The Economics of Zoonotic Diseases in China

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May 8, 2016
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1. A brief overview of zoonotic diseases

   *Three economic dimensions of the problem:*

2. “Unhealthy landscapes”: biodiversity, ecosystem disservices, and public health

3. Globalization of zoonotic risks: trade and travel networks and the spread of pathogens

4. Epidemiological economics: decision-making in an epidemic environment
Zoonotic Diseases

• Zoonosis: animal-borne diseases that infect people (e.g., Ebola, avian influenza, SARS).

• 61% of all known human-susceptible pathogens are zoonotic, as are 76% of emerging strains (Taylor et al. 2001).

• Due to the prevalence of certain socio-ecological factors, certain areas are much vulnerable to the emergence and spread of zoonoses than others.
China as a Zoonotic “Hotspot”

• **SARS (2002-2003)**
  – Likely transmitted to people from bats
  – SARS CoV found in at least 39 species
  – 8,273 confirmed cases, 775 deaths (WHO)

• **HPAI H5N1 (1998 – present)**
  – Found in chickens, ducks, swine, and wild birds
  – 45 H5N1 cases, 30 deaths (67% mortality rate)

• **HPAI H7N9 (2013 – present)**
  – Found in chickens, ducks, swine, and wild birds
  – Does not kill poultry
  – 681 H7N9 cases, 271 deaths (39.9% mortality rate)
2. “Unhealthy Landscapes”
- **Landscape modification** – e.g., changing connectivity, fragmentation – can increase pathogen transmission among wildlife, livestock, vectors, and people (Meetenmeyer et al. 2012; Reisen 2010; Jones et al. 2013)

- **Declining biodiversity** can raise risk of wildlife pathogens infecting humans - e.g., hantavirus (Keesing 2010) and Lyme disease (Ostfeld 2009)

- **But:** dynamics idiosyncratic, as higher biodiversity can also increase risk of pathogen transmission (Salkeld et al. 2013)
Avian influenza
Figure 1. Spatial distribution of HPAI H5N1 outbreaks in domestic poultry and wild birds and human cases in mainland China.


http://www.plosone.org/article/info:doi/10.1371/journal.pone.0002268
Avian influenzas in wide circulation among poultry and wild birds: H7N9, H5N1.

Influenzas in general circulation among people: H3N2, H1N1.

*Areas of infection*

- e.g., H3N2, H1N1
- e.g., H5N1, H7N9

*Areas of co-infection*

- Swine distribution ("mixing vessels")
- Wet markets (livestock-human transmission interface)

Emergence risk "hotspots"
• For many emerging zoonotic diseases prevention is better than cure – ex ante mitigation of disease risk is more economically efficient than ex post adaptation to an outbreak (Langwig et al., 2015; Voyles et al., 2014).

• The mitigation of emerging zoonotic disease risks requires preemptive measures against the socio-ecological drivers of zoonotic risk (Pike et al., 2014).
3. Trade, Travel, and the Globalization of Zoonotic Risk
- The 1918 influenza pandemic infected as many as 500 million people, a quarter of the world’s population, and killed as many as 50-100 million (Taubenberger 2006).

- Today, there are more people and livestock, aggregated in greater densities, and bound together more tightly by the movement of goods and people.

- Trade and travel networks have bridged previous epidemiological discontinuities created by biogeographic or other physical barriers: today, a zoonotic risk anywhere can rapidly become a zoonotic risk everywhere.
• For arboviruses like Zika, dengue, chikungunya, West Nile, and malaria, the primary mechanisms for disease spread has been international trade (Alirol et al., 2011; Hay et al., 2005; Kraemer et al., 2015; Tatem et al., 2006; Weaver, 2013).

• For directly communicable diseases such as SARS and MERS, international travel has been the conduit of global and regional spread (Parlak, 2015; Zumla et al., 2015).
• The spread of disease is a function of the distance (and by implication time) between the origin and the destination of trade, and the environment (e.g., pathogen or vector habitat) similarity/suitability of the destination.

• Suitability includes the presence of competent host species (for avian influenza, wild and domesticated bird species; for foot-and-mouth, hoofed wildlife and livestock) and the level of biosecurity.
An econometric model of foot-and-mouth spread by Shanafelt et al. (In Press)

\[ \theta_{it} = \exp \left[ \alpha_i + \sum_{j=1}^{19} X'_{jit} \beta_j + \sum_{s=1}^{3} \sum_{k=1}^{24} I'_{rkst} \beta_{24s+k-4} + \sum_{s=1}^{3} \sum_{k=1}^{24} E'_{24s+k+68} + \varepsilon_{it} \right] \]

for all countries \( i \) at time \( t \)

\( y_{it} \) - probability of an outbreak

\( X_{it} \) - bioclimatic/governmental variables, vet density, control measures, disease free indicator, value at risk

\( I_{it}, E_{it} \) - aggregate imports and export between region \( r \) containing \( i \) and all other regions \( k \)

\( \alpha_i, \varepsilon_{it} \) - constant and error terms respectively

\( y_{it} \sim \text{Negative binomial}(\theta_{it}, \kappa) \)
4. Epidemiological Economics (with special application to China)
Wet Markets in China

- **Wet market**: sells live or recently-killed animals, both “conventional” (e.g., chickens, ducks, pig) and “exotic” (e.g., civets, bats, field rats, snakes).

- Chinese and other Asian wet markets often have non-hygienic conditions.

✧ **SARS coronavirus** traced back to bats sold in southern Chinese wet markets (Li et al. 2005; Daszak et al. 2007)
Live Poultry Markets in China

- Live poultry markets are found across China, but are particularly numerous in the southern provinces.

- In Shanghai, of 190 million chickens consumed annually, 120 million are bought from live poultry markets (Pi et al., 2014).

- In 2010, 77% of all poultry products in China were sold at such markets (ANZ, 2013).
Epidemiological Economics

Drawing on insights and concepts from economics, epidemiology, and disease ecology, and grounded in bioeconomic models of renewable resource management, epidemiological economics provides more realistic, practical, and predictive models of disease dynamics (Perrings, 2014; Perrings et al., 2014).
Wet Market Management

• Current management approach to curb H5N1 and H7N9 spread has been heavy-handed, top-down, and ad hoc – e.g., complete market closure, interdiction of trade, and expensive cleaning efforts. This is not sustainable (Gao 2014).

• Understanding the “economic logic” behind market-goers decisions may allow more subtle, less costly, and more sustainable interventions.
An Epidemiological-Economic Model of Wet Markets

A discrete-time compartmental model of avian flu disease dynamics:

\[
\begin{align*}
\dot{S}_p &= -\beta_2(N_p, C, w_h, H)C(w_m, B)S_p \left( \frac{I_c}{N_c} \right) \\
\dot{I}_p &= \beta_2(N_p, C, w_h, H)C(w_m, B)S_p \left( \frac{I_c}{N_c} \right) - \varepsilon_p I_p - \gamma I_p \\
\dot{R}_p &= \gamma I_p \\
\dot{D}_p &= \varepsilon_p I_p
\end{align*}
\]

\( S_p \): number of susceptible people
\( I_p \): number of infected individuals
\( R_p \): number of recovered
\( D_p \): number of recovered
\( \beta_2 \): conditional probability of infection
The Decision-Maker’s Problem

\[ V_t(S) = \max_c \{ BC_t + \delta [(1 - P^I)V_{t+1}(S) + P^I V_{t+1}(I)] \} \]

\( V_t(S) \) is the value of being healthy at time \( t \), while \( V_{t+1}(S) \) and \( V_{t+1}(I) \) are, respectively, the future value of being healthy and the future value of being infected. The discount factor is \( \delta \), and \( P^I \) is the probability of transitioning to an infected state.
Thanks to:

Dr. Charles Perrings
Dr. David Shanafelt
Dr. Ben Morin
Ms. Mengye Zhu

THE END