Managing the risk of COVID-19 via vaccine passports: Modeling economic and policy implications

Rajeev K. Goel\textsuperscript{1,2} | James R. Jones\textsuperscript{3}

\begin{itemize}
\item \textsuperscript{1}Department of Economics, Illinois State University, Normal, Illinois, USA
\item \textsuperscript{2}Innovation and International Competition, Kiel Institute for the World Economy, Kiel, Germany
\item \textsuperscript{3}Katie School of Insurance, Illinois State University, Normal, Illinois, USA
\end{itemize}

Correspondence
Rajeev K. Goel, Department of Economics, Illinois State University, Normal, IL 61790, USA.
Email: rkg@ilstu.edu

The increasing use of vaccine passports (VPs) to certify immunity from the prevailing coronavirus has created positive and negative aspects that have shaken the workings of markets. The VPs are, however, not universally used and not required by all businesses and governments at this point. Given the newness associated with VPs and the ongoing uncertainty of the pandemic, full implications of VPs have not been considered. This paper provides some formal insights into the implications of the use of VPs, borrowing from the established economic theory. Recommendations for public policy are provided.

JEL CLASSIFICATION
I18, L51, I11, I14

1 | INTRODUCTION

The SARS-CoV-2 (severe acute respiratory syndrome coronavirus COVID-19) pandemic has led to unprecedented health and economic harm for individuals, businesses, and governments worldwide. At the time of this writing, there have been over 243 million cases leading to nearly 5 million deaths from COVID-19 worldwide\textsuperscript{1} making COVID-19 the most significant pandemic of our lifetime.

According to the World Economic Forum, 2021 Global Risk Report,\textsuperscript{2} infectious diseases are now listed as one of the “top global risks” in terms of the probability and severity of impact, second only to climate change inaction. The widespread transmission of the COVID-19 virus and its persistence over time has had profound social, economic, and health consequences globally (also see Jawad et al., 2021). Efforts to contain and control the virus and deal with its consequences have been compounded by the uncertainty in its spread and its recurrence in different variants. Yet, policymakers over time are reluctant to rely solely on lockdown strategies and have to balance economic and social revivals alongside containment/mitigation efforts. This effort is increasingly difficult in a globalized world that has intertwined supply chains and commerce, income disparities across nations, and nations’ differing reliance on resources to compete worldwide.

One of the ways risk management strategies contemplated by countries and businesses in order to control the transmission and mitigation of the social and economic impact of COVID is to institute a vaccine passport (VP). VPs are of a form of authorized ID, often digital, that has health and vaccination information of the bearer. VPs could be used by states, businesses, or countries to permit travel internationally or to permit people to participate in large gatherings such as concerts, conferences, and sporting events. This passport has a standardized format across nations, aimed at potentially reducing confusion/fraud, and lowering related transaction/information costs, to identify individuals who have been vaccinated against the virus. The underlying objectives are to lower the risk of transmission while also facilitating travel, which would especially benefit nations that are heavily dependent on tourism (Croatia, Italy, etc.) or in places where there are frequent concerts or other large gatherings. However, not all nations are yet in agreement with the VP idea and the public support does not seem universal. Thus, as support increases for controlling the spread of COVID and opening their economies more fully to activities, it seems useful to discuss the pros and cons of VPs, especially from a political–economy perspective.

In one sense, the VP concept is not entirely new, historically speaking. For years, people who have traveled to certain areas of
the world have needed to show papers—or a medical passport called a yellow card, created by the World Health Organization (WHO)—to prove that they have gotten vaccines against diseases like yellow fever, cholera, and rubella. We also recognize that VPs would meet the exception to least restrictive or coercive means as set for in Upshur (2002) for exceptional circumstances when more coercive methods must be employed. This is usually done only after less coercive methods such as education, facilitation, and public discussions have failed. Implementing policies that protect the health, safety, and economic well-being of its citizens is a foundational responsibility of the government. But the COVID-19 virus is ongoing, and thus, full recovery is not expected until well into the future. The Congressional Budget Office (2020) projects a total of $7.8 trillion in lost output during the next decade due to this pandemic.

Given the economic agents (buyers, sellers, and the government) involved in economic exchanges, the considerations or impacts of VPs must be considered with respect to the three entities. Whereas VPs have been adopted in some places (https://www.kff.org/coronavirus-covid-19/issue-brief/key-questions-about-covid-19-vaccine-passports-and-the-u-s/), other places have banned their use and still others are facing regulatory uncertainty regarding this impending regulation. Regulatory uncertainty can have spillover effects on R&D (Goel, 2007), which, in this case, can impact the development of future vaccine technologies and related accessories.

A precursor to the effectiveness and viability of the VPs is the success in vaccinating populations. Research on vaccinations has emerged in the past year in the sciences and other disciplines (Baldwin & Weder di Mauro, 2020). Most developed nations have had varying degrees of success in vaccinations; however, there are still differences within and across nations (https://ourworldindata.org/covid-vaccinations). The present study focuses on the political-economic causes and effects of VPs, given vaccinations (although, in some cases, vaccination efforts might be affected (speeded up) when vaccination passports are put in place). Research on VPs is still in infancy and is mostly in noneconomics disciplines; see Brown et al. (2020), Gans (2021), Hall and Studdert (2021), Jecker (2021), Memish et al. (2021), and Nalubola (2021).

This paper considers the pros and cons of VPs from an economic perspective. While data on the usage and effectiveness of VPs will emerge over time, it seems useful to consider the pros and cons of passports to formalize arguments and to guide public policy in the initial stages. The layout of the rest of the paper includes theoretical considerations in the next section, followed by concluding remarks.

2 | THEORETICAL CONSIDERATIONS

In this section, we consider the theoretical arguments surrounding VPs. For this purpose, we use a simple mathematical model and a graphical analysis.

Since the success of VPs will only be determined over time when enough nations have adopted them and enough time has elapsed for related data to come out, at this point, it seems useful and viable to consider the causes and effects of such passports theoretically.

Broadly speaking, VPs can be viewed as a new form of regulation. Although the intention is to facilitate travel and commerce, such regulation, as with all regulations, would come with an increase in the size and scope of the government. Besides direct costs on the government and taxpayers, government size had been linked to greater corruption via increased bureaucratic red tape (British Medical Journal, 2020; Goel & Nelson, 1998, 2021; Goel et al., 2021; Vrushi & Kukutchka, 2021). In regard to VPs, one potential avenue for corruption could be associated with the approval of certain vaccines to be included in the passports, while others (that failed to bribe regulators) are left out.

VPs can also be viewed as a tied good that is complementary to the other good(s) (e.g., travel). This complementarity would result in spillover effects on the other good whenever regulatory intervention in one good occurs (see Choi & Stefanadis, 2001 and Klein & Saft, 1985 for background on tied goods). Examples of such spillovers include market distortions and entry barriers.

What makes VPs somewhat different from other forms of regulation is that they would need at least bilateral cooperation, and ideally international cooperation. In other words, two nations (or two entities for that matter) would need to agree to honor the passports for them to offer potential benefits to passport holders. Since nations or states/provinces differ in their geopolitical significance, some nations with vested or strategic interests might be able to steer the passports to their advantage (e.g., favor their own vaccines over others) (also see Barberia et al., 2021). Furthermore, there may also be first-mover advantages or inertia, where early signatories to passport agreements have some advantages over later entrants. Initial firms mandating passports might be able to benefit from positive publicity and might make it harder/more expensive for followers to institute such measures. Thus, drawing on established industrial organization literature, VPs could create entry barriers for some vaccine manufacturers (Demsetz, 1982) and presumable exit barriers for vaccines that are approved; see Ghemawat & Nalebuff, 1985). Besides limiting competition in the short run, entry barriers can have long-term effects on innovation.

VPs can be viewed as a tool to counter vaccine hesitancy (Gans, 2021) and an instrument for internalizing disease and information externalities. They are primarily targeted to the unvaccinated and the recovered (who cannot get vaccinated in the short term). As more activities are restricted and their operation/entry tied to VPs, the potential benefits of obtaining these passports increase, as do the monitoring costs for noncompliance.

Viewed from a different perspective, VPs can be seen as analogous to regulations requiring masks for entry into certain areas. Thus, VPs would be a complementary good in demand, which could have related impacts on demand elasticities, market power, and pricing (Goel, 2009). The theoretical analysis by Goel and Haruna (2021) shows that social welfare would be greater when masks are recommended, but not mandated.
Demand uncertainty: Vaccination passports might add to the uncertainty of the demand for many products, notably, but not exclusively, in the travel industry.\textsuperscript{4} Investments and occupancy rates in hotels would less precisely be determined by past trends when there is uncertainty about how many (foreign) tourists would get vaccinated and/or obtain VPs (also see Carlton, 1978). Since demand and supply are intricately intertwined, both supply and demand projections would be less precise due to the uncertainty, resulting in excess capacity or shortages in some cases. Management of supply chains might also be more challenging when demand is uncertain (You & Grossmann, 2008).

Risk management of infectious diseases: As mentioned in Section 1, infectious diseases, including pandemics, are one of the top risks facing the world. Prevention and therapeutics are one way to manage this risk, but vaccines are a proven way to manage diseases effectively and will undoubtedly become even more important as urbanization and climate change affect the spread of infectious diseases. The World Health Organization (WHO) has been leading the world in vaccine and immunization efforts which have been able to prevent more than 20 life-threatening diseases and in preventing 2–3 million deaths every year.\textsuperscript{5} The WHO COVID vaccination dashboard provides a daily update of the world’s COVID-19 infections and deaths by country.\textsuperscript{6}

Dealing with various uncertainties would be subject to the risk attitudes of the market participants, with the more risk-averse looking to buy some insurance to hedge risks. In this context, VPs can be considered a sort of “insurance” against pandemic risks.\textsuperscript{7} Furthermore, long-term passports would need to change to reflect the changing nature of the pandemic and whatever future pandemics come out way. Further, although somewhat premature to contemplate during an ongoing pandemic, an exit strategy to eventually phase out instituted passports should also be considered.

VPs are a means of risk management, especially for managing the severity of a disease. Because of the nature of unknown disease variants that might develop (interestingly, the omicron variant reared its head after the initial draft of this research was written), controlling the risk of transmission and further spread is important. Avoiding big losses from COVID-related outbreaks—think, for example, of cruise ships not being able to come to port due to an outbreak or schools and universities struggling to remain open and the negative reputation effects associated with high infection rates. In the end, passports may actually lower business costs relative to the alternative options, shifting the supply of goods to the right (also see Vazirani & Bhattacharjee, 2021).

Digital divide issues: Once the VP is agreed upon, its form, whether digital or paper, would also be of some consequence. It might be the case that VPs are an add-on to the travel passports, in which case there would need to be greater coordination between the immigration authorities and the health authorities. Should the VP take an electronic/digital form, in which case the digital divide across population groups could create another layer of inequities (see Cheng & Luo, 2021; Nolubola, 2021; Osama et al., 2021).\textsuperscript{8} These inequities would make passport-tied goods less accessible to certain sections of the population. Thus, policymakers would have to weigh the equity-efficiency tradeoff along this dimension as well (Tanner & Flood, 2021).

As data are stored on the public’s vaccination status, digitization of VPs might also increase privacy concerns (https://www.nytimes.com/2021/08/04/technology/vaccine-passport-ny-privacy.html; Roccato et al., 2021; Tsoi et al., 2021; Wilford et al., 2021), with data leaks making it easier to identify the unvaccinated, who might fear spillover discriminations in the job market.\textsuperscript{9} This might prevent some from not seeking vaccinations or not applying for passports, which would adversely impact the demand for related goods. The risks of potential data leakages, through identity theft (Goel, 2019) or government impersonation (Goel, 2021b), could also have wider implications such as a loss of trust in the government.

Another related issue with information flows is the possibility of an infodemic, whereby too much information, including false and misleading information, flows during disease outbreaks (https://www.who.int/health-topics/infodemic#tab_1). This can also undermine trust in government and health authorities. The use of digital technologies facilitates the transmission of information, false or otherwise.

A couple of stylized scenarios are modeled below to formalize some of the arguments and their implications.

### 2.1 Theoretically modeling implications of VPs

In order to formalize some of the above ideas, it seems useful to sketch a simple theoretical model (especially since actual data on VPs would only emerge over time).

#### 2.1.1 No uncertainty with demand or with VP availability/regulation

Let us consider a numeraire good (e.g., travel) that is going to be tied to VPs.\textsuperscript{10} The demand for a numeraire good be of the constant elasticity form

\[
Q = P^{-\beta}, \quad \text{where } \beta > 0 \text{ is constant, and a negative slope of the demand curve } \left(\frac{\partial Q}{\partial P}\right) < 0. \tag{1}
\]

The simple demand function in (1) can be extended to incorporate some of the elements mentioned above like demand uncertainty. For instance, one could incorporate a parameter \(\alpha > 0\) to denote external influences on demand, such that the demand curve would then become \(Q = \alpha P^{-\beta}\).

It is easy to check that the corresponding price elasticity of demand is

\[
ed = -\beta \tag{2}
\]

Now, let us say that there is a vaccination mandate such that good \(Q\) can only be bought or sold using a VP (\(V\)).\textsuperscript{11} The VPs may be
considered as a binding regulation or a complementary good (see Goel, 2009). Then, the demand relation in (1) can be written as

\[ Q^* = VP^{b}, \text{where } b > 0 \text{ is constant and } V \geq 0 \quad (3) \]

Clearly, \( V = 0 \rightarrow Q^* = 0 \). This scenario would be related to a strict mandate whereby passports are required and enforced.

Interestingly, the price elasticity of demand, in this case, remains unchanged at \( e^* = -b \).

While the elasticity of demand with respect to VPs is unit-elastic, that is, \( eV = 1 \). In other words, a given percentage increase in VPs would produce a corresponding percentage increase in the demand for the product.

Furthermore, the responsiveness of the slope of the demand curve to VPs is

\[ \left( \frac{\partial^2 Q^*}{\partial P \partial V} \right) = -bP^{-b-1} \quad (4) \]

Relation (4) implies that an increase in VPs makes the slope of the demand less steep.\(^{13}\)

The above demand analysis shows that the price elasticity, and consequently the pricing ability of sellers, would not be affected by VP mandates. However, the stylized consideration above is unable to consider all dimensions involved. To somewhat address that shortcoming, we now introduce uncertainty.

### 2.1.2 Demand uncertainty for the product tied to VPs

Suppose that the product tied to VPs (e.g., cruise travel) has an uncertain demand. Some potential customers apprehensive about identity theft might choose to not obtain passports (see, e.g., Goel, 2019) and thereby forego going on a cruise. Let \( \rho \) denote that the probability that the projected demand would materialize and \( (1 - \rho) \) be the probability of no demand.\(^{14}\) Consumers’ attitudes towards riskiness (e.g., risk-averse, risk-neutral, or risk-loving) are determined by their marginal utilities of income and that shapes their propensities to buy insurance (Arrow, 1971; Rothschild & Stiglitz, 1976).

The linear (inverse) demand curve, with the quantity of the good dependent on the VP price \( Q(V); Q^* > 0 \) is given by

\[ P = \rho(a - bQ(V)) \quad (5) \]

Rather trivially, it follows that \( \frac{\partial P}{\partial \rho} > 0 \)—an increase in the probability that the demand of the product would materialize would boost the price of the product. Next, we consider a more sophisticated scenario, where, in addition to the demand for the product, the supply of VPs is uncertain.

### 2.1.3 Demand uncertainty for the product tied to VPs, whose supply is uncertain

A more realistic take on the above would involve both the demand for the tied product being uncertain (\( \rho \)), and this probability is now endogenous, being dependent on the probability of VPs’ supply (\( \mu \)), with \( V(\mu) \), and \( V^* > 0 \). Among other factors, the probability of infection would make the demand uncertain. The supply of VPs might be uncertain due to supply chain issues or due to regulatory/implementation issues.

However, the sign of \( \frac{\partial \rho}{\partial \mu} \) is less clear: A greater passport supply probability might increase the probability of the demand for the tied product, or it might lower it when data privacy concerns are dominant.\(^{15}\)

Formally,

\[ P = \rho(a - bQ(V(\mu))) \quad (6) \]

Then, an increase in the probability of VP supply thus impacts the price:

\[ \left( \frac{\partial P}{\partial \mu} \right) = \left( \frac{\partial \rho}{\partial \mu} \right) \left( a - bQ(V(\mu)) \right) + \rho \left( -b \frac{\partial Q}{\partial V} \frac{\partial V}{\partial \mu} \right) \quad (7) \]

The second term in (7) is negative (given \( \frac{\partial Q}{\partial V} > 0 \); and \( \frac{\partial V}{\partial \mu} > 0 \)). However, the sign of \( \frac{\partial \rho}{\partial \mu} \) would be unclear, since the sign of \( \frac{\partial \rho}{\partial \mu} \) is unclear. In case when \( \frac{\partial \rho}{\partial \mu} \leq 0 \), \( \frac{\partial P}{\partial \mu} \) would be negative. In other words, if the probabilities are independent or a greater passport supply probability reduces the probability of the tied product’s demand, the overall impact on the price of a greater probability of vaccine supply would be negative.

Given the uncertainties involved, governments might intervene to promote risk-sharing and might even underwrite some risks directly to facilitate market participation.

As the reader notes, we are deviating from formally modeling the supply-side aspects of the tied good and the VPs. The graphical analysis below addresses some of this and provides another dimension of insights into the effects of VPs.

### 2.2 Market for VPs

First, we consider the market for VPs. As discussed above, the demand for passports is uncertain, dependent upon many factors: demographic, trust in government/privacy concerns, prior experience with yellow fever certificates, education, and so forth. On the other hand, the supply of passports might be monopolized by the government (to check fraud, ensure standardization, etc.), or it may wholly or partially subcontract the supply of passports to a private vendor. On the negative side, government involvement might engender possibilities of fraud (Goel, 2021a, 2021b). Such fraud could entail both monetary and nonmonetary costs. One form of the nonmonetary cost would be the loss of confidence or trust in passports after fraud incidents. We consider both these aspects in turn.

#### A. Government sole supplier of VPs (\( P\nu \geq 0 \))

One scenario is where the government is the sole provider of VPs—just like it is for drivers’ licenses (Figure 1). This would be the case in nations where the health system is centralized and/or monopolized by the government. The demand for passports would be negatively
sloped, and the supply of passports would be horizontal or perfectly elastic. Of course, it is possible that the government subsidizes the price and sets it to zero. In this case, the passport price would stay the same as the demand for passports fluctuates.

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The quantity would depend upon how many instances the passports are mandated and the resulting demand for the tied goods. Thus, the frequency or prevalence of VP mandates would determine how many passports are demanded, with the price set by the government (which could even set the price to zero).

### B. Private vendor (with or without government) supplier of VP

The supply of passports may be entrusted to the private sector or there may be a mixed market with both private and government production. The supply of passports in such a market would respond positively to the price. The quantity would depend upon how many instances the passports are mandated and the resulting demand for the tied goods. Thus, the frequency or prevalence of VP mandates would determine how many passports are demanded, with the price set by the government (which could even set the price to zero).

Among other factors, the supply of passports would be sensitive to the supply chain uncertainty ($\mu$) considered in the theoretical model above (Section 2.1.3).

Next, we consider the market for the numeraire or tied good, when the arrival of VPs shifts the demand and/or supply of the numeraire good. Passports may be seen as an external shock, a regulatory requirement, a production input, or a complementary good. The immediate market implications are likely to be somewhat different than intermediate run implications, when the markets are able to mature and respond somewhat better.

### 2.3 | Market for a composite good (travel, areas, bars, cinemas, etc.) requiring VPs

Here we consider graphically the impacts on the demand and supply of a numeraire good. One could envision the numeraire good being airline travel, where VPs may be required to travel. The linear demand and supply curves can, respectively, be considered as $P = a - bQ_d$; and $P = A + BQ_s$, $(a,b,A,B > 0)$.

The demand and supply curves are linear. The linear demand and supply curves can, respectively, be considered as $P = a - bQ_d$; and $P = A + BQ_s$, $(a,b,A,B > 0)$.

(Dm0 and Sm0, respectively, refer to status quo—situation before the VPs (could be lockdown in some cases); without loss of generality, this can apply to pre-COVID levels. Dm1(V) and Sm1(V) refer to post-VP mandates).

### 2.4 | A. Short run

The supply of the good would decrease due to transaction costs or regulatory cost increases. The transaction costs could also be non-monetary in the form of time or delay costs. The demand would decrease due to some individuals choosing not to (due to privacy concerns, for example) or being unable (due to the digital divide or general illiteracy, for instance) to get passports (and thereby be excluded from the good consumption). The demand would also be responsive to the demand uncertainty ($\phi$) considered above in Sections 2.1.2 and 2.1.3. See Figure 3.
The supply could become more inelastic due to lesser ability to change scale with passports (a bar owner finding it more difficult to expand—monitor another entrance?) The significance of these (transaction) costs is likely to vary a great deal by industry. In the case of airlines, for example, there would be a simple, single-point VP check at boarding, with boarding times fixed at short time intervals. For a bar or a restaurant, on the other hand, this passport monitoring would be more costly given the uncertain and variable number of patrons/operating times, and, in many instances, multiple entrances. Standardization of passports would be essential to keep costs down.

In this instance, the effect on the price is unclear, but the quantity exchanged decreases. The demand would be more elastic—consumers without passports might prefer to use alternatives due to the hassle or privacy concerns.

Overall, economic activity would decrease, but this may be a slight decrease. However, passports would add stability and long-term viability to markets. The price effect might be uncertain—the government might consider subsidies—consumer vouchers or seller assistance (or both) at least in the initial stages to make VPs more popular. This is a classic case of negative externalities and an important role for government to play is to minimize these. Subsidizing passports is a strategy to do this.

2.5 | B. Intermediate run

The intermediate run would involve some learning by consumers (behavioral changes, better perception, and acceptance of the risks involved) and producers (resulting in lower transaction costs) and some scale/scope economies (Figure 4). Thus, the supply of the tied good would likely increase, while the demand likely stays the same or even decreases as consumers find legal and illegal alternatives.19

The price effect is unclear, but the quantity increases. It is, however, unclear whether the quantity traded will exceed prepandemic levels, which might have implications for both domestic and international trade (Salvatore et al., 2021). It should be pointed out that all this assumes fixed income and preferences (e.g., attitudes towards vaccinations, and aversion to risk); any changes there would further have spillover effects.

Overall, the analysis shows that the price impacts of VPs on the tied products are unclear. The indeterminacy of the price effect is consistent with the predictions of the theoretical model in Section 2.1.3 when uncertainty was considered. This has implications for the wider use of VPs when and if they are implemented. The concluding section follows.

3 | CONCLUDING REMARKS

The increasing use of VPs (VPs) to certify immunity from the prevailing coronavirus has created positive and negative aspects that have shaken the workings of markets, with implications on the demand and supply of VPs and on the goods to which they are tied. The VPs are, however, not universally used and not required by all businesses and governments at this point. Given the newness associated with VPs and the ongoing uncertainty of the pandemic, full implications of VPs have not been considered. In fact, in light of the uncertainty and controversy about their net benefits, some governments have backed off on their plans to use VPs (https://www.bbc.com/news/uk-58535258). This paper provides some formal insights into the implications of the use of VPs, borrowing from the established economic theory.

Given the recent and evolving nature of COVID-19 vaccination passports, the full pros and cons based on data will only emerge over time. This verification of the costs and benefits would be complicated as some consequences are long-term, with a delayed impact. Yet, this paper has outlined the major challenges and opportunities, borrowing, where possible, from established economic theory. Our conclusions are, therefore, tentative. However, they should still inform related policy, which will likely be revised along the way as new information (e.g., privacy safeguards) unfolds (also see Wilford et al., 2021).

One important implication from the analysis is that even without the demand elasticity for the product remaining unchanged, the relative shifts in the demand and supply of the numeraire (tied) good might lead to the net price going up or down. This would be true even in cases when the government subsidizes the price of VPs. Thus, VPs could have unintended market consequences even in instances when they are subsidized. Another unintended consequence is likely to be the impact on underground markets. Consumers who are unwilling or unable to obtain passports might lead to underground businesses (clandestine bars that do not monitor passport compliance) or underground vendors of fake passports (see Berdiev et al., 2021).

Several other consequences might emerge from the use of VPs, and it seems useful to at least outline some of those. For one, VPs might give birth or support to new complementary businesses, in testing and production. These would impose additional costs on the
buyers and sellers in these markets. They could also alter the investments in R&D in certain industries (see Wouters et al., 2020), impacting the nature and speed of innovation—would there be demand for new types of vaccines that might be invented or are in the pipeline? Finally, VPs might lead nations/regulatory agencies on a slippery path where different certifications might be added as new challenges emerge—health or otherwise (e.g., security); see Wilford et al., 2021). This potential proliferation of government regulation would then have economic and social consequences.

Policymakers should also be cognizant of spillovers from other policies on VP usage and their impacts on markets. For example, an increase in income taxes, intended to balance budgets or redistribute income, would have spillover effects on the demand for VPs and the demand for the related products. Furthermore, related policies might need to be revised as underlying uncertainties change. At a broader level, the trade policies might need to be revised in the postpandemic era (Salvatore, 2021; Salvatore et al., 2021).

Finally, policymakers would be interested in determining who (consumers or producers) would ultimately bear the costs of regulatory intervention in the form of VPs. This would depend upon the relative price elasticities of demand and supply and how, and to which extent, governments decide to participate directly in these markets (as sole dispersers of passports or not).

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the author upon reasonable request.

ORCID
Rajeev K. Goel https://orcid.org/0000-0001-9580-3196

ENDNOTES
1 https://www.worldometers.info/coronavirus/coronavirus-death-toll/
2 https://www.weforum.org/reports/the-global-risks-report-2021
3 https://www.usnews.com/news/best-states/artsICLES/which-states-have-banned-vaccine-passports
4 For a broader discussion of demand uncertainty, see Baron (1971) and Deneckere et al. (1997).
5 https://www.who.int/health-topics/vaccines-and-immunization#tab=1
6 https://covid19.who.int/
7 See https://www.theguardian.com/world/2021/aug/05/vaccine-passports-look-inevitable-so-what-rights-do-new-zealanders-have
8 Digital divides might be a function of income inequities, education inequities, religious-demographic differences, or some combination of these factors. These concerns have not only been met with public resistance (https://komonews.com/news/coronavirus/new-yorks-vaccine-passport-plan-stirs-fresh-debate-about-equity-privacy), but also from some lawmakers (https://www.nytimes.com/2021/08/05/world/boston-mayor-janey-vaccine-passport.html; https://abcnews.go.com/US/leaders-country-disagreement-require-covid-19-vaccine-passports/story?id=79264256).
9 Privacy concerns would in part be driven by culture (see Goel, 2019; Voegel & Wachsman, 2021).
10 The demand for vaccine passports would be driven by incentives to return to normal life, with vaccine passports lowering the transaction costs of a transition to normalcy. Indeed, as noted by Gostin et al. (2021; p. 1933) and others, “Digital health passes offer health and economic benefits until herd immunity is achieved. By allowing a safe return to more normal life, DHPs encourage people to be vaccinated. Digital health passes also allow a gradual reopening of the economy in key sectors such as food, retail, entertainment, and travel. Digital health passes offer a less restrictive means to relax COVID-19 preventive measures such as quarantines, business closures, and stay-at-home orders.” Beyond recreational travel, vaccine passports would also increase/restore international job search opportunities and improve the efficacy of other preventive measures such as lockdowns (see Alfano & Ercolano, 2020).
11 Without loss of generality, one can think that one passport is tied to one unit of the good—each air traveler demanding one seat and presenting his/her vaccine passport.
12 This obviously follows from our simple introduction of V in the demand function. A more sophisticated introduction would yield a different elasticity.
13 When one considers a related linear demand function of the form: Q = a - BPV, it is easy to see that the corresponding price elasticity of demand would be nonconstant.
14 Admittedly, this is a very simple consideration of the underlying demand uncertainty. Other more sophisticated scenarios may be considered, and we will consider one extension in the subsequent section.
15 In the special case, p’ = 0 when the demand probability is unaffected by the passport supply probability.
16 Governments could, of course, subsidize the price and it may even be set to zero.
17 It is also possible that an underground market emerges for vaccine passports that would undermine the credibility and efficacy of genuine/legitimate passports (also see Berdiev et al., 2021).
18 From textbook economics, for exchange, a > A. However, due to the demand uncertainty, p, discussed above, it is possible that the market demand size (a) might go down.
19 It is possible, however, that the demand might in fact increase. In that case, the price would increase but the quantity effect would be unclear.

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