The economic implications of *delaying* CRISPR in livestock

A simple economic application

Felipe Silva

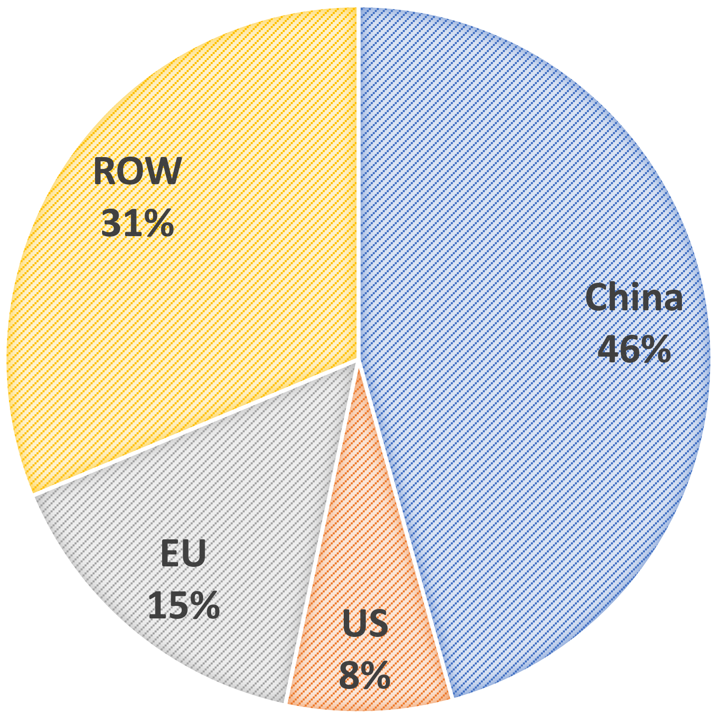
CLEMSON UNIVERSITY

Cost of the Porcine Reproductive and Respiratory Syndrome (PRRS)

- PRRS virus is one of the costliest pig diseases globally.
- Annual production losses in breeding and growing-pig herds from PRRS was estimated to be around $663 million in the US alone.
  Holtkamp et al. (2013)
- European countries were surveyed in 2013 and calculations revealed that PRRS virus infections had cost over $1.6 billion.
  Bitsouni et al. (2019) and Pileri and Mateu (2016)

Pig stock

- China, EU and US had almost 70% of the world pig stock in 2018 (FAO).
- China alone had more than 442 million pigs (FAO).
- The *Porcine Reproductive and Respiratory Syndrome* (PRRS) virus can disrupt these domestic markets and the international trade.



Porcine Reproductive and Respiratory Syndrome (PRRS) virus-resistant pig

- There is no foreign transgene or rDNA present in these knock-out pigs, meaning that they do not fit the classical definition of a GE animal.
  - They would not be considered a GMO in many South American counties (e.g. Argentina)
  - However, in the EU and the US they would be regulated as GMOs or drugs, respectively.
- In 2015, the University of Missouri signed an exclusive global licensing deal for potential future commercialization with UK-based Genus plc.
  - Strategic collaboration with Beijing Capital Agribusiness Co. Ltd

Pig market
Key information

- Pig industry is vertically integrated industry.
- Pigs have high reproductive rates and relatively short generation intervals.
  - This allows incremental improvements in efficiency to be multiplied across many animals.
  - This directly influences the level of investments that are directed at genetically improved pig.

Ex-ante analysis

- There is a vast literature that estimates the ex-ante benefits of research and the cost of delaying adoption in several commodities:
  - Genetically Modified Banana Resistant to *Xanthomonas Wilt* (*Ainembabazi et al 2015*)
  - Bt corn, Bt cowpea and disease resistant bananas (*Wesseler et al 2017*)
  - Bt cotton in West Africa (*Falck-Zepeda et al. 2007* - IFPRI)
  - Cassava in Africa, Latin America and Caribbean, and Asia (*Alene et al 2018* – IITA)
  - Golden rice (*Wesseler and Zilberman 2013*)
  - GM wheat, Golden rice and GM corn (Zilberman et al 2015)

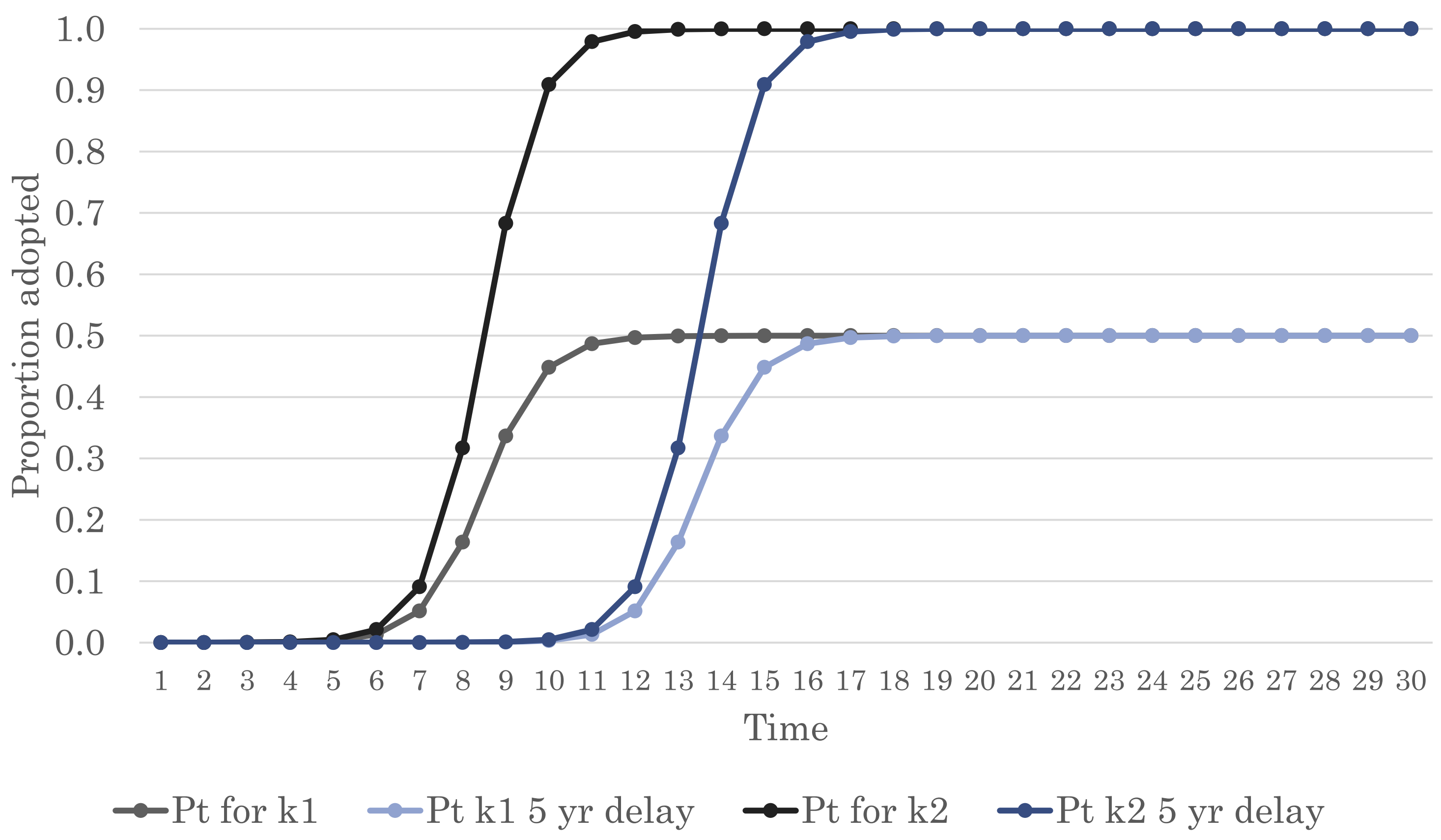
Simple economic analysis

- The analyses were based on three points in time:
    1. the year the technology appeared in the peer-reviewed literature;
    2. the year in which the technology was potentially available in the market, and
    3. the year in which the technology started to be adopted
- Regulatory procedures timespan is case-dependent.
    - It could be around 10 years for GE products.
    - However, genome edited products containing **no novel DNA (e.g. knock-outs)** could be commercialized immediately in several countries.
        - For the PRRS virus-resistant pigs we assumed a four-year period from first publication in 2016, to potential commercial availability in 2020.

Simple economic analysis

- Four scenarios to identify the cost of banning, or delaying, the approval of the technology:
  1. no diffusion (status quo/banning the technology),
  2. diffusion starts when commercially available (2020)
  3. diffusion is delayed 5 years (2025), and
  4. diffusion is delayed 10 years (2030).

Simple economic analysis



- Adoption diffusion process takes time, we assumed it would take 15 years to reach peak
  - We modelled two uptake scenarios:
    - 50% and
    - 100% (full)

adoption at the end of the diffusion period

Simple economic analysis

- Calculate the yearly gains from adoption as the yearly decrease in losses incurred by the disease.
  - For the US we assume that the cost is $663 million and EU $1.6 billion.
  - S-Shaped curve is used to model the gains in year *t*
- Net present Value is calculated for each scenario with $r = 4\%$ over the 30-years period.
- Cost of delay is calculated as the difference between each scenario and adoption in year $t = 0$.

Results for
PRRS virus-resistant CD 163 knockout pigs

Year of adoption	Cost ($ billion)		Benefit of diffusion ($ billion)				Cost of delay ($ billion)			
	0% adoption		*50% adoption*		*100% Adoption*		*50% adoption*		*100% Adoption*	
	US	**EU**	**US**	**EU**	**US**	**EU**	**US**	**EU**	**US**	**EU**
Never	11.92	28.86	-	-	-	-	-	-	-	-
2020			3.65	8.83	7.30	17.66	-	-	-	-
2025			2.53	6.11	5.05	12.22	1.12	2.72	2.25	5.44
2030			1.60	3.88	3.20	7.76	2.05	4.95	4.09	9.90

Results for *PRRS virus-resistant CD 163 knockout pigs*

- These numbers would be even higher if diffusion in China and other countries were included in the model.
  - We assumed that the cost of PRRS per pig in China was approximately half of the cost in the US, ~$5/pig
- The NPV cost associated with PRRS in China would therefore be $39.74 billion over the period.
  - Delaying the adoption in China by 10 years would therefore be associated with opportunity costs of $6.82 and $13.64 billion, respectively, for the 50% and 100% adoption scenarios.