Investigating the risks of Covid-19 vaccine supply chain

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Abstract

The development of the Covid-19 vaccines is promising to end the pandemic. However, having a safe and efficacy vaccine is one thing, ensuring them get delivered is quite another. The 'Great Lockdown' has not only largely restricted the movement of people and goods, but also caused significant impacts on the delivery of PPEs and other healthcare products. This study aims to understand how supply chains can mirror the demand for Covid-19 vaccinations. It employs the Protection Motiving Theory to investigate the relationships between participants' information on vaccine availability and their decisions on vaccine uptake.

Keywords: Covid-19 vaccine supply chain, supply chain risks, Protection Motiving Theory

Introduction

First reported in Wuhan in China, the Covid-19 pandemic began last year and has now spread around the world, "… as of 4:42pm CEST, 26 April 2021, there have been 146,881,882 confirmed cases of Covid-19…" (https://covid19.who.int/). As the world grapples with COVID-19's rapid spread, vaccination has been widely regarded as the exit strategy from this pandemic. Mass public vaccination has been recognised as the only true global exit strategy from the pandemic (Bingham, 2021); recent deployment of vaccination has made a decisive turning point in the battle against the Coronavirus (NHS, 2020). However, the pandemic has not only infected people throughout the world but also triggered severe recession in very industry and geographic region, brought the global economies to a standstill (Nikolopoulos et al., 2021). The 'Great Lockdown' has largely restricted the movement of people and goods to remain staying local only. As a nature of globalisation, lockdown has also amplified the glitches of local demand and supply shocks to cause significant and unprecedented issues on global supply chains (Craighead et al., 2020). As a consequence, the pandemic has impacted the delivery of PPEs and other healthcare products due to the issues like transport disruptions and closing borders.

At the time of this paper was being written, at least 7 different vaccines (3 platforms) have been approved for administrations to block the virus transmission globally. However, all vaccines would require two doses to be effective, ensuring these vaccines to get safely and rapidly delivered for the global rollout programme is not easy. On top of that, all of these vaccines are temperature sensitive and have poor thermostability. They are required to be stored in special refrigerators to maintain low temperatures and within narrow temperature windows during the cold chain distribution, storage and last-mile delivery. They must be administered promptly once received (Golan et al., 2020). However, as the global supply chains are under historic strain, the rollout of the life-saving vaccines will be hindered. This could largely affect the vaccine availability and slow down the vaccine rollout programme in many countries, such as some countries are already forced to delay the sconed dose (Plotkin and Halsey, 2021).

As much is still unknown about this new and highly infectious disease, guidance and advice on protection steps have been published prior the vaccine availability. However, the shortages of the Covid-19 vaccines due to the supply chain risks could pose significant challenges for many countries to battle the pandemic. The delay in vaccine shipment could also affect people's protective motivations and measures, ultimately lead to the change of their vaccine decision as many could rush to get the vaccine.

This study aims to integrate the Protection Motiving Theory (PMT) to analyse general public's protective motivations and their behaviour towards Covid-19 and evaluate factors affecting their vaccine uptake decision, especially when vaccines become unavailable due to the delay in shipment and other vaccine supply chain crises. Therefore, the study has the follow research questions:

RQ1: What are the key supply chain risks in relation to the Covid-19 vaccine supply chain
RQ2: How the unavailability of vaccine due to supply chain risk have affected perceived risk of Covid 19?
RQ3: How the unavailability of vaccine due to supply chain risk have affected coping strategy of Covid 19?

Theoretical background

The vaccine supply chain risks

The development of the Covid-19 vaccines is promising, and multiple clinical trial milestones have been witnessed. However, having a safe and efficacy vaccine is one thing, ensuring them get delivered is quite another, and failure to address the issues in delivery could greatly reduce the efficacy of vaccine (Lee and Haidari, 2017). The modern supply chains are already vast and geographically disjointed (Saberi et al., 2019), the vaccine cold chain or lately vaccine supply chain is more complex (Lee and Haidari 2017), it could pose a significant challenge to the later physical vaccine delivery journey (Chandra and Kumar, 2019). It is deliberately separated from other medical distribution systems to assure timely access (Lloyd and Cheyne, 2017) and high traceability for chain of custody and regulatory compliance (Antal et al., 2021). Many vaccines are highly perishable and temperature sensitive. Their storage and transportation require not only harmonised handling procedures, rigorous humidity- and temperature-controlled equipment, but also high traceability to ensure the chain of custody and regulatory compliance. Such challenges could pose a significant barrier to the later physical delivery journey (Chandra

and Kumar, 2019). Thus, the vaccine supply chain is seldom simple and building a safe supply chain for the global rollout of Covid-19 vaccine could even be harder (Dai et al., 2021).

There are many problems and risks with the routine vaccine supply chain encountered in the past (e.g., Lloyd & Cheyne, 2017, Lemmens et al. 2016, Ashok et al. 2017), not to mention the inherent complexities create further opportunities for bad actors to thrive (e.g., Sykes, 2018, BBC, 2021). Now with the requirements to distribute millions of Covid-19 vaccines across the world on a timely basis, there could be new and additional challenges and pressure on the already fragile vaccine supply chain (Handfield et al., 2020).

The Covid-19 pandemic has highlighted the low resiliency of the vaccine supply chain (Golan et al., 2020) and many issues that can delay vaccine distributions and cause vaccine shortage (Zu'bi and Abdallah, 2016). They include the high demand pressure put on the vaccine manufacturers, hence great potential to produce defects; new impose border policies to slow down the vaccines movement and poor logistics performance of transportation and cold chain equipment. Location is also an contributing factor (Lemmens et al., 2016), as current factories to make Covid-19 vaccines are spread unevenly across the globe and many of them could be far away from destination countries. Therefore, long distance means added difficulties for the already limited shelf life in the cold chain distribution, high requirements of the packaging and limited choices of delivery routes and frequencies (Zaffran et al., 2013, Duijzer et al., 2018). Other popular issues include limited capacity (Castillo et al., 2021), lack of transparency and trust issues (Khurshid, 2020), delay or unavailability of accurate information transmission (Chandra and Kumar, 2018) and natural disaster or similar catastrophic risks (Organization, 2021).

Protection motivation theory

Protection motivation theory (PMT) was initially developed by Rogers (1975) to disentangle how threats, with an adequate level of efficacy, affect health attitudes and motivate one to engage in protective behaviours. The theory's central premise contends that protective behaviours are elicited as a response to a fear appeal. The theory considers two types of information inputs (including environmental and intrapersonal sources) that activate two appraisal processes: the threat appraisal and the coping appraisal. Protective responses/decisions (i.e., to initiate, continue, or inhibit) are outputs of the two cognitive appraisal processes.

On the one hand, the threat appraisal process evaluates the (i) severity and (ii) vulnerability of the threat. Severity refers to the perception of how serious the threat is. Susceptibility refers to the perception of the likelihood that one will experience the threat. On the other hand, the coping appraisal process assesses the (i) efficacy of the protective response, (ii) self-efficacy of the individual and (iii) cost of the protective response. Response efficacy refers to the perception of the effectiveness of the protective responses in mitigating or avoiding the perceived threat. Self-efficacy refers to the ability of one to complete the protective responses successfully. Response costs are any perceived direct and indirect personal costs incurred by an individual (e.g., time, money, effort, or trouble) while taking the protective responses (Maddux and Rogers, 1983).

Protection motivation theory has been utilised to understand various individuals' decision-making in personal health-related contexts. Its explanatory power has been demonstrated in

meta-analytic review (Floyd et al., 2000) and explained a wide spectrum of outcomes related to disease prevention and health promotion, such as cancer prevention, exercise/diet/healthy lifestyle, AIDS prevention, and adherence to medical treatment regimens. With regard to its application in vaccine uptake, Richards (2016) applied the theory to examine what influences the intentions of college students to receive the human papillomavirus vaccine and reported that susceptibility (but not severity) influenced the intention to get vaccinated. Ling et al. (2019) utilised the theory to investigate US adults' intention to receive a seasonal flu vaccination and suggested that both susceptibility and severity influenced vaccination intention.

Despite increasing scholarly attention that has been devoted to understanding the interplay between threat appraisal and coping appraisal processes, there is a paucity of research identifying the inputs (e.g., environmental sources) that affect the two appraisal processes. Only recently, Wang et al. (2021) examined the role of various information sources (i.e., whether they obtain the vaccine information from a formal vs. informal channel, or interpersonal contacts vs. media) on coping appraisal among university students in China and the subsequent impacts on their motivation to have Covid-19 vaccination. Their results showed that receiving information concerning the vaccination from medical personnel was positively associated with self-efficacy and response efficacy, whereas receiving information concerning the vaccination from online channels positively associated with response cost.

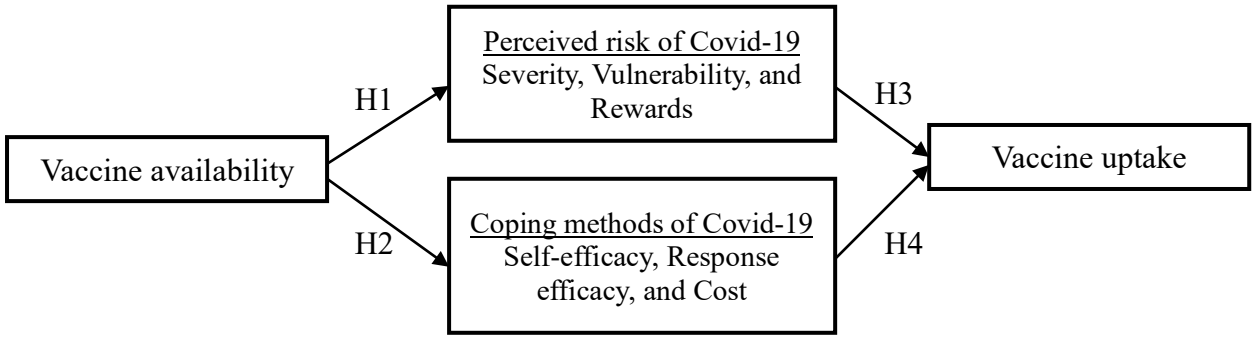
Methodology

Study Design

This study aims to contribute to the theory and research on Covid-19 vaccination supply chain by systematically examining the input (i.e., as manifested through knowledge on vaccine supply chain) that affects the two appraisal processes in PMT. It aims to investigate the relationships between participants' information on vaccine availability, the six constructs of the PMT (severity, vulnerability, intrinsic and extrinsic rewards, response efficacy, self-efficacy, and response cost), and their decisions on vaccine uptake. Therefore, the study has the following theoretical model (Figure 1) and hypotheses:

H1: Participants' information about vaccine availability would have a significant direct effect on their perceived risk of Covid-19.
H2: Participants' information about vaccine availability would have a significant direct effect on their coping of Covid-19.
H3: Participants' perceived risk of Covid-19 would have a significant direct effect on their vaccine uptake decision.
H4: Participants' coping methods of Covid-19 would have a significant direct effect on their vaccine uptake decision.

Figure 1. the theoretical model



The study uses a cross-sectional design to study and analyse the relationships. Data are collected using a self-reported survey. The study was approved by the Northumbria University's Ethics Committee. The participants of the questionnaires are completely voluntarily, and the collected data is handled confidentially and analysed anonymously.

Constructs

The survey of this study has constructs fall in four main sections. These constructs are developed based on the existing questions. The first section collects participants' general demographic information, including age, gender, education, and place residence (Rad et al., 2021). The second section includes self-reported questions on participants' information about the vaccine availability due to the vaccine supply chain risk (e.g., 'it is likely that the availability of vaccine will be affected by poor logistics performance of transportation') is measured in twelve items and rated on a seven-point Likert scale, ranging from 1 'not likely at all' to 7 'very likely at all'.

The third sections are questions about the seven PMT constructs and rated on a seven-point Likert scales (range 1-7), ranging from 'strongly disagree' to 'strongly agree'. They include three items on severity (e.g., 'if I get the Covid-19, it will be severe'); four items on vulnerability (e.g., 'I think I am very vulnerable to Covid-19'); six items on intrinsic and extrinsic rewards (e.g., 'It is very enjoyable for me to get out and see and be with others despite the warnings of social distancing'); four items on response efficacy (e.g., 'I always wear a mask/face covering'); three items on self-efficacy (e.g., 'I am confident in my ability to protect myself from Covid-19'); and four items on response cost (e.g., 'I find it costly to wear a mask/face covering'). The fourth section consists of questions on measuring participants' decision on vaccine uptake.

Sampling method

in order to reduce the risk of virus transmission during the Pandemic and boost the rapid collection of survey data (Ali et al., 2020), participants are recruited only online via social media. The link of the questionnaire is posted on the researchers' social media platforms (i.e., LinkedIn, Twitter and Instagram). The link is reposted every 3 days to increase engagement and later also share in WhatsApp and WeChat groups for more potential participants.

The target survey population is adults aged 18 years or above. They are asked to sign a consent form and have the choice to not participant in the study if they feel uncomfortable about and have the right to withdraw from the study at any time.

Expected Conclusion and contributions

The purpose of this study is to understand how supply chains can mirror the demand for Covid-19 vaccinations. One of the research areas that both Handfield et al. (2020) and Sarkis (2020) proposed researchers address is what impact the bullwhip effect has during a crisis, and what waste can exist as a result. This is one area where a contribution can be made. Whilst the bullwhip effect appeared throughout the pandemic with people stockpiling what they believed to be essential items – even though such purchases were attempted to be controlled, it led to a large amount of stock outs (Handfield et al., 2020). As no vaccination existed for Covid-19 many countries adopted 'lockdowns' meaning many supply chains were faced with unpredictable demand meaning decision making became extremely difficult – this was particularly relevant to medical supply chains (Gunessee and Subramanian, 2020). Once vaccinations were created, these would need to move through medical supply chains so predicating demand becomes important. With many products being in demand, however, there

becomes a race to move items downstream to end customers.

Due to the complexity and sensitivity of creating, transporting, and storing vaccinations, it is important that vaccine supply arrives just-in-time. Failure to administer vaccinations to a country's citizens due to under demand with vaccinations being wasted, or over demand as there is not enough vaccinations to administer, is a key challenge. As no previous data exists, it becomes problematic for the supply chain to predict demand and prepare effectively. This is a second area where we expect to contribute. By predicating vaccine uptake could be one way of helping to support an effective vaccine supply chain. For example, if we can identify citizens behaviours, we could predict the likelihood of the citizen's intention to take the vaccine. Whilst it may seem logical that all citizens would want to receive a vaccination, this is not necessarily the case. For example, Gunessee and Subramanian (2020) identified how behavioural decision theory (BDT) can help understand how people actually make decisions within the supply chain when faced with ambiguity.

Whilst the authors took a supply chain perspective, this research looks at this problem from the 'end user' or the citizen in terms of their decision making in whether to receive a vaccination or not. We expect to be able to test and propose what factors are identified as perceived risks (for example, by contracting Covid-19 would have a major impact on a citizen's life) as well as test what elements citizens are undertaking to protect themselves from infection from Covid-19 (for example, by always wearing a face covering). This will allow us to test these hypotheses and link the outcomes to demographic information. As demographic information is routinely collected by governments and other local authorities, it could provide valuable information as to the predicated number of citizens who will want to be vaccinated. This will, therefore, provide better data to vaccine supply chain stakeholders in terms of how much vaccine to make at a particular point in time and where to send it to in terms of geography.

The limitations of this work relate to the sampling method adopted. Whilst we can get a high response rate to test the model, as Covid-19 is a global problem, we would seek to obtain responses from different countries. As the survey is administered through a snowball sampling approach, it would be difficult to target different populations, which may allow further insights to be drawn on predicated vaccine uptake.

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