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Environmental Risk from Globalization

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Introduction

People have traded and transported alien species wittingly and unwittingly for thousands of years with two notable increases at the end of the Middle Ages and the beginning of the Industrial Revolution. Since 1950, technical and logistic improvements including pressurized transport have accelerated the ease with which commodities are transported globally establishing new pathways for the spread of alien species (Hulme 2009). A 2017 study found that over one third of all introductions in the past 200 years occurred after 1970 (IUCN 2020). With the ease of transport comes the difficulty of tracking and hindering unwanted species, be they vertebrate, invertebrate, plant, or pathogen. While a great deal of damage is done to native species by invasive species, it is likely the damage to property, health, and life that is of primary concern to actuaries. Globalization causes insurable loss through disease, crop damage, infrastructure damage, and ecosystem services damage.

Globalization of Disease

Infectious diseases can spread at the speed of an airplane, meaning diseases, stemming from environmental risks in other countries, can easily spread to North America. For example, live wild-animal markets with animals for consumption and for use in traditional medicine are common in Asia and some other parts of the world. These markets are known to transmit diseases and parasites, which can spread to the rest of the world. Disease outbreaks, propagated by wildlife trade, have caused hundreds of billions of dollars of economic damage globally. It is estimated that tens of millions of wild animals are shipped each year regionally and around the world for food or use in traditional medicine. Each step in the trade involves some type of contact with each animal: hunting, middle marketing, consuming. Each step is an opportunity for an animal-specific or local pathogen to spread (Karesh et al., 2005).

Over 35 new infectious diseases have emerged in humans since 1980. In a list of 1,415 human pathogens, 61% are known to be zoonotic (spread between animals and people). Notable examples include HIV (from the human consumption of non-human primates); Ebola (from great apes hunted for food), and SARS-associated coronavirus (from small non-domestic carnivores). Diseases can also be transmitted from wild to domestic animals, causing economic damage (over $80 million) and sometimes leading to human health problems. Examples of such diseases include bovine spongiform encephalopathy, foot-and-mouth disease, avian influenza, and swine fever. (Karesh et al. 2005) Most recently, we see wild-animal-to-human transmission with SARS-CoV (Severe Acute Respiratory Syndrome) and COVID-19, which are both thought to have jumped to humans from wild animal markets in China. The consequences of this type of transmission can be quite severe.

HIV costs have been substantial. As of 2018 the average annual cost for recommended HIV-drug-treatment regimens was $36K to $48K per patient. Costs have increased up to 7 times faster than inflation in recent years. Even though the U.S. HIV prevalence is low, Antiretroviral (ART) is the nation's fifth costliest therapeutic drug class and accounted for $22.5 billion in spending in 2018. (McCann et al. 2020)

SARS-CoV was identified in 2003 and is thought to be an animal virus from an as-yet-uncertain animal reservoir, perhaps bats, that spread to other animals (civet cats) and first infected humans in the Guangdong province of southern China in 2002. The epidemic of SARS affected 26 countries (WHO 2020).

COVID-19, a novel coronavirus which has been linked to viruses in bats (though the method by which the virus was transmitted to humans is in question), caused a pandemic, shutting down massive portions of the economy worldwide. At the time of this writing, the outbreak is ongoing. There are 195 countries, areas, or territories with reported cases. As of October 27, 2020, there were over 44 million confirmed cases with over 1.1 million deaths (Worldometer, 2020).

Pandemics, such as COVID-19, cause massive and rapid changes in the macroeconomic, financial, and regulatory environments. These changes, in turn, generate unexpectedly high losses in multiple lines of insurance as well as claims from unusual or new sources.

- Health Insurance will be affected as people infected with COVID-19 seek medical assistance and an overwhelming number of COVID-19 cases reduces the availability and increases of cost for other procedures due to a lack of healthcare supplies and personnel. Temporarily, there may be lower claims associated with all other diagnoses; and these claims may never occur, may occur in the future, or may lead to higher future claims as untreated medical conditions lead to higher total costs.
- The Medical Professional Liability industry expects direct and indirect impacts from the coronavirus pandemic. If spread can be slowed to a rate at which most hospitals have the capacity to handle these cases, some may allege malpractice against those hospitals with overwhelmed emergency departments or that experience adverse results relative to others. Hospital-acquired infections and medical providers working outside their areas of expertise, hospitals turning away patients to have beds for those in greater need, and delays in non-urgent treatment may all spur allegations of malpractice. Though Good Samaritan laws may provide some defense, there could still be high costs. An indirect effect on professional liability insurance may include fewer working physicians by the end of the pandemic as those who acquire the virus may not return to work. (Forray, 2020)
- Life insurance may be affected if mortality increases past the expected values used when the policies were sold, especially for policies not yet fully funded.
- The financial market drop due to COVID-19 may cause difficulties for insurers, particularly pension insurers. Though there may be lower payouts in the long run due to higher death rates, the short run drop in assets may be severe.
- Directors and officers liability insurance may also have increased claims that were brought on by securities class action lawsuits from allegedly inadequate or misleading disclosures in financial statements due to COVID-19 and the related business shut-downs or changes or inadequate handling of COVID-19-related business practices. There have already been actions against Norwegian Cruise Line Holdings, Ltd. and Inovio Pharmaceuticals for COVID-19-related business practices. (D'Annunzio, 2020; Hunton Insurace Recovery Blog 2020)
- Workers' compensation may be hard-hit. Businesses that close during quarantine or lock-down will have decreased payroll, decreasing premium. (The decreased premiums, identified by audit, may be carried in subsequent years, leading to a mismatch of premium, and losses and leading current year losses to be understated, and future year losses to be higher.) Workers may be infected at work. They could claim under one of two theories: the virus may be deemed a workplace injury or the virus may be classified an

occupational disease in the occupations for which risk of contracting the disease is higher than in the general population (such as healthcare workers). Infected workers may expose their families to the disease, leading the families to claim under employers' liability. (Willis Towers Watson 2020)

- CMP and business property insurance may be affected. While there should be no business interruption coverage as the pandemic will cause no physical damage to the property, there are lawsuits from policyholders and bills being put forward to force insurers to cover business interruption anyway (Blosfield, 2020).
- Automobile Insurance will likely be affected. Personal auto insurers are seeing fewer miles driven and fewer trips. While this decrease should result in lower loss ratios, returned premiums may negate any advantages. In commercial auto, those policies rated by power unit are seeing units garaged, leading to lower premiums.
- General Liability may possibly be affected if claimants can prove a liability link. Product-related liability may come into play in the case of antiviral drug manufacturers, who may be open to product liability claims (Willis Towers Watson 2020).
- Trade disruption insurance could be hard-hit if, for example, many businesses with global supply chains claim lost income or increased expenses because a portion of their supply chain falls under a government that has imposed trade restrictions in responses to a pandemic (Willis Towers Watson 2020).

Many diseases either have recent origin in the natural environment, are transmitted by a wildlife vector (transmission agent), or both. There is risk of new diseases emerging, and of the spreading of already familiar diseases into new geographic areas. As climate change intensifies, tropical diseases may spread away from the equator into larger areas of North America, affecting health insurance, workers' compensation, and perhaps life insurance, depending on the severity of the diseases.

Invasive Species

Invasive species, defined as an organism that causes ecological and/or economic harm in a new environment where it is not native (NOAA 2020), cost the United States hundreds of billions of dollars in damages every year (estimated at anywhere from $120 billion annually in 2005 (Pimentel et al. 2005) to $220 billion annually more recently (Marbuah et al. 2014)). Invasive species can harm infrastructure, property values, agricultural productivity, public utility operations, native fisheries, tourism, outdoor recreation, and the health of an ecosystem (USF&WS, 2012). Much of this damage is to forests, crops, land, ecosystems, and ecosystem services, the majority of which are not insured. However, many invasive species cause insured or insurable loss to property, business, and health. About 80% of the costs associated with invasive species in the U.S. are attributable to a few groups of alien invaders: pests and pathogens of crop plants, crop weeds, non-native rats, feral cats, and non-native diseases that infect livestock and humans. Two other notable invaders include the zebra mussel and the imported red fire ant. Each of these two costs over $1 billion annually (Levin 2009).

PLANT PATHOGENS

Plant Pathogens can cause economic harm for agricultural producers both through direct damage to crops and through costly disease management measures that may include quarantine or more complex propagation measures (Gergeritch et al. 2015). For almost 250 years, societies have recognized that limiting trade can limit spread of pathogens; in 1878 European countries first instituted regulations on grape imports to slow the spread of grape Phylloxera (reviewed by Santini et al. 2018). In the United States, live plants were imported without regulation, with accidental introductions of insects and plant pathogens, until the passage of the Plant Quarantine Act in 1912 (Santini et al. 2018). Still, in the U.S., the main pathway for plant pest and pathogen introductions is imports of living plants; even in countries like Australia and New Zealand, where the live plant trade is more strictly regulated,

pathogens can come in on contaminated goods (Santini et al. 2018). Seed contamination is another way that plant pathogens may enter agricultural areas undetected (Gilardi et al. 2018).

As an example of how devastating plant pathogens can be, the disease Huanglongbing (HLB) was first discovered in the United States in 2005; it kills all varieties of citrus trees and threatens the citrus industry (reviewed by Alvarez et al. 2016). Economic analyses suggest that over a 20-year period, the damages associated with this disease could be up to $2.7 billion in California alone (Durburow and Lopez 2013).

INVASIVE PLANTS

The highest losses attributable to invasive plants, are either the cost of management/removal or agricultural losses. However, invasive plants can also cause infrastructure damage, which, in turn, can increase the frequency and magnitude of natural risks such as fire and flood.

Averaged over all major crops globally, weeds represent more potential productivity losses than either insects or pathogens (Oerke et al. 2006). They reduce crop productivity by reducing plant germination, plant growth rates, or plant yields. For example in a seven year study of corn production alone, Soltani et al. found that crop losses due to weeds in corn in the U.S. and Canada led to an average of 50% yield loss, equal to a total loss of 148 million tons of corn (U.S.$26.7 billion per year). Similarly, Soltani et al. (2018) found, using data from the 2016 Weed Science Society of America Census, that average yield losses due to uncontrolled weeds in dry beans were 71.4% in North America, representing a reduction of 941 million kg of beans, ($622 million).

Salt cedar (of many species of ***Tamarix***) causes high non-crop damage, including water, municipal, agricultural, hydropower, as well as cause flood-control issues and increase fire risk. In 2000, financial losses from salt cedar in the U.S. were estimated at $169-$362 million (Zavaleta, 2000) (Hultine et al., 2010) and have grown since. Tamarix trees and shrubs were introduced more than a century ago from Eurasia for ornamentation, for windbreak, and for stabilization of eroding stream banks (Lindgren et al, 2010). Unfortunately, the various ***Tamarix*** species have spread rates exceeding 20km/yr and are now a dominant plant on the banks of rivers, streams, springs, and ponds, ranging from Mexico to British Columbia, Canada and from western California to eastern Oklahoma. The invasion of salt cedar is one of the worst ecological disasters impacting riparian ecosystems in the United States, causing a host of ecological problems. They thrive in dry areas, hogging precious water, causing areas to become dryer and secreting salt into the soil. This leads to hydrological impacts, increase of fire frequency, displacement of native flora and fauna, and increased soil salinity. In addition to control costs, the plants cause economic damage (stemming from water loss within irrigation and municipal water systems), flooding from impeded water channels, reduction in hydropower capacity, and loss of wildlife habitat and recreational opportunities. Cost is forecast to be between $7 and $16 million in lost ecosystem functions over the next 55 years (Zavaleta 2000) (Lindgren et al. 2010). With wildfires increasing in intensity and costs, and ***Tamarix*** present in many of the highest fire-risk areas, the increased fire frequency in the presence of salt cedar may end up being the costliest type of loss caused by this species for insurers.

Lesser risks for insurers are weeds like hydrilla (***Hydrilla verticilata***) and watermilfoil (many species of ***Myriophyllum***). In addition to crowding out native species, hydrilla, a noxious weed, impedes irrigation and boating and clogs intakes at power generation and water supply facilities. Watermilfoil is a feathery submerged aquatic plant that quickly forms thick mats in shallow freshwater entangling boat propellers and hindering recreation (swimming, boating, fishing, waterfowl hunting). Eurasian watermilfoil reduced Vermont lakefront property values up to 16% and Wisconsin lakefront property values by 13% (USF&W 2012). Luckily for insurers, the structures of the homes themselves were not affected so their insured value likely was not affected.

Sudden oak death (***Phytophthora ramorum***) is a pathogen that affects multiple oak species. In California alone, it is estimated to have cost $7.5 million to treat, remove, and replace more than 10 thousand oak trees. The weeds also

caused additional property losses of $135 million to single-family homes in one community. This does not include the potential losses from increased fire and safety risks, attributable to the dead trees and the loss of ecosystem services. (Kovacs et al 2010). Potential insured losses arise from damage to homes or commercial buildings or passersby by falling dead trees and increased fire risk.

The Emerald Ash borer (***Agrilus planipennis***) pest incurred mean discounted costs, estimated at $10.7 billion for the 10-year period within 2009-2018 (Kovacs et al 2010). These costs were for the treatment and removal of trees killed by the pest.

RODENTS

Rodents can cause much damage. Black and Norway rats consume or destroy stored grains and property, valued over $19 billion annually in the U.S. (USF&W 2012). However, the destruction attributable to rats is known, understood, and recognized by agricultural and similar property insurers. The nutria (***Myocastor coypus***) is a very destructive but a much lesser-known invasive rodent, currently affecting the U.S. The nutria is a rather large rodent, which can grow heavier than 20 pounds.

Nutria, brought from South America for the fur trade in the 19th century, are prolific breeders. They reach sexual maturity in four to six months with each female being able to birth up to 200 young in a year (National Geographic 2018). Nutria are wasteful feeders that can leave as much as 90% of damaged plant material unconsumed, when foraging on belowground roots, which means they destroy much more than their appetite might indicate. Nutria decimate native plants that both hold marsh soils together and support the survival of native wildlife species. They cause the destruction of marshes and loss of wetlands, weakening the significant and important storm surge protection, provided by wetlands. For every mile of coastal wetlands lost, storm surges increase on average by about a foot. It is difficult to generalize the increase in insured property loss attributable to nutria damage. However, it is clear that storm surge modelling, based on past storms, will under-forecast damage if nutria have subsequently destroyed marshes, which had previously dampened the waves or storm surge.

Nutria also breach and undermine water-retention and flood-control levees; weaken the foundations of reservoir dams, buildings, and roadbeds; damage vegetation and crops—particularly rice and sugarcane but also others—and destroy banks of ditches, lakes, other water bodies. Nutria also spread diseases including pathogens such as tuberculosis and septicemia and host parasites, such as blood flukes, tapeworms, liver flukes, and other nematodes which can infect people, pets, and livestock.

Nutria populations are currently heaviest in the South along the Gulf Coast and in the Chesapeake Bay, and in the Pacific Northwest and in California. As the nutria numbers and range increase, these diseases and parasites may increase health costs in a large area of the U.S. in addition to the agricultural and infrastructure damage they cause. (USF&W, 2012)

INSECTS

Invasive insects take a large human and financial toll, costing a minimum of $70 billion annually globally of which over $6.9 billion is for associated health costs, though these figures likely underestimate global costs (Bradshaw et al. 2016). U.S. Agriculture alone loses $13 billion in crops annually because of invasive insects, such as vine mealybugs (***Planococcus ficus***) (USF&W 2012).

Red fire ants (***Solenopsis invicta***) may be the most directly damaging. The economic impact of fire ant infestations is enormous. In the U.S., current cost estimates for control, medical treatment, and property damage top $6 billion annually (Ascunce et al. 2011). Red fire ants damage young citrus trees, potatoes, dry crop seed, and other crops. They attack humans and domestic and wild animals in large numbers stinging simultaneously and causing injury. Fire ants are currently along the Gulf Coast of Texas up to Virginia and in California with small patches elsewhere,

including Arkansas and New Mexico (Ascunce et al. 2011). Up to 25% of residents in some regions of the United States are highly sensitive to fire ant stings. Fire ants are a constant danger, especially to young toddlers and the elderly. Stings often induce anaphylaxis in minutes (Fox 2014).

Another insect that causes both agricultural and health costs is the Africanized honeybee (a hybrid ***Apis*** species). These bees have spread rapidly throughout the southern U.S. from California to Florida and as far north as Arkansas. They are aggressive with a tendency to swarm. They disrupt the traditional pollination service industry, causing enormous agricultural losses. Their stings are a potential health and casualty risk for farm workers. They caused 89 fatalities in their first 5 years in Mexico (USDA 2020).

The spotted lanternfly (***Lycorma delicatula***), native to China, Bangladesh, and Vietnam, is currently making its way across the mid-Atlantic states (PA, NJ, MD, DE, VA) causing huge agricultural damage to grapes, apples, hops, hardwood, and other crops. Insecticide costs have trebled, and some growers are losing entire vineyards. In addition, the lanternfly eats most ornamental plants and causes property damage by coating property with honeydew, a sticky substance that is deposited on trees and other outdoor property. The honeydew can attract a black fungus, further damaging trees. Lanternfly egg mass can be cemented to anything and the living bugs can hitch rides on cars, trucks, and airplanes.

Insects also have indirect costs when they are vectors for disease. For example, mosquitoes can transmit diseases from one human or animal to another. Typically, the diseases are caused by viruses or parasites, which live in an animal (or possibly a human) that is a disease reservoir. When a mosquito takes a blood meal from an infected animal, it acquires the virus or parasite, which does not harm the mosquito but reproduces inside the mosquito. If the mosquito takes a second blood meal, the virus or parasite can be transferred to the bitten animal. Some mosquitoes feed preferentially on non-human species but are also opportunistic feeders that take human blood meals when they are available.

There are both native and invasive mosquitoes (of numerous species) in North America (Juliano & Lounibos 2005). Although the main vectors in some states are native (Moran personal communication), most of the mosquito vectors responsible for transmitting diseases are invasive species (Wilke et al. 2020). The increased incidence of vector-borne diseases can be partially attributed to the fact that invasive mosquitoes of epidemiological importance such as ***Aedes aegypti***, ***Aedes albopictus***, and ***Culex quinquefasciatus*** easily adapt and thrive in urban environments in low-latitude parts of the world. Invasive species often benefit from biotic homogenization processes and the reduction in overall biodiversity, and then respond by increasing range and abundance. (Wilke et al. 2020)

There are several important invasive mosquitoes.

Culex coronator is a primary vector of Saint Louis encephalitis and the West Nile virus. A native to Trinidad and Tobago, this mosquito is now established in most U.S. southern states, north to Virginia (Wilke et al. 2020).

Aedes albopictus, the Asian tiger mosquito, is native to southeast Asia and has been imported through the trade of used tires to the rest of the world where it is primary vector of chikungunya, dengue, yellow fever, and Zika. It has been detected in 36 states (Wilke et al. 2020).

Aedes aegypti, the Yellow Fever mosquito, originated in Africa and has likely been present in the western hemisphere for centuries. It is the primary vector in the United States of Zika and also transmits dengue, yellow fever (for which there is a vaccine), and chikungunya.

Cases of some of these lesser known diseases are increasing in the United States. Chikungungya is now present in 115 countries, including in the Americas. In 2017, the ***Aedes vexans***, a native species with a wide geographic distribution, was the first native North American mosquito species, shown to be able to transmit Zika, although it has not yet been shown to transmit it in the wild. (O'Donnell et al. 2017). Many native species, such as ***Culex pipiens***

(the common house mosquito), have peridomestic breeding habits (largely highly organic water found in containers) and thus also live in proximity to humans, which encourages them to take opportunistic human blood meals. Also, populations of invasive and native species can change. The invasion of ***A. albopictus*** has decreased the population of ***A. aegypti*** dramatically, especially in Florida as the ***A. albopictus*** larvae outcompete for food. (Zettel and Kaufman, 2020). The cost has been estimated for certain mosquito-borne diseases in contained geographic areas, such as counties, which if added or multiplied would indicate costs in the billions.

MAMMALS

Feral swine (***Sus scrofa***) cause an estimated $1.5 billion in damage and control costs in the United States each year. They cause major damage to agriculture, transmit diseases to livestock and wildlife, damage residential and commercial property, destroy cultural and historic resources, and involve themselves in wildlife-vehicle collisions (WVCs). Feral swine have become widespread throughout much of the United states where they are present in 38 states, primarily in the South and in California (up from 17 states just 30 years ago) (USDA 2016).

AQUATIC INVASIVES

The bivalve mollusks, Zebra mussels (***Dreissena polymorpha***) and the related Quagga mussels (***Dreissena rostriformis bugensis***), cost the U.S. economy $1 billion in 2002 (Quinn et al. 2013) and have spread far wider since. Zebra mussels cause both abiotic and biotic impact, affecting both health insurance and property coverage, such as business interruption insurance. The U.S. Geological Survey estimates that they are present around all the Great Lakes and in many tributaries of the Mississippi River as well as in the short-grass prairie states. Eurasian Dreissenid mussels entered the Great Lakes in the mid-1980s through ballast water of oceanic ships from the Ponto-Caspian region of Eastern Europe and have now spread throughout much of the United States (Hansen 2010). One of the most prolific freshwater invasive species, it can occur in densities as high as 750,000 individuals per square meter (McLaughlan et al. 2014), driving ecosystem-level change and becoming a costly biofouler to industry. The mussel fouls submerged substrates including canal and dock walls as well as watercraft and motor outdrives. It clogs water intake pipes and associated installations, severely impairing water delivery to hydroelectric, municipal, and industrial users; increases water clarity, which increases light transmittance and growth of benthic plants; and concentrates organic pesticides and polychlorinated biphenyl compounds, which enter the food chain, including waterfowl, and are later consumed by humans (MacIsaac 1996). Infestations of mollusks can severely clog intake pipes forcing power generation facilities to stop production to clean the pipes before they can return to generating power. The shutdown and resulting lack of power to the surrounding area may continue for days (Rosaen et al. 2016), potentially causing further insured loss. The cleaning costs for the power plants (often over $1 million per cleaning per facility) are additional to the business interruption costs to the plant itself and to businesses relying on the power. Any other facilities with water intake pipes, such as manufacturing plants, can suffer the same fate with business interruption and high cleaning costs. In the Great Lakes area, where the industrial base relies heavily on water, the losses can be severe.

Beyond property damage, the mussels can also affect health. Dreissenid mussels filter the upper layers of water, leaving them clearer and creating conditions that promote blue-green algae blooms, which in turn can clog water intakes and pipes. If infested water is a source of drinking water (the Great Lakes, for example, provide drinking water for 40 million people in the U.S. and Canada.), the mussels contribute to the formation of disinfection by-products, reducing water quality . (Chakraborti et al 2016) Since the blue-green algal blooms can be toxic, they increase the cost to treat the drinking water. The contaminated water can be harmful to human health if touched or swallowed, or if airborne droplets are inhaled. The consumption of fish, caught in contaminated areas, can cause illness. Further negative health effects are the biomagnification of contaminants and cut feet, which can further become infected from the toxic algae.

Litigation for issues surrounding aquatic invasives is an additional cost. Private companies that do not comply with the ballast water management regulations (put in place to stop further spread) face fines and fees of hundreds of thousands of dollars or higher, depending on the severity of the act. Any company that ships in freshwater is at risk, especially those in the Great Lakes (Rosaen et al. 2016).

Asian carp (several species) not only wreak ecological havoc and threaten fisheries—including the over $7 billion annual Great Lakes fisheries—but also cause injury and property damage. Asian carp escaped from aquaculture in the Deep South. They now have been documented in most of the Mississippi, Ohio, Missouri, and Illinois River Systems, where Asian carp now make up more than 95% of the biomass. One species of Asian carp—the silver carp (*Hypophthalmichthys molitrix*)—tends to leap out of the water at the sound of boat engines, resulting in injuries when the fish collide with boaters (Wittmann et al, 2014) (Hansen 2010). This Asian carp can jump at least 10 feet out of the water and grow to 110 pounds. Collisions between boaters and jumping silver carp have the potential to cause human fatalities (USF&W 2004).

Emerging Environmental Risks from Products–Nano- and Microplastics

Globalization has led not just to the spread of infectious diseases and invasive species, but also to the proliferation of plastics for packaging and transportation of goods over long distances. When plastics degrade, they break down into smaller particles, referred to as micro- (0.1-1000microm) and nano- (<=0.1microm) particles (henceforth referred to as microplastics). There is a growing concern over the health risk of these particles in the environment. These risks affect health and workers' compensation insurance and could trigger products claims.

Global production of plastic exceeds 320 million tons (Mt) per year, over 40% of which is single-use packaging. Substantial amounts are lost to the marine environment (estimated accumulative potential 250Mt by 2025). Exposure to ultraviolet radiation in combination with wind, wave action, and abrasion degrade plastic, potentially affecting the marine environment. Microplastics are also found in synthetic clothing and can end up in the water supply when they wear off with washing. Though greater than 98% of the microplastics are stopped by wastewater treatment plants, the residual (estimated 65Mt microplastics) is directly released to the environment in municipal effluent. Microplastics are hydrophobic and thus can adsorb and concentrate hydrophobic organic contaminants, such as polycyclic aromatic hydrocarbons (PAHs), organochorine pesticides, and polychlorinated biphenyls (PCBs) to a high degree and accumulate heavy metals such as cadmium, zinc, nickel, and lead. Microplastics are a vector for these priority pollutants, listed in the Stockholm Convention for potential adverse health effects. (Wright and Kelly, 2017). Additionally, chemical additives in the plastic may leach.

Humans are exposed through ingestion and/or inhalation, negatively affecting health, in turn leading to increased health and workers' compensation insurance costs. Microplastics have been found in fish and shellfish worldwide, even after they have undergone a depuration period. Microplastics have also been found in honey, sugar, beer, and sea salt. The presence in honey implies atmospheric contamination. Wastewater treatment plant sludge, used on agricultural land as fertilizer, contains microplastics, which have been detected in field-site soils 15 years after application and can kick up into the atmosphere with dust. Direct measures of ambient air have found micro- and nanoplastics at European sites. (Wright and Kelly, 2017)

Tires are acknowledged as a key source of microplastics (Wright and Kelly, 2017) as are other more general categories of products, such as synthetic clothing and plastic bags. It is possible that as the health effects of microplastics become more well-known, there may be products claims against the most egregious of the products that shed microplastics.

Microplastics can be an occupational hazard. Indoor exposure levels can be orders of magnitude above allowable or safe critical-particle concentrations in certain manufacturing plants, such as for polyester and other flock-

manufacturing (Wright and Kelly, 2017). Workers' compensation claims for occupational diseases and injury from inhalation of microplastics could run similar to those for asbestos or silicosis. Studies of nylon flock workers suggest no increased cancer risk, but there is higher prevalence of respiratory irritation, often resulting in interstitial lung disease (4% of workers in U.S. and Canada). Occupational asthma is another outcome as are interstitial fibrosis and granulomatous lesions. Cellulosic and plastic microfibers have been observed in malignant lung tissue of lung cancer patients. (Wright and Kelly, 2017)

Microplastics, whether inhaled or ingested, may resist mechanical clearance causing biopersistence. These particles can translocate across living cells to the lymphatic and/or circulatory system, potentially impacting the health of cells and the immune system or accumulating in secondary organs. (Wright and Kelly, 2017). Microplastic particles have been found in cerebrospinal fluid, liver, spleen, bone marrow and blood of test subjects. Microplastics are eliminated through bile, urine, and lactation (Wright and Kelly, 2017)

The effects of micro- and nanoplastic particles on human health include inflammation and compromised immune responses. As the microplastics are a vector of the adsorbed chemicals and heavy metals, as well as leaching their own chemicals, adverse effects attributable to any of these toxic substances may also be attributable to microplastics in the environment. Phthalates and bisphenol A have known reproductive toxicity. Vinyl chloride and butadiene are carcinogenic. Benzene and phenol have mutagenicity. Phthlalates disrupt hormones. These are just a few examples. In addition to chemical and metal contamination, biological contamination is also a risk from microplastics. Biofilms that develop on microplastics can include harmful human pathogens. Though the extent of potential effects is not fully known, liver damage and damage to brain development in fetuses and children from biofilms has been documented. (Wright and Kelly, 2017)

As the amount of micro- and nanoplastics increases worldwide, the health effects may increase healthcare costs because of the large number of people exposed (pretty much everyone in every state, province, or territory), even if treatment and/or hospitalization is only needed in a small fraction of the exposed population. Since the amount of microplastics is increasing, estimation from historical costs may not be sufficient to cover future costs without a specific trend applied. As the costs to treat microplastic exposure mount, there may be attempts to collect, based on product liability theories.

Climate Change and Exacerbation of Globalization Environmental Risk

Models of actual events indicate an increase in extreme wind and precipitation events, such as heavy rain, thunderstorms, tornadoes, hurricanes, and extreme drought. As invasive species and further human development destroy natural barriers to storm surge, coastal losses will likely rise. Extreme climatic events can increase the spread of invasive species as enclosures are destroyed and floodwaters and winds transport organisms into new areas. Hurricanes, floods and drought can also decrease the resistance of habitats to invasions, allowing more to establish themselves. Climate change is opening up new transport pathways. For example, melting ice is allowing for new Arctic shipping passages to open, reducing the transport time for ships between Asia and Europe and increasing the probability of alien species surviving the journey. At the same time, climate change could change the ranges of many of the species as warmer weather spreads northward. North America may offer a larger home to subtropical and even tropical species, including pest species and disease vectors. Property, casualty, and health losses are likely to rise from these changes.

Conclusion

Globalization's environmental risks touch many lines of business. It is important that actuaries recognize and try to quantify these risks for each line of business. Globalization accelerates the increase in risks to life, health, liability and property. Thus, including trend in analysis is key to more accurately project risks of future policies.

Environmental risks from globalization have the potential to become catastrophic. It is difficult to estimate and impossible to know which of the risks may become the next Superfund risk or the next asbestos. However, the more actuaries know about the risks, the better predictions we can make. Whether microplastics suddenly become the next big products claim or whether some new invasive species emerges to destroy our infrastructure, insurers will want their actuaries to be cognizant of the risks.

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