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Cross-Country Differences in Personal Protective Equipment Use*

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Abstract
Why does the use of personal protective equipment (PPE) differ across countries? I develop a simple model and then offer several hypotheses. While the primary objective is to explain cross-country differences, the model suggests potential reasons for within-country and time-series variation as well. The list of plausible explanations consistent with the model is extensive. In addition to providing a framework for considering observed differences in PPE, this exercise demonstrates the difficulty of explaining relatively simple phenomena.

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I. Introduction

A global pandemic led to a surge in demand for personal protective equipment (PPE)—like masks, gowns, gloves, goggles, and face shields—in early 2020. US hospitals and governments were left scrambling to stock up.[1] In an effort to help fill the gap, many companies quickly pivoted to PPE production.[2] Criminals seized the opportunity as well, with advance fee scams and business email

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[1] Goodnough (2020) reports dwindling supplies of N95 masks as early as March 9.

[2] That many small companies began producing PPE was somewhat surprising, considering the extensive regulation pertaining to medical equipment and the limited guidance from governments (Mark 2020).

compromise schemes.[3] And individuals produced PPE at home for personal use, to protect themselves from COVID-19 and to comply with government- or business-imposed mandates.[4]

Before the pandemic, few Americans outside of the healthcare industry used PPE. Routine use was much more common in some Asian countries, like China and Vietnam. Even during the pandemic, routine use has been far from universal in the United States. And few expect widespread, routine use to continue in the United States when virus fears subside.

Why does the use of PPE differ across countries? I develop a simple model and offer several hypotheses. While the primary objective is to explain cross-country differences, the model suggests potential reasons for within-country and intertemporal variation as well.

II. Model

Consider a world with N infinitely lived agents. Agents are indexed by type $i = [1, 2, ..., I]$ and live in isolated communities. Specifically, $N_i < N$ live in location i and $\sum_1^I N_i = N$.

Initially, no agent uses PPE. Any agent can chose to adopt PPE by incurring a one-time, up-front cost $c_i \geq 0$. Let $V_{i,1}$ be the value function of a representative agent choosing to adopt PPE and use it from time T onward. $V_{i,1} = b_i + s_i n_i^\alpha \int_T^\infty e^{-r_i(t-T)} dt - c_i$, where $b_i, s_i, \alpha, r_i, and\ c_i$ are fixed parameters, r_i is the discount rate, n_i is the number of other agents employing PPE, $0 < \alpha < 1$, and $0 \leq n_i \leq N_i - 1$. Hence,

$$V_{i,1} = \frac{b_i + s_i n_i^\alpha}{r_i} - c_i$$

The first term in the value function, b_i/r_i, denotes the benefits that accrue to the agent regardless of whether others in the community employ PPE. It reflects the effectiveness of PPE at preventing infection to the user $(+)$, the risk of infection to the user $(+)$, and the extent to which using PPE is bothersome to the user $(-)$. It also captures any warm glow or status one gets from helping—or appearing to help—others $(+)$.

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[3] In April, the Federal Bureau of Investigation (2020) issued an "alert to warn government and health care industry buyers of rapidly emerging fraud trends related to procurement of personal protective equipment."

[4] Haggerty (2020) offers several examples.

The second term in the value function, $s_i n_i^{\alpha}/r_i$, denotes the spillover benefits that accrue to the agent when others in the community employ PPE.[5]

Intuitively, the agent derives no benefits from other users in the community employing PPE when the agent is the only one in the community employing PPE; derives more benefits from others using PPE as more agents in the community use PPE; and the marginal value to the agent of an additional PPE user in the community is greater when few agents in the community are using PPE than when many agents in the community are using PPE. The parameter s_i captures the social characteristics of PPE. It reflects the effectiveness of PPE at preventing infection to others in the community $(+)$, the risk of infection to the representative community member $(+)$, and any status conferred to the user by others in the community using PPE $(+)$.

Alternatively, an agent might forgo the use of PPE. An agent refusing to adopt PPE continues to enjoy the spillover benefits, $s_i n_i^{\alpha}/r_i$, but risks incurring a social sanction. Specifically, a social sanction $\rho_i n_i^{\psi}$ is levied on an agent refusing to adopt PPE with probability $\phi_i n_i^{\gamma}$ each period, where ρ_i, ψ, ϕ_i, and γ are fixed parameters, $\rho_i \geq 0$, $\psi > 1$, $0 \leq \phi_i \leq 1$, and $0 < \gamma < 1$. The parameter ρ_i captures the severity of the minimum sanction levied by the community. The parameter ϕ_i captures the effectiveness of the available technology to detect the antisocial behavior in the community.

Let $V_{i,0}$ be the value function of a representative agent forgoing the use of PPE from time T onward. $V_{i,0} = (s_i n_i^{\alpha} - \phi_i \rho_i n_i^{\beta}) \int_T^{\infty} e^{-r_i(t-T)} dt$, where $\beta = \psi + \gamma$. Hence, $V_{i,0} = \frac{s_i n_i^{\alpha} - \phi_i \rho_i n_i^{\beta}}{r_i}$.

Intuitively, the representative agent incurs no social sanction when no other agent uses PPE and incurs a bigger social sanction when more other agents use PPE. The latter results because the magnitude of the social sanction, $\rho_i n_i^{\psi}$, and the probability of detection, $\phi_i n_i^{\gamma}$, increase with the number of other users in the community. The magnitude of the social sanction increases with the

[5] Shy (2011) surveys the relevant literature. Fafchamps, Leij, and Goyal (2010) consider the social dimensions of networks.

number of other users in the community at an increasing rate, while the probability of detection increases at a decreasing rate.

Given that all agents of type *i* are identical and there are no interactions between agents of different types, adopting PPE at time *T* is socially optimal when $N_i V_{i,1} \big| (n_i = N_i - 1) > N_i V_{i,0} \big| (n_i = 0)$, where $N_i V_{i,1} | (n_i = N_i - 1)$ denotes equation 1 evaluated at $n_i = N_i - 1$ and $V_{i,0} | (n_i = 0)$ denotes equation 2 evaluated at $n_i = 0$. Substitution yields $N_i[b_i + s_i(N_i - 1)^\alpha]/r_i - N_i c_i > 0.$ Rearranging and simplifying indicates that it is socially optimal to adopt PPE when $c_i < \frac{b_i + s_i(N_i - 1)^\alpha}{r_i}$.

In other words, it is socially optimal to adopt PPE when the per capita cost of adoption is less than the per capita net gain from using PPE in the community when everyone in the community uses PPE. Consider, next, the representative agent's decision to adopt PPE at time *T*. Agents do not observe the true values of $b_i, s_i,$ or n_i and must form expectations. Let $E(X)$ denote the expected value of *X*. Hence, an agent will adopt PPE if $E(V_{i,1}) > E(V_{i,0})$. Substitution yields $\frac{[E(b_i) + E(s_i)E(n_i)^\alpha])}{r_i} - c_i > [E(s_i)E(n_i)^\alpha - \varphi_i \rho_i E(n_i)^\beta]/r_i$. Rearranging indicates that the representative agent will adopt PPE if $c_i < \frac{E(b_i) + \varphi_i \rho_i E(n_i)^\beta}{r_i}$. In other words, the representative agent will adopt PPE when the cost of adoption is sufficiently low.

In what follows, I define four equilibria in terms of $\hat{c}_i$, where $\hat{c}_i = [b_i + s_i(N_i - 1)^\alpha]/r_i$: optimal adoption, suboptimal adoption, optimal refusal, and suboptimal refusal.[6]

Definition. *An optimal adoption equilibrium results when agents in a given location adopt PPE and adopting PPE is socially optimal. An optimal adoption equilibrium results when* $c_i < \hat{c}_i \le \frac{E(b_i) + \varphi_i \rho_i E(n_i)^\beta}{r_i}$.

Definition. *A suboptimal adoption equilibrium results when agents in a given location adopt PPE and refusing to adopt PPE is socially optimal. A suboptimal adoption equilibrium results when* $\hat{c}_i < c_i < \frac{E(b_i) + \varphi_i \rho_i E(n_i)^\beta}{r_i}$.

[6] Boundary cases, where adopting and refusing to adopt PPE are equivalent in terms of social welfare, or agents are indifferent between adopting and refusing to adopt PPE, are ignored.

Definition. *An optimal refusal equilibrium results when agents in a given location refuse to adopt PPE and refusing to adopt PPE is socially optimal. An optimal refusal equilibrium results when* $c_i > \hat{c}_i \geq \frac{E(b_i)+\varphi_i\rho_i E(n_i)^\beta}{r_i}$.

Definition. *A suboptimal refusal equilibrium results when agents in a given location refuse to adopt PPE and adopting PPE is socially optimal. A suboptimal refusal equilibrium results when* $\hat{c}_i > c_i > \frac{E(b_i)+\varphi_i\rho_i E(n_i)^\beta}{r_i}$.

III. Hypotheses

With a simple model to serve as a guide, I offer several potential explanations for the observed differences in PPE use across countries. The hypotheses result from a comparative statics approach and the usual *ceteris paribus* assumption applies. For ease of exposition, I refer to those in some Asian countries like China and Vietnam, where use is widespread, as "Asians" and those in the United States, where use is limited, as "Americans." Hypotheses are grouped according to the parameter or variable presumed to differ with the explanation, though some explanations could conceivably affect more than one parameter or variable. The list is long, but not exhaustive.

H1. $c_1 < c_2$

H1.1. PPE production costs are lower in Asia than in America.

H2. $E(b_2) < E(b_1)$

H2.1. Air pollution is worse in Asian cities than in American cities.

H2.2. Asians are more likely to live in densely populated cities than Americans.

H2.3. Asian cities are more densely populated than American cities.

H2.4. Asians are older than Americans.

H2.5. Asian households are more likely than American households to include an elderly person.

H2.6. Asians suffer from a greater number of comorbidities than Americans.

H2.7. Asian households are more likely than American households to include someone suffering from a comorbidity.

H2.8. Asians have less access to healthcare than Americans, where access takes into account quality and ability to pay.

H2.9. Asians have a better understanding of disease transmission; Americans underestimate risk.

H2.10. Americans have a better understanding of disease transmission; Asians overestimate risk.
H2.11. Asians more accurately estimate risk of infection than Americans; Americans underestimate risk.
H2.12. Americans more accurately estimate risk of infection than Asians; Asians overestimate risk.
H2.13. Asians more accurately estimate risk of case fatality than Americans; Americans underestimate risk.
H2.14. Americans more accurately estimate risk of case fatality than Asians; Asians overestimate risk.
H2.15. Americans find it more personally bothersome or uncomfortable to employ PPE than Asians.

H3. $\phi_2 < \phi_1$
H3.1. Asian cities have more surveillance cameras than American cities.
H3.2. Asians enjoy fewer privacy protections than Americans.
H3.3. Asians are more likely to report antisocial behavior than Americans.
H3.4. Asians are more active or widely connected on social media platforms than Americans.

H4. $\rho_2 < \rho_1$
H4.1. Asians enjoy fewer civil liberties than Americans.
H4.2. Asians are more willing to mete out social sanctions than Americans.
H4.3. Asians are willing to mete out harsher social sanctions than Americans.
H4.4. Asians are more sensitive to social sanctions than Americans.

H5. $E(n_2) < E(n_1)$
H5.1. Asians are better able to coordinate their actions than Americans.
H5.2. Asians more accurately estimate the actions of others than Americans; Americans underestimate adoption.
H5.3. Americans more accurately estimate the actions of others than Asians; Asians overestimate adoption.

H6. $r_1 < r_2$
H6.1. Asians are more patient or forward-looking than Americans.

H6.2. Americans have more access to financial markets than Asians, where access accounts for quality and ability to pay.

IV. Conclusion

It is far from clear why some people choose to employ PPE while others refuse. I have developed a simple model to explain cross-country variation. The list of plausible explanations consistent with the model is extensive. In addition to providing a framework for considering observed differences in PPE, this exercise demonstrates the difficulty of explaining relatively simple phenomena. As with most other questions, much empirical analysis would be required to reduce the set of potential explanations to the two or three hypotheses typically considered in the popular press.

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