

## 1. Overview of research interests

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I am an applied economist working in the area of labour and health. The focus of my work is on the implications of externality and selection effects in health production, and I am particularly interested in how aspects of externalities and selection can interact with policy in intended or unintended ways.

Under this agenda, I have developed two main themes of research. The first deals with externalities in respiratory health, where, for example, I consider the gap between standard evidence on vaccine effectiveness and optimal policy design. The second theme extends my research on immunization and fits within the economics literature on early child development. Here, my interests have built beyond my early work to more broadly consider selection effects at birth.

I have included a summary of each of these research themes in what follows. Each theme includes a brief introduction followed by the paper abstracts.

In addition to the research summarized here, I have included three full-length samples of research in the application.

## 2. Research themes

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### A. Health Externalities and Respiratory Disease

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#### Context

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Health policy is often based on evidence estimating the effectiveness of health technologies; in some cases, this evidence is parsed by demographic factors that suggest different approaches to policy design by group status. I am interested in what this evidence misses, and moreover, if these gaps have distributional implications. For instance, the first paper listed below (Ward 2014; published in AEJ: Applied) explores the context of vaccination. While evidence indicates higher effectiveness of influenza vaccine among older ages, I show that vaccination of the young can yield large gains across the full age distribution. In this case, policy design based on effectiveness will set distributional targets that lead to lower gains for all.

In a second paper, I set up a theoretical model of heterogeneous externalities calibrated to influenza, and use the model to illustrate how the marginal effect of vaccination depends on the age profile of vaccination in the population. This model provides a theoretical basis for the size of externalities across the age distribution, and illustrates how policy grounded on evidence that ignores these externalities actually runs counter to lowering the overall disease burden.

The value of the model, though, is that it traces out externality effects for any age profile at any point in the overall vaccination distribution. This allows us benchmark the effect of different policy changes. For example, we can see that Ward (2014) is a special case of the model where that particular policy change leads to increased vaccination due solely to changes for those under 65. The theoretical model shows that this change, starting from this particular baseline level of vaccination, occurred at exactly the right point to deliver large externality gains, which is what we see empirically in that paper.

My further work in this area builds on my earlier empirical work, but is able to offer further context with the theoretical model. For example, I look at the effect of changes to pharmacy statutes allowing pharmacists to vaccinate, which differ in timing and age target across U.S. states. I find here that there is a small increase in vaccination following a statute change (1.6 percentage points), but the age profile of

vaccination tilts substantially towards younger groups. Using the model, I am able to trace out the overall and externality effects of this change. In this case, for example, the disease rate falls by 3.5 percentage points (more than 2 times the change in the vaccination rate indicating large externality effects), and the disease burden falls by 9 percent.

In the future, I intend to calibrate the theoretical model to other diseases to provide similar context to externality effects in other diseases types. This includes my own work on school entry immunization laws, but also the recent work by others in this area, e.g. Carpenter and Lawler (2019), White (2019), and Lawler (2017).

Another leg of my work on externalities explores the impact of air pollution on health and compares it to air quality standards set by Canadian and American governments. While the notion that standards will place undue restriction on economic activity is compelling, I show that pollution has particularly harmful effects for the health of children. There are three aspects I find notable about this evidence: (1) these effects occur at levels below the newly issued air quality standards, (2) these effects are, in part, due to transboundary pollution from U.S. jurisdictions (with less stringent standards) and (3) I find the harm for children is larger at older ages and more often exacerbating chronic problems, suggesting that upfront productivity gains of industrial activity could deliver their own negative productivity effects later on. This first in this line of inquiry is published in Ward (2015).

## Papers

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### **1. Ward, Courtney J. 2014. “Influenza Vaccination Campaigns: Is An Ounce of Prevention Worth a Pound of Cure?” *American Economic Journal: Applied Economics*, 6(1).**

This paper estimates the overall impact and externality effects of an influenza-vaccination program expanding coverage outside the typical target group. Using a triple-difference design, which exploits the introduction of a broad based vaccination program in Ontario and the quality of the vaccine from year to year, I link higher vaccination to health improvements. Results indicate: (i) coverage expansion leads to large excess gains for program regions; (ii) benefits exhibit decreasing returns corresponding to a standard model of disease dynamics; and (iii) substantial external benefits accrue to older adults.

### **2. Ward, Courtney J. “Health Policy in the Face of Heterogeneous Externalities: the Case of Influenza Vaccination**

Heterogeneous treatments effects can lead to policies prioritizing groups with high estimated treatment gains. However, where there are treatment externalities, this strategy may not take advantage of large within and cross group gains because externalities are unmeasured. This paper illustrates the problem using the example of influenza vaccine. This is an ideal example to illustrate the case as externalities are large and heterogeneous across age, but existing evidence-based policy does not take these into account. Using a theoretical model of disease, this paper shows that due to heterogeneous externalities across age group, a zero-sum redistribution away from the typical “evidence-based” vaccination strategy leads to gains for all. The paper also illustrates the point by providing an empirical assessment of a particular policy: statutes allowing pharmacists to vaccinate. Using year-by-state variation in U.S. pharmacist statutes this paper shows that statutes lead to very little change in the overall vaccination rate but tip the age distribution of vaccination towards younger age groups and away from older age groups. Using estimates of the distributional change, the model shows that even though statutes made very little difference to overall vaccination, the change in distribution substantially lowers the rate of infection and other measures of loss from influenza.

### **3. Ward, Courtney J. "Influenza, Mortality and Externalities for Long Term Care Residents". Working Paper.**

Policy makers often rely on group-specific evidence from randomized control trials in designing vaccination campaigns and in gauging their expected impact. However, even where trials are informative of vaccine effectiveness by group, optimal policy design may run counter to this evidence because of unmeasured vaccine externalities. For instance, previous literature on the influenza vaccine and mortality finds high effectiveness for residents of long term care homes, suggesting this group for targeted policy. However, depending on the nature of externalities across group, this approach may yield low relative gains. This paper addresses this question by using hospital records over the last decade and focusing on the introduction of a broad based vaccination program in Ontario. I find evidence that vaccination in younger groups leads to large mortality gains for residents in long-term care homes, indicating that substantial external gains for this group are still possible even where vaccination rates are in the excess of 90 percent.

### **4. Air Pollution and Respiratory Health**

Courtney J. Ward, 2015. "It's an ill wind: The effect of fine particulate air pollution on respiratory hospitalizations," *Canadian Journal of Economics*, Canadian Economics Association, vol. 48(5), pages 1694-1732, December.

While a growing literature in economics has established the harmful health effects of longstanding criteria air pollutants such as ozone and carbon monoxide, fine particulate air pollution is relatively understudied. This paper provides evidence on the harmful effects of fine particulate pollution for Ontario, where municipalities enjoy particulate levels well below US Environmental Protection Agency (EPA) standards and predominantly below Canada-wide standards. Results provide strong evidence for the detrimental effect of fine particulate pollution for the respiratory health of children, with a one standard deviation change in particulate pollution, leading to a 4% increase in respiratory admissions. While these results inform the stringency of current pollution standards, they also highlight the importance of an international approach to air quality. For instance, the paper also shows that particulate levels in Ontario municipalities are strongly influenced by southerly winds from US jurisdictions, which adhere to more lenient EPA standards

### **5. Spin, P., Sketris, I., Hill-Taylor, B., Ward, C., & Hurley, K. 2016. A cost analysis of salbutamol administration by metered-dose inhalers with spacers versus nebulization for patients with wheeze in the paediatric emergency department. *Canadian Journal of Emergency Medicine*, 8(1).**

Despite evidence demonstrating the advantages of metered-dose inhalers with spacers (MDI-s), nebulization (NEB) remains the primary method of asthma treatment in some pediatric emergency departments (PEDs). There is a perception that delivering salbutamol by MDI-s is more costly than by NEB. This research evaluates the relative costs of MDI-s and NEB using local, hospital-specific, patient-level data. Our results suggest economic gains associated with MDI-s for salbutamol inhalation in PEDs. Sensitivity analyses show that this conclusion is not affected by changes in model parameters that may differ by jurisdiction. Since most facilities already collect the data used for this study, our methods could be adopted for a cross-jurisdictional account of the cost effectiveness of MDI-s.

Spin, P., Sketris, I., Hill-Taylor, B., Ward, C., & Hurley, K. (2017). Response to Review Regarding Cost Analysis of Salbutamol Administration. *Canadian Journal of Emergency Medicine*, 19(6), 500-502. doi:10.1017/cem.2017.358

## B. Early Childhood Development

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### Context

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The literature on early life influences is growing, with analysis focusing on detecting causal pathways from early exposures to later life outcomes. My first contribution to this literature was to extend my research on immunization by assessing the long-term impact of early school immunization mandates for measles, mumps, and rubella (MMR). I was motivated by the fact that, prior to school mandates, seasonal MMR epidemics occurred quite sharply in March-April. Moreover, this timing corresponded to the birth-quarter differences described in the Labor economics literature, which as Bound and Jaeger (2001) note, grew weaker in more recently born cohorts. I wanted to see if there was a link, and in 2012, I was awarded SSHRC funding to collect a historical account of school mandates and disease in the U.S. since the 1960s. This paper is described below.

My interests have built beyond my early work to more broadly consider: (1) differential effects by timing of exposures and (2) the implications of selection at birth. For example, my work on immunization mandates points to the early *in utero* period as the most sensitive. My next question in this area is whether disease exposure has different impacts on cognitive ability versus physical health depending on timing of exposure (e.g. as a scan across the early influences literature seems to suggest). In order to explore this, I use a dataset that includes childhood measures of cognitive and physical health along with detailed information on infection status and health at birth. This paper is described below.

The second question I am interested in is the role that selection may play in our interpretation of this literature. For instance, *in utero* influences may, on the margin, impact whether a child is born alive and, further, whether that child is observed later in life. This implies that survivorship, itself, is policy amendable and that our assessment of protective interventions will be undervalued in cases where the health of the child on the margin of survival is below the average (and fetal health is valued). Depending on the nature of selection for different policy interventions, this could lead to biases in our evaluations of the relative returns to these interventions. My work in this area has begun by documenting the nature of selection from conception to early infancy. For instance, in the second paper listed below, I assess the degree of selection from a well-documented negative health behavior: smoking. In the fifth paper below, I assess broader patterns in birth outcomes over time and changes in the willingness to medically intervene over the distribution of gestational age. Both these papers are described below.

### Papers

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#### 1. “The Effects of Immunization Mandates: Does Prenatal Exposure to State School Immunization Policy Impact Later Economic Well-Being?”

State school immunization mandates of the late 1960s and 1970s had a substantial and immediate impact on measles, mumps and rubella incidence. While these mandates were targeted at the school age population, evidence implies benefits for children in-utero. Specifically, this paper shows that individuals whose prenatal period occurred after mandate adoption had much to gain from such policies. Using variability in the timing of immunization mandates across states and comparing individuals with prenatal periods before and after immunization laws were enacted, shows that adoption of school mandates had an immediate effect on birth weight and a long-term effect on adult health. This is after controlling for individual characteristics, state specific characteristics and flexible functions of the date of conception. Moreover, results are strongest for individuals whose gestational period covers the seasonal epidemic period for measles, mumps and rubella. Evidence of the contemporaneous and long term-effect of

prenatal exposure to entry laws suggests that external benefits from mandatory immunization policies are much broader than accounted for in previous literature.

## **2. “Fetal health, sex ratios and cigarette policies”**

Males are more vulnerable to maternal condition in utero, a fact that aligns with the long standing evolutionary theory that women in good condition are more likely to produce a male child (Trivers and Willard 1973). While the sex ratio is responsive to maternal characteristics like marital status, education and age (even in white U.S. mothers), the mechanisms by which these factors differentially affect male fetal health are still unclear. This paper adds to this literature by looking at a specific health behavior that has a well-documented effect on infant health: smoking. Using the universe of US birth files for 1989-2004 and anti-smoking policies exogenous sources of variation to fetal health, I look at the sex ratio of live births. Aside from signaling important differences in the underlying condition of the fetus, evidence of the sensitivity of the sex ratio is used to provide an estimate of the overall fetal loss associated with smoking behavior. Using this sensitivity I find that a doubling of cigarette taxes leads to a decrease of fetal loss on the order of 3 percent of the birth population. On the other hand, adoption of a workplace ban leads to an increase in fetal loss on the order of 11 percent of the birth population.

## **3. “Influenza, the *in-utero* environment, and child development”\* with Shelley Phipps**

In a well-known demonstration of the “fetal origins hypothesis,” Almond (2006) showed that exposure to the 1918 influenza epidemic in the prenatal period had substantial and long lasting effects on income and educational attainment in adulthood. However, while the historical link for the prominent 1918 epidemic is clear, much less is known about the modern day implications of prenatal exposure to seasonal influenza epidemics. Moreover, these implications may be much broader in scope, possibly contributing to well-known seasonal differences in outcomes over birth quarter, and pointing to inequality in health and ability at the earliest stage of life. Using comprehensive data on influenza epidemics over the last two decades, this paper estimates the effect of prenatal exposure on birth outcomes, and tracks the impact on health and skill accumulation throughout early childhood.

## **4. Willingness to Intervene by Gestational Age: Are Child Characteristics Important?**

The willingness to medically intervene is lower for babies with earlier gestational ages (Wilkinson, et al. 2009). Using the census of birth records for the last 3 decades in the U.S., I describe the factors most strongly associated with resuscitation across the gestational distribution, and, further, how survivorship across the gestational distribution has changed over time. The analysis provides four primary results. First, the survival rate for infants at earlier gestational ages has improved over this period. Second, there is a sharp discontinuous drop in the rate of assisted ventilation before 23 weeks gestation, which accords with clinical recommendations. Third, the APGAR score (a standard measure of health at birth) is negatively associated with assisted ventilation at the top of the distribution, but positively associated with assisted ventilation at the bottom, suggesting differences in the underlying willingness to intervene. Finally, after APGAR, the characteristic most strongly associated with the use of assisted ventilation by gestational age is whether the child is male. For instance, while there are no sex differences in the rate of assisted ventilation for babies born before 23 weeks or after 34 weeks, the rate for males is 17 percent higher in the case of 24-34 weeks, the zone where clinical guidelines on intervention are not absolute. This evidence, together, suggests that factors related to medical intervention at birth can lead to both differences in survivorship and differences in the characteristics of survivors.

## **5. “Influenza The 1918 flu pandemic in Canada: Parental characteristics and long-term economic outcomes” with Shelly Phipps and Paul Spin**

While the cohort effects of *in utero* exposure to the 1918 influenza pandemic have been well documented (Almond 2006; Almond and Mazumder 2005), more recent work has questioned the interpretation of this evidence (Brown 2011). Specifically, Brown (2011) uses the 1920 and 1930 U.S. censuses to show that World War I triggered important differences in the type of men available for conception around the time of the epidemic. To shed light on these issues, we will use recently released census files from the Canadian Century Research Infrastructure project. In combining these census data over the last century, we will provide further insight into the sensitivity of results to differences in parental characteristics, exploiting, particularly, differences in military enrollment along linguistic lines (i.e. French and English), which occurred even in the face of conscription.