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Managing dynamic epidemiological risks through trade

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ABSTRACT

There is growing concern that trade, by connecting geographically isolated regions, unintentionally facilitates the spread of invasive pathogens and pests – forms of biological pollution that pose significant risks to ecosystem and human health. We use a bioeconomic framework to examine whether trade always increases private risks, focusing specifically on pathogen risks from live animal trade. When the pathogens have already established and traders bear some private risk, we find two results that run counter to the conventional wisdom on trade. First, uncertainty about the disease status of individual animals held in inventory may *increase* the incentives to trade relative to the disease-free case. Second, trade may facilitate *reduced* long-run disease prevalence among buyers. These results arise because disease risks are endogenous due to dynamic feedback processes involving valuable inventories, and markets facilitate the management of private risks that producers face with or without trade.

1. Introduction

Trade creates value as a coordinating mechanism to exploit comparative advantages and to redistribute private risks. Yet this mechanism may also connect geographically isolated regions, unintentionally facilitating the spread of external risks. Prominent examples are the introduction and spread of pathogens and pests – forms of biological pollution that pose significant risks to ecosystem and human health and valuable economic sectors like agriculture (Perrings et al., 2010; Finnoff et al., 2010; MEA, 2005; The Economist, 2005; McAusland and Costello, 2004).

Concerns over biological risks have led to many costly measures to prevent the spread of pathogens and pests among animals and plants, some of which restrict or ban certain trades. For instance, the Sanitary and Phytosanitary Measures Agreement of the World Trade Organization allows member nations to ban products from infected/invaded areas to prevent new introductions (WTO, 2014). International and local trade bans have been used to protect against harmful livestock diseases such as foot-and-mouth disease (FMD), bovine tuberculosis (bTB), and bovine spongiform encephalopathy (BSE) (USDA-APHIS, 2013), and they have been applied to trade in plants, exotic pets, or wildlife that may carry invasive pathogens or pests (e.g., USTR, 2014).

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Local trade restrictions may also be implemented to reduce the spread of pathogen and pests within endemic (already-infected) areas. For instance, livestock movement (trade) controls have been implemented in response to the FMD outbreaks in the UK and other parts of the EU (Schley et al., 2009). Movement controls have also been imposed within parts of the UK, New Zealand, US, and elsewhere to prevent the spread of bTB (DEFRA, 2014; Barlow et al., 1998; MDARD, 2011; OIE, 2013), and in Canada to prevent spread of BSE (LeRoy et al., 2005).

While there is a growing chorus for more trade sanctions to protect against biological risks (Sanderson, 2012; Liu et al., 2013), there are also calls for relaxing costly trade restrictions while adopting scientifically sound risk management approaches (ECCFMD, 2012; DEFRA, 2014; MDARD, 2011). One such approach, known as risk-based trading, would allow livestock trades within endemic areas after importers have been made aware of the exporting herd's health history (DEFRA, 2014). Similarly, the EU's Progressive Control Pathway (ECCFMD, 2012) suggests various stages of control, including targeted movement controls that depend on risk differences between and within infected areas. The potential economic and epidemiological performance of such programs is unclear, however, because understanding of the relation between trade, epidemiological risks, and private incentives for risk management is limited.

This study examines how endemic biological risks within a sector like agriculture affect the private incentives for trade, and in turn how trade affects the sector's ability to manage biological risks. The problem of trade introducing new biological risks into a region emerges as a limiting case of our model. Livestock disease is used as a motivating example because of the important role of trade in this sector and because livestock diseases pose major risks to agriculture as well as to human and ecosystem health. Almost two-thirds of human diseases are zoonotic (transmitted from animals to people), with livestock often serving as a conduit to humans (Cleaveland et al., 2001), particularly for emerging infectious diseases (The Economist, 2005). Livestock diseases also pose major risks to wildlife, with infectious diseases being a significant driver of biodiversity loss (MEA, 2005). Our bioeconomic model is easily adapted to examine pathogen or pest risks in the trade of other live inventories, such as pets or plants.

We find the incentives to trade may be increased relative to the disease-free case when both buyers and sellers face uncertainty about the health status of individual livestock being traded.[1] This result contrasts with the standard view that uncertain product quality (defined here as animal health status) reduces private incentives for trade, even for symmetric uncertainty among buyers and sellers (Akerlof, 1970). We find greater trade incentives may arise because disease risks are endogenous due to dynamic feedback processes involving valuable inventories, and markets facilitate producers' management of the inventory risks they face with or without trade. Specifically, livestock trade enables producers to manage the two components of infection risks, herd prevalence and economic costs, by an arbitrage process between buyers and sellers. To the best of our knowledge, the result that infection-driven inventory risks may increase trade incentives is new to the risk and trade literature.[2]

We also find trade may reduce buyers' long-run herd prevalence compared to autarky, reducing any associated externalities to other producers, ecosystems or human health. This result contrasts with the prevailing notion that trade of potentially infected animals always increases ecological risks, but supports the idea that institutional responses, such as trade bans that fail to account for economic–ecological feedbacks, may increase ecological risks (Bulte et al., 2003; Horan et al., 2011; Finnoff et al., 2010).[3] We show trade may increase sellers' herd prevalence, contrary to the notion that trade primarily puts buyers at risk.

Finally, our analysis contributes to the epidemiology and health economics literatures by showing how trade creates an epi-economic geography involving endogenously determined epidemiological and economic relations, extending prior work on endogenous economic–epidemiological systems within a single region (Aadland et al., 2013; Fenichel et al., 2011, 2010).

2. Production and epidemiological model

Our analytic model integrates disease dynamics and an economic model of livestock production and trade, using (beef) cattle as a motivating example.[4] As a first attempt at such integration, we adopt a parsimonious model characterized by two key industry features: trade is driven by cattle having different production requirements as they mature, and cattle are assets whose value is diminished by infection. Also, we maintain our focus on how infection risks influence and are

[1] Asymmetric information could be a problem if traders were willing to pay for animal testing. A small literature (Sheriff and Osgood, 2010; Wang and Hennessy, 2014) examines livestock disease problems where sellers have private information about animal health status. They focus on behavioral dynamics arising from multi-period interactions, and how markets may evolve to induce information disclosure. However, they do not model infection dynamics. Our analysis complements this work. We do not examine asymmetric information, and so we can only analyze pooling equilibria in which there is a single price for animals, regardless of infection status. But this approach allows us to more clearly examine how infection dynamics involving animal inventories affect trade incentives and associated behavioral and epidemiological outcomes over time, not analyzed in prior work.

[2] More generally, examples of possible non-ecological areas where the theory could be relevant include file sharing where computer viruses pose a risk, and trading players across sports teams that have been infected by or are susceptible to behavioral and morale problems.

[3] Trade is also an important adaptation mechanism for biological invasions (Finnoff et al., 2005; Perrings, 2005).

[4] A small literature examines livestock trade and disease risk management but does not consider dynamic economic–epidemiological feedbacks or foresighted risk management (Hennessy et al., 2005; Rich and Winter-Nelson, 2007). In particular, Hennessy et al.'s (2005) static model incorporates neither epidemiological dynamics nor differences in infection levels across trading partners. Rather, they assume a single infection index that is an exogenous, increasing function of aggregate production and trade volume. It is common to assume trade exogenously increases infection (Momota et al., 2005), but empirical findings suggest there are reciprocal relationships. For example, Perrings et al. (2010) find trade can increase spread but it can also increase incentives to mitigate spread via biosecurity.