-51911070.
[17] See a proposed solution in this space by Altawy and Gong (2019).

otherwise the owners of information may prefer to keep it private.

Recent advances in DLTs, such as the development of blockchains, in fact, provide the technological capabilities to address many of the issues raised in this paper. As the name suggests, a distributed ledger records information (and is therefore a ledger) in a network of independent computers simultaneously (and is therefore distributed). This is in contrast to a traditional ledger such as a bank ledger, where a centralized agent records and maintains the information. While prominent blockchains like bitcoin are public in the sense that any agent has the right to access and amend information on the ledger, a permissioned distributed ledger limits the set of agents who can do so. A permissioned distributed ledger is somewhere between a purely centralized ledger which allocates all access and writing ability to a single agent, and a purely decentralized ledger that allows anyone to do so. In a permissioned ledger, a specific set of agents have access to view information in the ledger and a (possibly different) set of agents possess the right to write information on the ledger. Clearly for the context at hand, a centralized record keeper is too slow to absorb decentralized information, while a fully decentralized system is inefficient because it provides access to agents in the economy who do not need the information in the ledger. The permissioned distributed ledger emerges as an optimal system that occupies the happy middle-ground in terms of the trade-offs between speed and access.

Distributed ledgers are typically built around cryptographic principles of information protection, specifically public key algorithms, which involve the usage of a private key that is kept secret and a public key that is distributed to the network. These keys perform the function of ensuring, essentially, that the information lodged in the ledger is not hacked. But, at the same time, public-private keys also allow for anonymity; that is, while the public key is known, the identity of the agent holding the private key can be kept secret. This is an important feature because it allows any agent on the network to post information that carries their digital signature and certifies authenticity over authorship, without revealing their identity. In the context of supply chains, therefore, a firm can post information about their existing stock of goods that does not reveal to other firms any information other than quantities. It also allows a diverse set of agents on the network (whether they are government agencies, firms of households, depending on the context) to see information that is updated synchronously across the network.

The high-level model we suggest in this paper, in sum, is a confidentiality-aware, scalable, interoperable, permissioned DLT. Whether built by a government, an international agency or a coalition of private interests, a pandemic management supply chain relying on distributed ledger infrastructure, allows for the supply chain to be made visible to agents who most need to see it, with anonymity preserved if necessary. It can be used *ex ante* to ensure quantity assurance, thereby

reducing panic and hoarding, and *ex post* to coordinate logistics among firms, health and government agencies, both within a country and internationally. During normal times it may perform no function, but when it is activated during a pandemic, it reduces the fragility of the global supply chain system, which is something that the COVID-19 has exposed tragically in many countries so far.

4. Conclusions

COVID-19 has underscored to this generation the devastating effects a pandemic can have, both directly in terms of the spread of disease and indirectly through the economic sacrifices that have to be made to end the pandemic. But attempts to balance the trade-offs involved in managing health and economy are vitiated by other elements. While fear over health issues is understandable, it very quickly translates into a quest for quantity assurance that leads to panic buying of retail staples, hoarding of medical equipment and so on. The problem of quantity assurance then permeates all sectors of the economy, and eventually becomes a global phenomenon, with countries enacting export restrictions and hoarding vital equipment needed to fight the pandemic if it is already present within its borders, or in anticipation of disease arriving within its borders in the near future. The symptoms of panic and coordination failure, such as empty shelves at grocery stores or hospital staff pleading for equipment, are very visible and occupy much of the social and mainstream media reporting on a 24/7 basis.

The classic response to this coordination failure is quantity restrictions and rationing. For example, grocery stores limiting sales of items to customers, the federal government restricting PPE equipment that is made available to states, state governments channelling all available supplies to hospitals, countries restricting exports of medical equipment, and so on. Ultimately, these quantity restrictions are inefficient because they hamper the movement of resources to where they are needed the most. Moreover, one of the features that enhances allocative efficiency during normal times, the price mechanism, is relatively ineffective (or inefficient) during a pandemic. Purchase of domestic equipment, for example, by a government of a foreign country that can run deficits cannot be matched by domestic private agents. Similarly, the imposition of export restrictions can be counterproductive because it fails to factor in a fundamental aspect of a pandemic, that there are externalities arising from the fact that controlling the disease in one country is less likely to spread the disease to another country. Thus, if a disease spreads sequentially in a pandemic, resources should flow to the areas that have the maximum impact in curtailing the disease from a global perspective. A disease knows no political boundaries, so a response that is constrained by the presence of artificial (man-made) nation states is bound to be

sub-optimal. Yet, such restrictions do exist in reality, so the response must strive at least to be second-best.

In this paper, we have identified the visibility of the supply chain as a feature that can help control the symptoms of coordination failure, such as panic and hoarding; moreover, it is also important for the logistics and coordination of a global health response. Recent advances in DLTs can play a vital role in designing an infrastructure, be it local, national or international, that allows supply chain visibility while maintaining network security, control over access to information and necessary anonymity. It also allows for information to flow from a distributed set of agents to a central agency leading the response, while at the same time permitting information flows between the agents themselves upstream, downstream, and sideways in a supply chain. The digital infrastructure built to make the supply chain visible may not be useful during normal times, but can be activated during any black swan event – flood, famines, pandemics, earthquakes and so on – to ensure resilience of the supply chain when it is needed the most.

Reference

AlTawy, R. and Gong, G., 2019. Mesh: A Supply Chain Solution with Locally Private Blockchain Transactions. *Proceedings on Privacy Enhancing Technologies*, *2019*(3): 149-169.

Bown, C.P. 2020. EU Limits on Medical Gear Exports Put Poor Countries and Europeans at Risk. *Peterson Institute for International Economics Trade and Investment Policy Watch*, 19 March.

Chari, V.V. and Jagannathan, R. 1988. Bank Panics, Information and Rational Expectations Equilibrium. *The Journal of Finance*, 43: 749 - 761.

Dasaklis, T.K., Pappis, C.P. and Rachaniotis, N.P. 2012. Epidemics Control and Logistics Operation: A Review. *International Journal of Production Economics,* 139: 393 - 410.

Diamond, D.W. and Dybvig, P.H. 1983. Bank Runs, Deposit Insurance, and Liquidity. *The Journal of Political Economy*, 91: 401 - 419.

Ding, H. 2014. *Rhetoric of a Global Epidemic: Transcultural Communication about SARS*. Carbondale: Southern Illinois University Press.

Faye, C. 2020. Loose Lips: The Psychology of Rumor During Crisis, Behavioral Scientist, https://behavioralscientist.org/loose-lips-the-psychology-of-rumor-during-crisis-coronavirus/

Hayek, F. A. 1945. The Use of Knowledge in Society. *The American Economic Review*, 35: 519 - 530.

The Economist. 2020. New Trade Barriers Could Hamper the Supply of Masks and Medicines. *The Economist, Finance and Economics,* 11 March.

Park, S. 1991. Bank Failure Contagion in Historical Perspective. *Journal of Monetary Economics*, 28: 271 - 286.

Poblet, M., García-Cuesta, E. and Casanovas, P., 2013, December. Crowdsourcing Tools for Disaster Management: A Review of Platforms and Methods. In *International Workshop on AI Approaches to the Complexity of Legal Systems* (pp. 261-274). Springer, Berlin, Heidelberg.

Poblet, M., García-Cuesta, E. and Casanovas, P., 2018. Crowdsourcing Roles, Methods and tools for Data-intensive Disaster Management. *Information Systems Frontiers*, *20*(6), pp.1363-1379.

Taleb, N.N., 2007. *The Black Swan: The Impact of the Highly Improbable*. Random House.