# Government Subsidies and Policies for Mask Production Under COVID-19: The Use of Blockchain

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## 1. Introduction

Under the threat of pandemics such as COVID-19, on the one hand, encouraging citizens to wear masks is important; on the other hand, developing an efficient mask supply chain (MSC) with subsidy programs is sensible. For instance, Hong Kong, Japan, Germany, and Italy announced in 2020 that they would subsidize manufacturers for mask production, whereas Mainland China and Singapore subsidized consumers directly when purchasing masks. Undoubtedly, both subsidies would potentially help enhance manufacturers' benefits. However, which subsidy program is more effective for the government to implement to tackle a pandemic like COVID-19 is unclear.

In real-world practices, manufacturers' dishonest behavior (e.g., over-claiming its production yield) has been widely observed in MSC subsidy programs. To combat this issue, the government may consider implementing blockchain to help ensure the honesty of manufacturers. Blockchain is an emerging, innovative, and disruptive technology that can lessen the risk of dishonesty by providing transparent and permanent records that can be verified (Babich and Hilary 2020). With the implementation of blockchain, the manufacturer is deterred from dishonesty since it will need to bear a serious consequence if the dishonest behavior is found upon inspection with respect to the permanent record in the blockchain. In this study, we analytically examine different subsidy schemes as well as explore the value of blockchain adoption in avoiding dishonesty in MSCs.

In operations management (OM), subsidy is widely regarded as an efficient means for policymakers to enhance social welfare. Subsidy design has in fact been explored in various industries, such as healthcare (Taylor and Xiao 2014), technology (Cohen et al. 2016), and agriculture (Alizamir et al. 2018). A prior study particularly relevant to this paper is Arifoğlu and Tang (2022), which examines the efficiency of government subsidies on a vaccine supply chain. Moreover, prior studies have proven that blockchain is an efficient tool to eliminate dishonest behaviors and help improve supply chain operations by providing traceable and transparent information (Hastig and Sodhi 2020).

## 2. Research Methodology

Motivated by the real-world observations and the healthcare related OM literature, we establish consumer utility-based models to analytically examine how the government can use a subsidy program to enhance MSC operations under the COVID-19 outbreak. We consider a three-echelon supply chain wherein the manufacturer decides the price and quality of the mask to maximize its profit and the government makes a subsidizing decision (i.e., either grants subsidies to consumers (Model C) or to manufacturers (Model M)) by optimizing the total social welfare. The social welfare includes four parts: manufacturer's profit $\Pi$ , consumer surplus CS, social health risk R, and government's expenditure $sD + F^i$ (i.e., subsidizing cost + implementation cost):

$$SW(s)= \alpha\Pi + \beta CS - \gamma R - \eta(sD + Fi),$$

where $\alpha$ , $\beta$ ,$\gamma$ ,$\eta$ represent the weights of four parts on social welfare, and $\alpha+\beta+\gamma+\eta = 1$. Without blockchain adoption, a manufacturer may over-claim its output to enjoy "free lunch" on the increased subsidies for those unqualified masks. The profit function is: $\Pi^A = pD_M + s_M Q_M - (k + \xi q)Q_M - \frac{\lambda q2}{2}$ , where $Q_M$ refers to the expected real production output of masks (including those unqualified ones), which should be larger than the real qualified output $D_M$ , i.e., $Q_M = D_M/\varepsilon$, where $\varepsilon$ is the manufacturer's production yield (of qualified products). With the use of blockchain, the manufacturer should pay for a unit blockchain implementation cost $c_{BNA}$ and a fixed operations cost $F_{BNA}$, and it can no longer over-claim its output. Hence, the manufacturer's profit is expressed as $\Pi_{BNA} = (p + S_M - c_{BNA})D_M - \frac{\lambda q2}{2} -(k + \xi q)Q_M - F_{BNA}$ By using backward induction, we derive the optimal solutions of governments, manufacturers, and consumers in closed-form under a three-stage Stackelberg game.

## 3. Findings and Implications

To our best knowledge, this work is the first study to analytically evaluate the efficiency of government subsidy programs in an MSC under a disease outbreak such as COVID-19. We highlight the impacts of subsidies on social welfare and the value of blockchain adoption in MSC operations. On the basis of our analytical and numerical results, we provide several important managerial implications for each member of the MSC, namely, consumers, manufacturer(s), and the government. Major findings and implications are summarized in Table 2.

**Table 2.** Major findings and implications for MSC members.

| Parties | Findings and implications |
|---|---|
| ***Consumers*** | - Consumer and manufacturer subsidies are equally welcomed by consumers.<br>- The deployment of blockchain technology surprisingly, should be unwelcomed by consumers. |
| ***Manufacturers*** | - Consumer and manufacturer subsidies are equally welcomed by manufacturer(s) in terms of the increased profit. The manufacturer(s) is benefited when the infection rate is higher, if the level of supply disruption is strong.<br>- Under the case with blockchain deployment, the manufacturer's profit can deteriorate as over-claiming of sponsors for mask output no longer exists. |
| ***Governments*** | - The decision rule provided for the government is to conduct the subsidy scheme that is cheaper (in terms of the fixed cost) to implement.<br>- The subsidy schemes are no longer effective for social welfare in the post-pandemic stage, when both original infection rate and supply disruption are relatively low.<br>- The government may "turn a blind eye" if the dishonest behavior can be anticipated or the government has adequate financial resources. |

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