Testing and Risk Attitude under Incomplete Information: A Game Theory Perspective

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Abstract

- This research employs a game theoretic framework to model decision-making processes for both government and individuals under information asymmetry.
- Governments face the critical decision of selecting testing strategies with associated expected costs to combat COVID-19:
  - Universal testing
  - Hybrid or partial testing where the government either tests only the less immune (Hybrid A) or only the immune (Hybrid B)
  - No testing
- Population is categorised into high-Type1 and low-Type 2 individuals based on immunity status, known only to individuals.
  - Government holds a prior belief derived from a probability distribution regarding immunity status.
  - Individuals engage in risk-prone or risk-averse activities, linked to their expected benefits.
  - The expected payoffs by considering costs and benefits are compared across various strategies.
- From a policy perspective a two-pronged approach is recommended to minimise the cost of containing the epidemic:
  - (a) Implement a hybrid testing strategy and
  - (b) create awareness or incentivise risk-averse behaviour, thereby, improving the odds ratio of immune individuals.

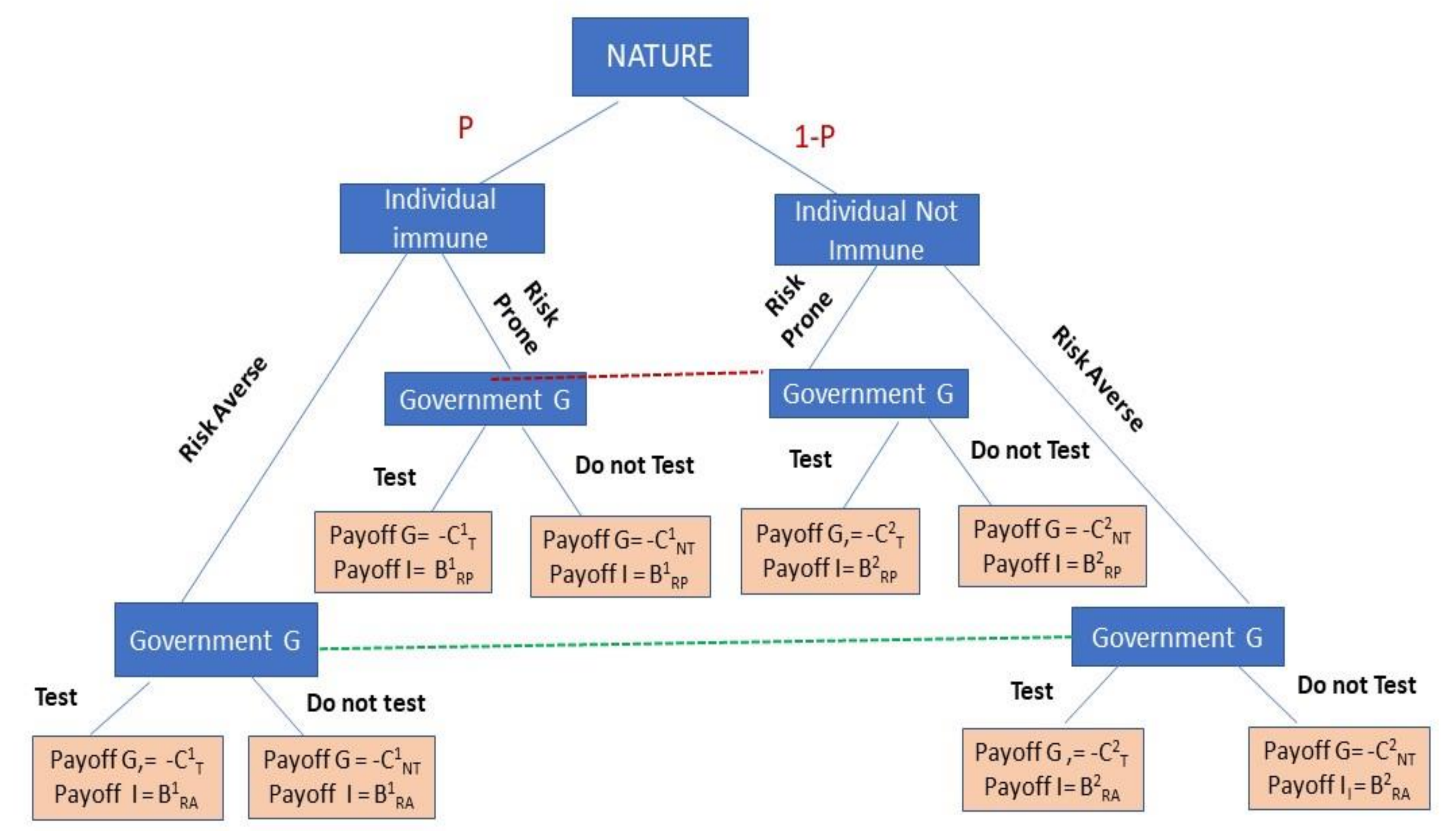
Introduction

- Governments worldwide implemented several measures (lockdowns, quarantines, social distancing and testing) to combat COVID-19.
- Many studies have analysed the impact of government measures on infection rates with mixed results.
- Fewer studies on the behavioural aspects and risk attitudes of individuals under incomplete information.
- This research models the outcome of policy interventions as a strategic Bayesian game where "nature" generates uncertainty and information asymmetry with respect to the "types of individuals" in terms of immunity status.
- Given the distribution of immunity status, individuals engage in different types of activities (risk-prone or risk-averse) and the government is faced with the decision to implement testing or not.
- The study analyses the possible equilibrium outcomes to the government and the public, given the actions available and the respective payoffs associated with such actions.

The Model

- Nature throws a random toss and assigns two states (1-" high", 2-" low" immunity) to individuals with probability p and 1-p respectively.
- Individuals are categorised as "risk-prone or "risk-averse" based on their actions
  - Individual risk attitudes also play a critical role in curtailing the spread of the disease.
  - Individuals who do not follow hygiene protocols are risk-prone and increase the chances of spreading the disease compared to those who are risk-averse and follow the protocols.
- Infection rate depends upon individual immunity and socio-demographic factors such as age, and income.
- Type 1 and 2 risk-averse individuals derive benefit, B^1_{RA} or B^2_{RA}.
- Type 1 and 2 risk-prone individuals derive benefit B^1_{RP} and B^2_{RP} if they engage in risk-prone activities.
- We assume a static game because both players simultaneously choose their strategy and there is no revision of beliefs.
- C_T^1 and C_T^2 reflect the testing costs for type 1 and type 2 individuals.
- C_{NT}^1 and C_{NT}^2 reflect the cost of not testing the two types of individuals.
- Figure 1 depicts the game tree, with the dotted line showing the information set, which is joined to indicate the static nature of the game where players are not aware of the history of the game.

Figure 1



*Payoff to the government are mentioned in negative units because of the cost incurred by the government. Individual payoffs are in positive units because they are assumed to derive positive utility/benefit from their actions.

Key Propositions

There are three testing strategies: Universal (testing all), Hybrid (partial testing) and No testing. In Hybrid Strategy A, the government conducts testing for the less immune, no testing for the immune, and vice versa for Hybrid Strategy B.

Proposition 1: Universal testing dominates No testing if the expected cost of the universal testing strategy is lesser than the expected cost of the No testing strategy. This happens if: $p * C_T^1 + (1-p) * C_T^2 < p * C_{NT}^1 + (1-p) * C_{NT}^2$

Proposition 2: The hybrid A strategy dominates the universal strategy if

$(1-p) * C_T^2 + p * C_{NT}^1 < p * C_T^1 + (1-p) * C_T^2$………………………….(9)

Cancelling out terms, we get $C_{NT}^1 < C_T^1$.

whereas, the hybrid B strategy dominates the universal if $C_{NT}^2 < C_T^2$.

Proposition 3: The hybrid testing strategy A will dominate the No testing strategy if $C_T^2 < C_{NT}^2$ and the hybrid B testing will dominate No Testing if $C_T^1 < C_{NT}^1$

Proposition 4: the expected benefits of risk-averse activities will be greater than risk-prone activities if $EB_{RA} > EB_{RP}$.

That is, $p * B^1_{RA} + (1-p) * B^2_{RA} > p * B^1_{RP} + (1-p) * B^2_{RP}$

$$\frac{p}{1-p} > \frac{B^2_{RA} - B^2_{RP}}{B^1_{RA} - B^1_{RP}}$$

Discussion

- As long as the costs of not testing are higher than that of testing, it is better to test the entire population (universal testing strategy) or use a Hybrid testing strategy, than not testing anyone. However, the choice between a universal and a hybrid strategy depends on the relative costs of not testing type 2 and type 1. The costs of not testing both population types are unknown.
- On the contrary, a Hybrid test or partial testing of the population is better than testing everyone if the cost of not testing both types is less than that of testing.
- The ratio $\frac{p}{1-p}$ is the odds ratio of immune individuals in the population and it increases with an increase in the benefit type 2 individuals derive from risk-averse activities, relative to type 1 individuals.

Conclusions

- Universal testing is preferred if testing costs are lower than costs of not testing.
- In reality, a hybrid testing strategy is being followed in most countries:
  - This is due to information asymmetry with respect to the cost of not testing type 2 versus that of type 1 as the distribution of their immune status is unknown to the government.
  - This distribution can be improved if the expected benefits of risk-averse behaviour of type 2 are greater than that of risk-prone behaviour.
  - Therefore, instead of focusing on the cost of not testing / testing, policymakers can promulgate the expected benefits of risk-averse behaviour and incentivise the same such that the odds ratio of the immune population in the economy increases.

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