PIAAS

Plateforme de Intelligence Artificielle AgroSanté

médecine vétérinaire umontréal

Could PRRS-Resistant Pigs Change the Economics of Swine Production? A Spatio-Temporal and Scenario-Based Modeling Approach

Ralph P. Jean-Pierre, PhD.

Postdoctoral Researcher

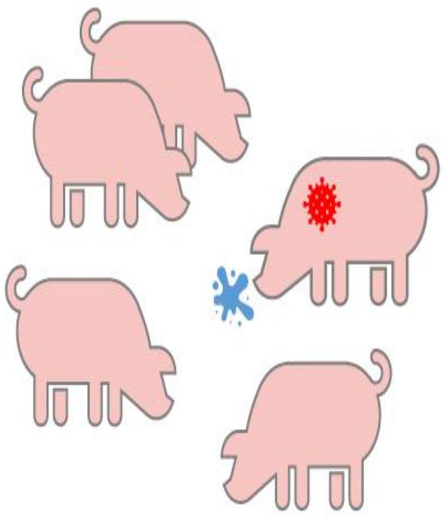
Plateforme Intelligence Artificielle Agro-Santé

Université de Montréal

Background

PIAAS

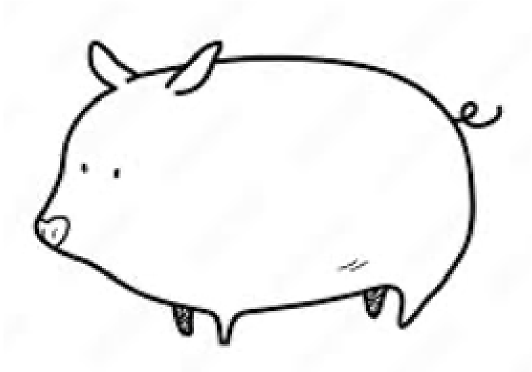
- Porcine Reproductive and Respiratory Syndrome (PRRS) is one of the most economically damaging diseases affecting global pig production
- U.S. losses have been estimated at $560-660 million per year
- A recent study by Lusk (2025) estimates that widespread adoption of gene-edited PRRS-resistant pigs could transform global pork markets
- These estimates come from a multi-country equilibrium displacement model
- **Question**: How does PRRS resistance affects farm-level transmissions and economic outcomes?
- Answering this question requires studying disease transmission dynamics within and between farms , the variation in prevalence by different farm types, the costs of diseases, and other factors affecting adoption
- Coauthors of this manuscript have explored production losses and vaccinations strategies (Valdes-Donoso et al., 2018; Valdes-Donoso and Jarvis, 2022)

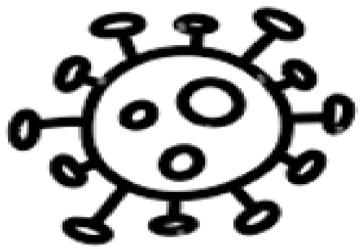


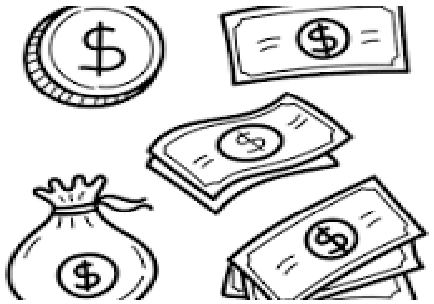
Objectives

PIAAS

- **General Objective**: Assess how PRRS resistance affects farm-level profitability and disease outcomes across different farm types and sizes.
  - Step one: how avoided losses per animal vary over time depending on farm type, size, and resistance level.
  - Step 2: differences in disease impact and profit patterns by farm types and production scales.
  - Step 3: how resistance and market premiums influence farmers' adoption decisions.







Data

- Anonymized dataset of 817 swine farms from the RCP-N212 (Minnesota)
- Includes farm type, herd inventory, geographic location, and network links
- Farm connections based on modeled animal movements (Valdes-Donoso et al., 2017)
- Reflects a typical U.S. integrated production system:
- Sow farms → supply piglets
- Nursery & finishing farms → grow pigs
- Boar-stud farms → provide semen
- Captures spatial and network structure of disease transmission
- For simulations of PRRS spread and control strategies (e.g., resistance, vaccir

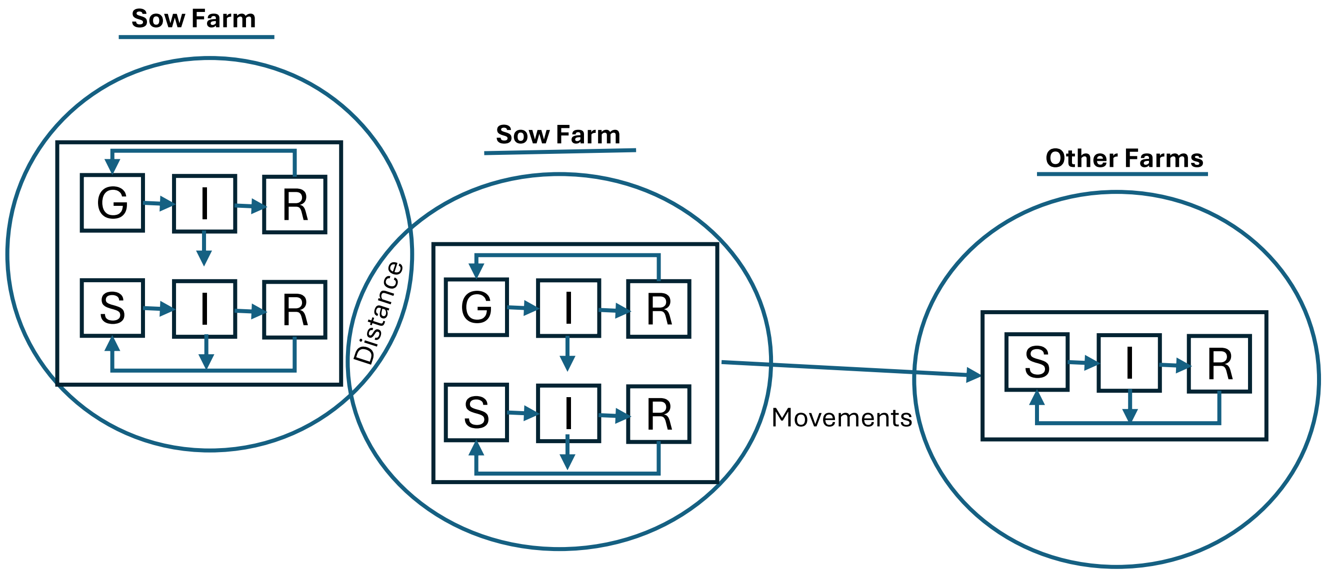
Data

PIAAS

Farm Type	No. Farms	Avg. Inventory	Total Animals
Boar Stud	8	158 (86)	1,260
Fattening Farms	537	1,984 (1,692)	1,065,666
Nursery Farms	83	3,637 (3,728)	301,893
Sow Farms	189	1,247 (1,774)	235,593
Total	**817**		**1,604,412**

- Boar studs are small, specialized units with limited direct impact on total production
- Fattening farms dominate the system (~66% of all animals) and drive aggregate production outcomes
- Nursery farms have high variability in size
- Sow farms are critical for upstream disease dynamics and intervention strategies

Model structure



- SIR framework extended to include genetic resistance (G). Four epidemiological states: Susceptible (S), Infected (I), Recovered (R), Genetically resistant (G)
- Susceptible & resistant animals → can become infected (different probabilities); Infected animals → recover or die; Recovered animals → lose immunity and return to S or G
- transmission across farms are driven by farm type, distance, and animal movements

Model Equations

PIAAS

$$\frac{dS_f}{dt} = \mu N_f - \lambda_f S_f - \mu S_f - \omega R_f - v S_f \ (1)$$

$$\frac{dI_f}{dt} = \lambda_f S_f - (\gamma_f + \mu + m_f) I_f \ (2)$$

$$\frac{dR_f}{dt} = \gamma_f I_f - \omega R_f - \mu R_f + v S_f \ (3)$$

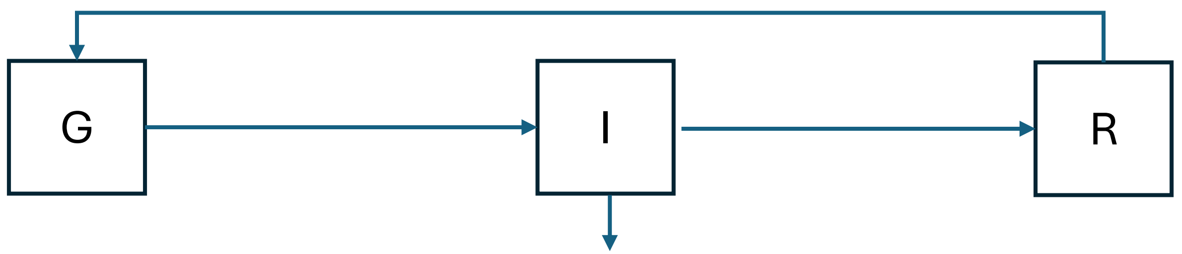
$$\frac{dG_f}{dt} = \mu N_f - \lambda_f^G G_f - \mu G_f - \omega^G R_f \ (4)$$

- S_f, I_f, R_f, and G_f denote the number of susceptible, infected, recovered, and genetically resistant animals on farm f
- N_f is the total herd size; λ the force of infection; γ_f is the recovery rate from infection
- μ is the natural replacement (entry/exit)
- m_f denotes the additional mortality associated with severe infection outcomes
- Immunity wanes at rate $\omega = 1/D_I$, D_I being immunity duration.
- Vaccine efficacy ($vacc\_eff \rightarrow v = (1 - vacc\_eff$) reduces susceptibility of sows to infection and acts multiplicatively with genetic resistance to lower the effective infection risk.

Genetic Resistance

Genetic resistance intensity is represented by $\epsilon = 0, 0.25, 0.5, 0.75, 1$, corresponding to increasing levels of biological protection.

- Reduced susceptibility (lower probability of becoming infected) due to higher resistance intensity (ϵ).
- Reduced infectiousness (lower transmission from infected animals) due to higher resistance intensity.
- Reduced disease severity (lower mortality and productivity losses) due to higher resistance intensity.
- Three strains: Each strain $s \in \{low, medium, high\}$ is modeled by assigning different values to epidemiological parameters — transmission rate ,recovery rate ,and mortality rate
- 52 weeks simulation

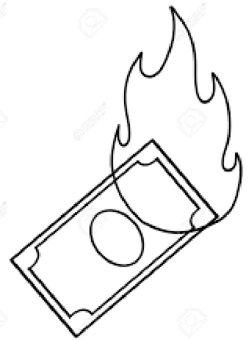


Economic Calculations

- Total losses: $TL_f = P\int_0^t m\, I_f \cdot dt + V_f \int_0^t I_f \cdot dt$ (5),

  P is the market price per animal, and V_f is the decrease in present value of expected production affected by PRRS.

- Avoided $losses$: $B_f = TL_f^{baseline} - TL_f^{resistance}$ (6)



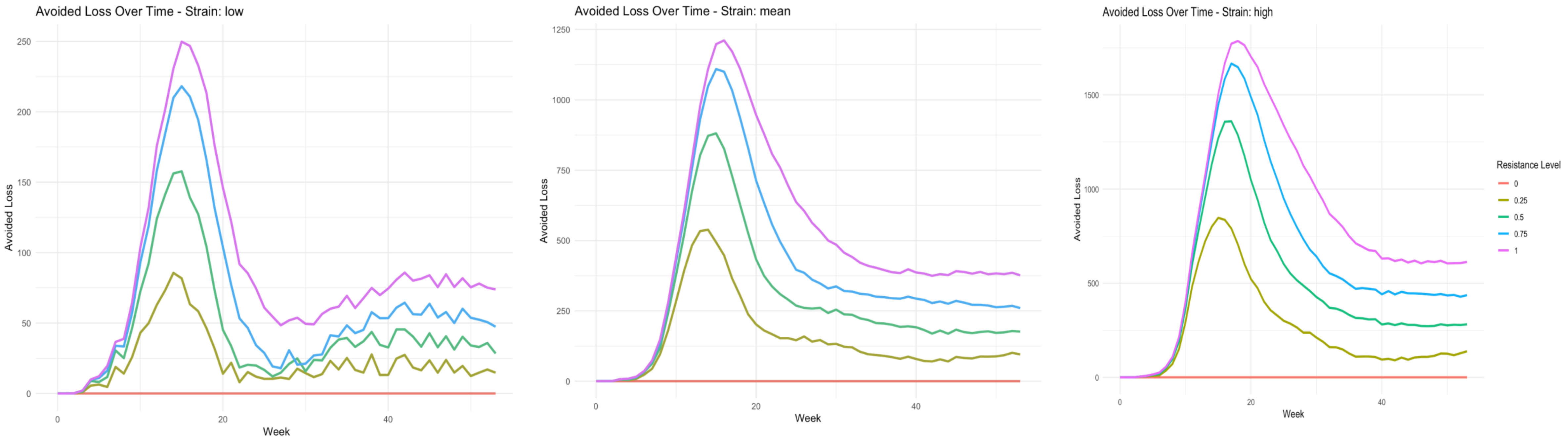
- Adoption cost: $C_f = Resistance\ Premium \cdot Inventory_f$ (7)

  Resistance Premium ($0 - $10 per pig, $1 increments)

- Farm Profit from Adoption: $\pi_f = B_f - C_f$ ()

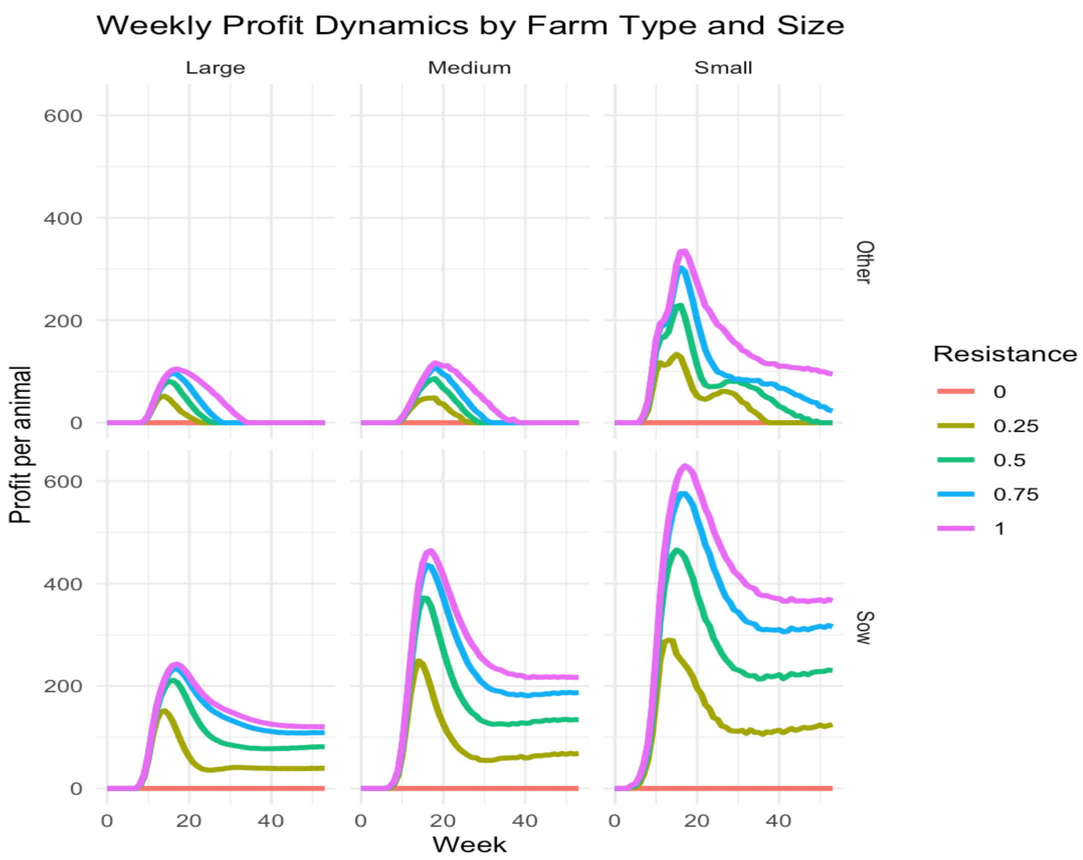
  $A\ farm\ adopts\ if\ Adopt_f = \begin{cases} 1\ when\ \pi_f > 0 \\ 0\ otherwise \end{cases}$

Results – Avoided Losses



- Weekly avoided losses increase with the level of PRRS resistance and vary over the course of the production cycle.
- The gains are largest during peak infection periods, when disease pressure is highest and resistance most effectively reduces transmission and severity.
- Stronger resistance levels consistently generate both direct reductions in mortality and indirect effects through lower infection spread.

Results – Profits and Externalities

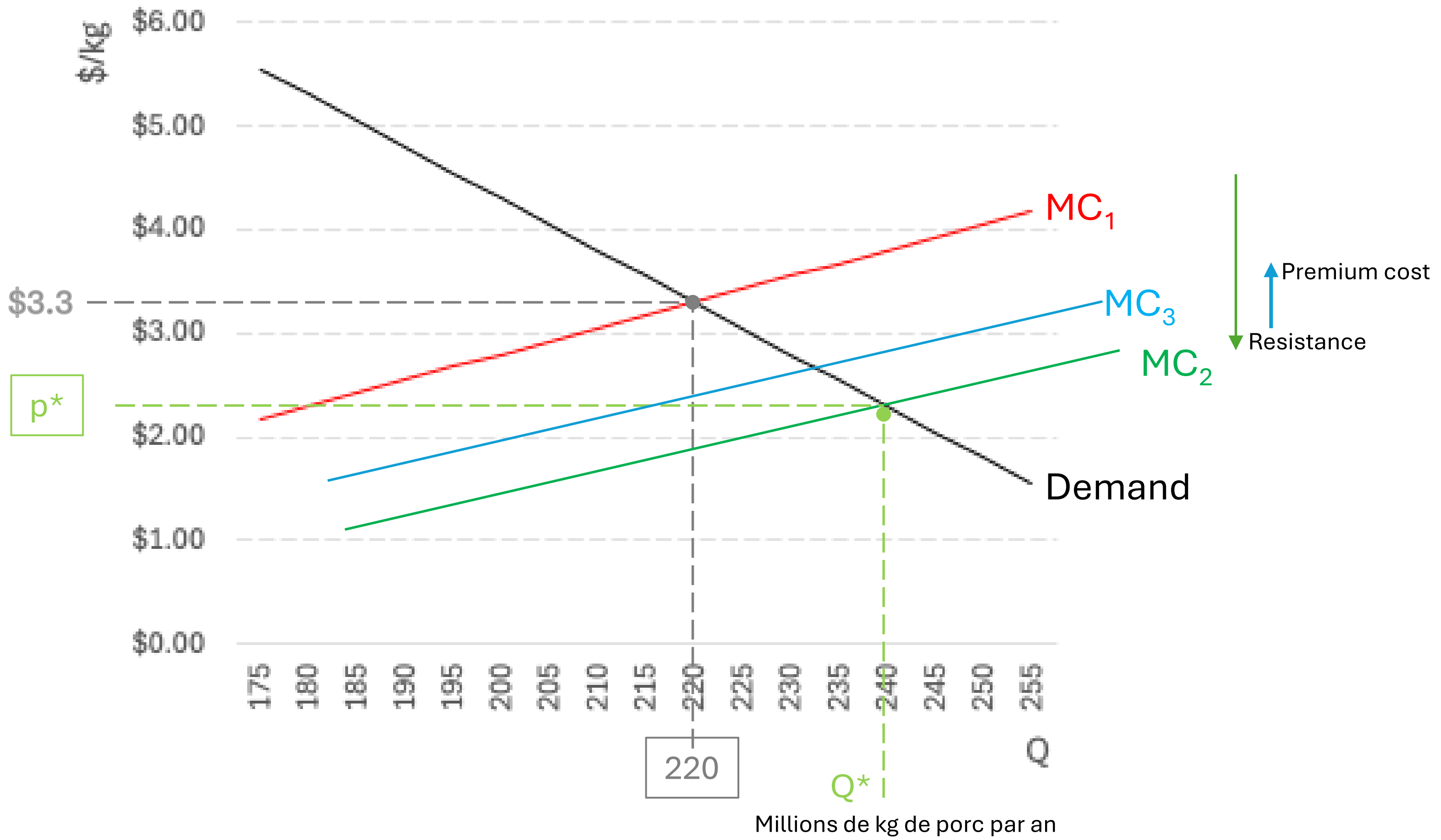


Resistance Level	high	low	mean
0	0	0	0
0.25	150.3884	16.7704	97.1868
0.5	289.7557	34.6923	178.7988
0.75	414.0014	53.6506	263.8995
1	594.3542	86.8539	397.8515

Table 1. The positive externality table reports the aggregate avoided losses experienced by non-sow farms, which is the indirect benefits of PRRS resistance adoption on downstream production stages through reduced disease transmission.

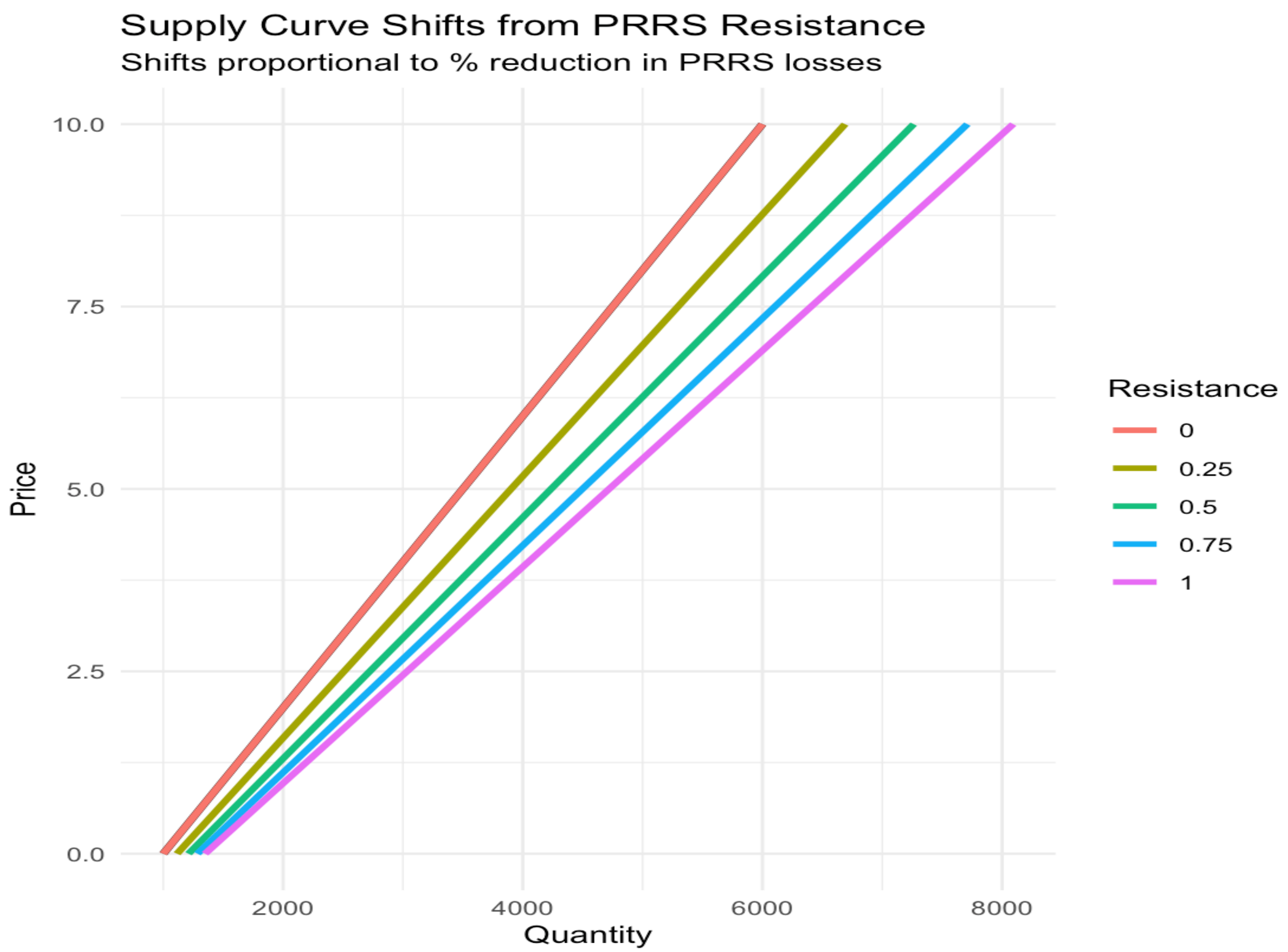
- The positive externality are the profits extend extend beyond the farms that adopt resistant pigs. These spillover effects increase with the level of resistance. Importantly, this creates a divergence between private incentives and social gains.

Results – Marginal Costs



Results – Private Costs

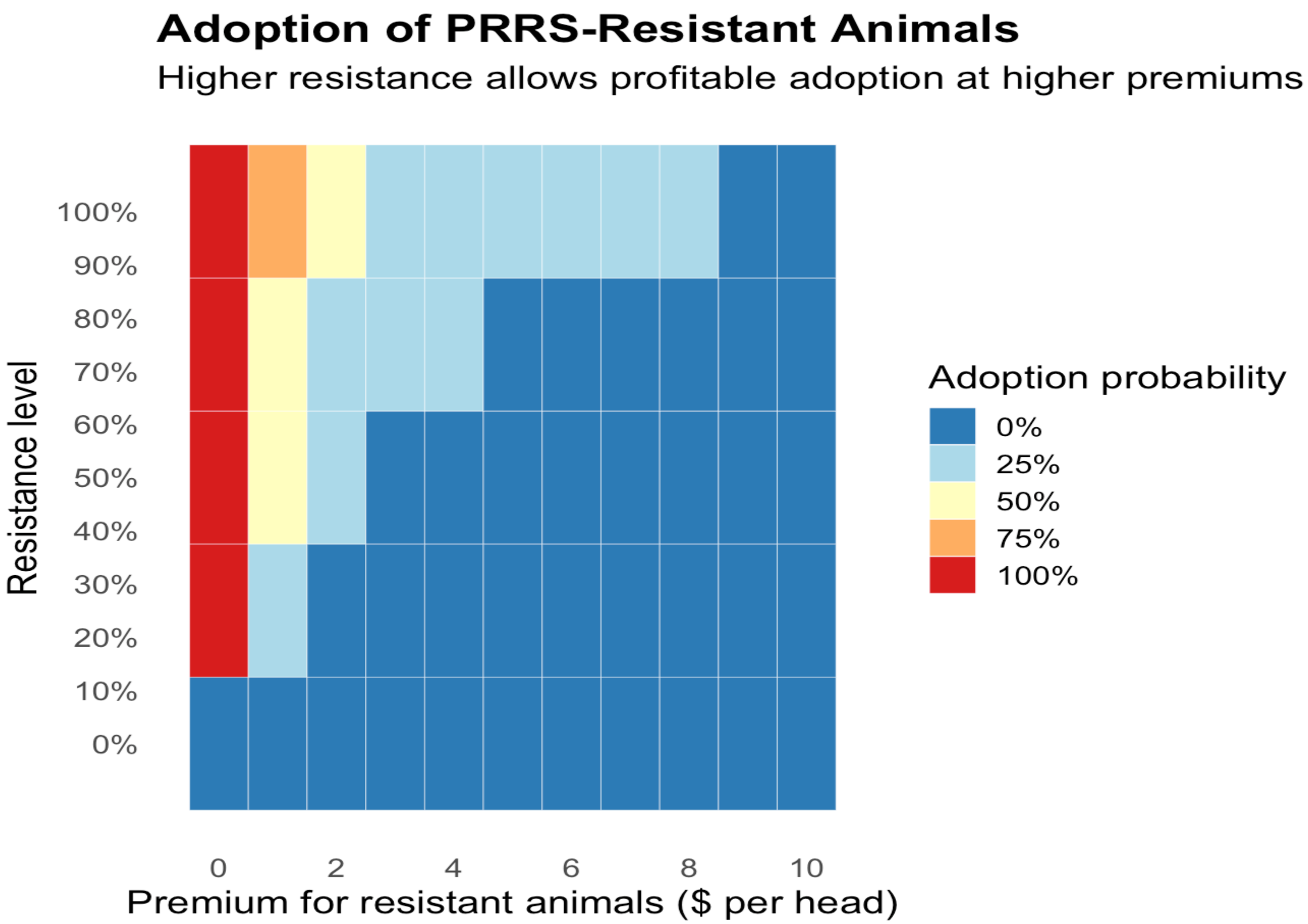
PIAAS



- PRRS resistance shifts the supply curve outward, reflecting productivity gains from reduced disease losses
- The figure highlights an important trade-off: PRRS resistance generates efficiency gains and expands supply.
- The extent of this shift depends on the cost of adoption.
- Lower premiums allow the full benefits of resistance to result in into increased market supply, whereas higher premiums reduce or eliminate these gains.

Results – Adoption Probability

PIAAS



- This heatmap shows how the likelihood of farmers adopting PRRS-resistant pigs varies with the genetic resistance of the animals and the premium price per head.
- Darker red colors indicate higher adoption probabilities, meaning that farms are more likely to adopt highly resistant pigs, especially when premiums are very low
- At premiums larger than $8, the technology is not profitable, regardless of the resistance level.

Conclusions

PIAAS

- Adopting PRRS-resistant pigs can generate substantial economic benefits by reducing disease losses, particularly under high-resistance and high-virulence scenarios.

- However, the profitability and adoption of this technology are highly sensitive to the premium price of resistant animals, with adoption occurring primarily when premiums are low and resistance is strong.

- The results highlight the presence of positive externalities, as non-adopting farms benefit from reduced disease transmission, implying that private incentives may underestimate total system-wide gains.

- Finally, the overall impact of PRRS resistance depends not only on its biological effectiveness but also on pricing strategies, complementary interventions, and regulatory conditions that affect market access and adoption decisions.

PIAAS

THANK YOU!

Ralph P. Jean-Pierre, PhD.
Postdoctoral Researcher
Plateforme Intelligence Artificielle Agro-Santé
Université de Montréal