



Causal Inference in Observational Settings



COMPASS
RESEARCH CENTRE

FACULTY OF ARTS
THE UNIVERSITY OF AUCKLAND

Whare Wānanga o Tāmaki Makaurau

7th Wellington Colloquium

Statistics NZ

30 August 2013

Professor Peter Davis

University of Auckland, New Zealand
and COMPASS Research Centre

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Outline



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FACULTY OF ARTS
THE UNIVERSITY OF AUCKLAND

Whare Wānanga o Tāmaki Makaurau

- ❑ Rationale, motivation
- ❑ Two background papers
- ❑ Handbook Outline
 - Volume I – Background
 - Volume II – Analytical techniques
 - Volume III – Temporal relations
 - Volume IV – Experimental analogues
- ❑ Two exemplar papers
- ❑ Implications for theory and practice

What's at Issue

- **Fundamental issue of the “policy sciences”**
 - are Randomised Controlled Trials (RCTs) the only path to credible causal inference (see UK Cabinet paper)?
 - If not, how can we draw “credible” (causal?) inferences from observational data, particularly for policy?

SPECIAL INTRODUCTORY OFFER!



Data Inference in Observational Settings

/// Four-Volume Set

SAGE Benchmarks in Social Research Methods

Edited by **Peter Davis** *University of Auckland*

Most social research is carried out in observational settings; that is, most social researchers collect information in the 'real world' trying to do as little possible to alter the circumstances of study. However, there is a fundamental problem with this kind of research, in that it is very hard to draw 'causal' conclusions, because of the complexity and obduracy of social reality. This is not just a problem for social scientists interested in policy or social action. It applies across the board, more generally, because it becomes difficult to know, without the conditions for credible inference, what conclusions can be drawn from any piece of empirical research that aspires to be anything more than descriptive of social phenomena.

Drawing from a variety of sources - from logicians and philosophers, to applied statisticians, computer scientists, econometricians, epidemiologists and social researchers - this collection provides an invaluable resource for scholars in the field.

Volume One: Background

Volume Two: Analytical Techniques

Volume Three: Temporal Relations

Volume Four: Experimental Analogues

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 **SAGE**

Test, Learn, Adapt:

Developing Public Policy with Randomised Controlled Trials

Laura Haynes

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Ben Goldacre

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 **CabinetOffice**
Behavioural Insights Team

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 - often a form of speculative post-mortem
 - But, see my two health services research papers

Davis et al. (Medical Care article)



ORIGINAL ARTICLE

Do Hospital Bed Reduction and Multiple System Reform Affect Patient Mortality?

A Trend and Multilevel Analysis in New Zealand Over the Period 1988–2001

Peter Davis, PhD,* Roy Lay-Yee, MA,* Alastair Scott, PhD,† and Robin Gauld, PhD‡

Background: The impact of hospital and system restructuring on the quality and pattern of care is an important issue of public policy concern.

Objective: To assess the effect on patterns of care and patient outcomes of a substantial reduction in public hospital bed availability and multiple reorganizations in New Zealand through the 1990s.

Research Design: Trend analysis using both tabular and multilevel techniques.

Subjects: Access to discharge data, amounting to 6,639,487 records, was secured for all 34 major public hospitals in New Zealand over the period 1988–2001.

Outcome Measures: Number of discharges, admission rate, access levels, mean length of stay, unplanned readmission rate, and 60-day postadmission mortality rate.

Results: Although the number of inpatient beds in use declined by one-third over the period and the national population grew by nearly one-fifth, discharge volumes increased significantly and rates of inpatient admission were maintained, as were access levels for vulnerable groups. These changes were accompanied by workload adjustments (a halving in length of stay and an increase by a quarter in readmission rates). Yet age-adjusted postadmission patient mortality decreased by a quarter over the period of study, a rate of decline that was slowed by the major workload adjustments but not by reform phases.

Conclusions: Other things being equal, a substantial reduction in inpatient bed availability can be effected in national public hospital systems, while largely maintaining access and quality of care. However, the workload adjustments that are required may slow improvements in patient outcomes.

Key Words: health system reform, patient outcomes, multilevel analysis

(*Med Care* 2007;45: 1186–1194)

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Internationally there has been a considerable change in the role of the hospital through the 1990s, with higher rates of admission, shorter periods of stay, and growing rates of outpatient and day care.¹ An important strand in this change in role was a conscious restructuring of hospital workforce and redesign of work in inpatient settings across the developed world.² Over this same period, many of these countries also underwent bouts of broader health reform.³ New Zealand, where the government pays for 80% of health care and public institutions dominate the health system, was no exception. The country undertook 4 sets of changes to the publicly-funded health system up to 2001 (see Fig. 1), including a succession of public hospital sector reorganizations.⁴ At the same time, in a related trend, the sector experienced a substantial reduction in the availability of inpatient beds.⁵

The substantive interest in the New Zealand case is 4-fold. First, it was one of a group of countries with national health service-type systems that implemented a suite of market-oriented reforms from the late-1980s to the mid-1990s (the others being Italy, Spain, Sweden, and the United Kingdom).⁶ These reforms were typically intended to create a "market" for publicly-funded health services by instituting competitive tendering between government-purchasing agencies and service providers vying among one another to win contracts to provide public services, and also by transforming public hospitals into public corporations expected to function like private cost-conscious businesses. These were features of the second and third reform phases in New Zealand (see Fig. 1). Second, this suite of reforms probably went further and faster in New Zealand than anywhere else and were part of a broader reform thrust in economic and social policy. They also drew widespread popular and political opposition.⁶ Third, New Zealand simultaneously experienced both a substantial reduction in availability of public hospital beds and 4 separate structural reorganizations (Fig. 1).⁴ Fourth, even though many of these reform experiments were short lived, internationally, as Or has noted, "the lack of proper evaluation . . . is striking,"⁷ particularly with concerns about possible effects on access and quality.⁸

Given the strength and coherence of the reform program, and its powerfully managerial and efficiency objectives,⁸ 3 key questions arise. First, how did the performance

Davis et al (Lancet article)



Articles

Quality of hospital care for Māori patients in New Zealand: retrospective cross-sectional assessment

Matthew J. Gray, Stephen J. Legg, Stephen J. Legg, Matthew J. Gray, Stephen J. Legg, Stephen J. Legg

Summary
Background New Zealand has a substantial indigenous minority—the Māori—but has consistently worse health status than the majority population. We aimed to assess possible disparities in quality of hospital care for Māori with data on post-able adverse events as an indicator of suboptimum treatment.

Methods We undertook a nationally representative cross-sectional survey of admissions to general public hospitals with more than 100 beds providing acute care. A sample of 670 patients admitted in 1996 to 14 hospitals was selected by stratified systematic sampling. We did a retrospective cross-sectional assessment of events by examining hospital notes. Outcomes measured were treatment delays, and preventable and preventable adverse events.

Findings Māori accounted for just greater than 10% of admissions and were on average younger, were more likely to be from rural deprived areas, had a different case mix, and were in hospital for a shorter stay compared with patients of non-Māori race. But in origin, 5% could offer equivalent decision, 14% of admissions for Māori were associated with an adverse event, compared with 11% for non-Māori (non-factorial patients) (p=0.01 for difference between groups). For preventable, in-hospital events, this disparity persisted after controlling for age, other sociodemographic factors, and case mix (adjusted odds ratio 1.47 [p=0.03]). Analysis of potential causal factors showed no markedly or consistently different patterns between the groups.

Interpretation People in predominantly publicly funded hospital systems are finding regions that hospital care received by Māori is comparably poorer than that received by New Zealand citizens of non-Māori race-ethnic origin. Although no causal claims to Māori was evident, various policy and system issues can be addressed.

Introduction
Quality of care (defined as the degree to which health services meet an attainable health outcome and are consistent with professional knowledge) can differ consistently between ethnic groups (However, where these differences are due to variations in access, ethical considerations of treatment, and patients' preferences, or whether they are disparities in quality that are attributable to the potentially controllable factors of the delivery system and those who staff it is unclear). Moreover, whether these differences affect indigenous groups is not evident, since indigenous health care is often not as well as that of non-indigenous patients (often in such analyses).

New Zealand has a large indigenous minority—the Māori—that has substantial disadvantages in health status compared with the majority population, which is generally of British descent origin.¹ The sample Māori life expectancy at birth is about 8.5 years lower than for non-Māori individuals.² Māori women and Pacific women groups also exist; the latter largely being descendants of indigenous indigenous in the remaining regions of the South Pacific. Although the government has committed to a strategy of enhancing access to primary care and improvements in quality of care for Māori, little information is available on disparities in and quality of the quality of treatment.^{3,4}

New Zealand's health-care system is predominantly tax funded, with family doctors managing access to specialist and hospital care. Hospital care is available free of charge and is generally distributed in a fairly uniform and coordinated fashion across the country with Māori of the population being white or nearly white of a diverse hospital.

One difficulty in assessment of disparities in the health care system is measuring the quality of care that is available and needed. For example, research might identify low rates of use of a procedure in a minority group, but higher rates of use in the majority group could be due to overuse rather than clinical necessity.⁵

Preventable adverse events are measures of quality that are not susceptible to such methodological problems, since they measure outcomes of care in terms of patients that can be caused by one of both outcomes and outcomes during treatment.⁶ Such events also avoid the commonness of quality of care, albeit with a narrow interpretation: they are undesirable health outcomes produced by health-care interventions and, because of their preventability, indicate potentially remediable deficiencies in professional knowledge and practice. Although equally heavy on a narrow interpretation of quality, they provide powerful evidence of suboptimum treatment and can be included in broader quality metrics that are systemic in origin. We assessed whether preventable adverse events were more frequent among Māori patients than in other patients in public hospitals in New Zealand.

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- **Causal identification via data analysis is problematic**
 - often a form of speculative post-mortem
 - But, see my two health services research papers
- **Basic conundrum of causal reasoning**
 - impossible to observe unit response under alternative
 - So, how do we know what “works”, what is evidence-based?



HM Government

What Works: evidence centres for social policy

March 2013



Alliance
for Useful
Evidence

SQUARING THE CIRCLE

EVIDENCE AT THE LOCAL LEVEL

Derrick Johnstone

May 2013

Rationale of Handbook

1. **Traditional statistical theory**

mainly about representation not causation (i.e. sampling)

2. **Statistical inference=>causal inference**

random assignment and manipulation of treatment conditions

3. **Counterfactual/potential outcomes**

conceptually bridges experimental/observational settings

4. **Forward causation only**

cause-to-effect (e.g. impact of policy intervention)

5. **Econometrics**

a parallel community of policy practice (e.g. to public health)

Rationale, motivation

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Two Background Papers

1. Counterfactual thinking

2. Statistical reasoning

- Fisher never related his work on likelihoods and models to his work on experimental design

3. Causal diagrams

- Using diagrams to clarify causal relationships

4. The econometric paradigm

- Relying on research design rather than questionable statistical assumptions

5. Within-study comparisons

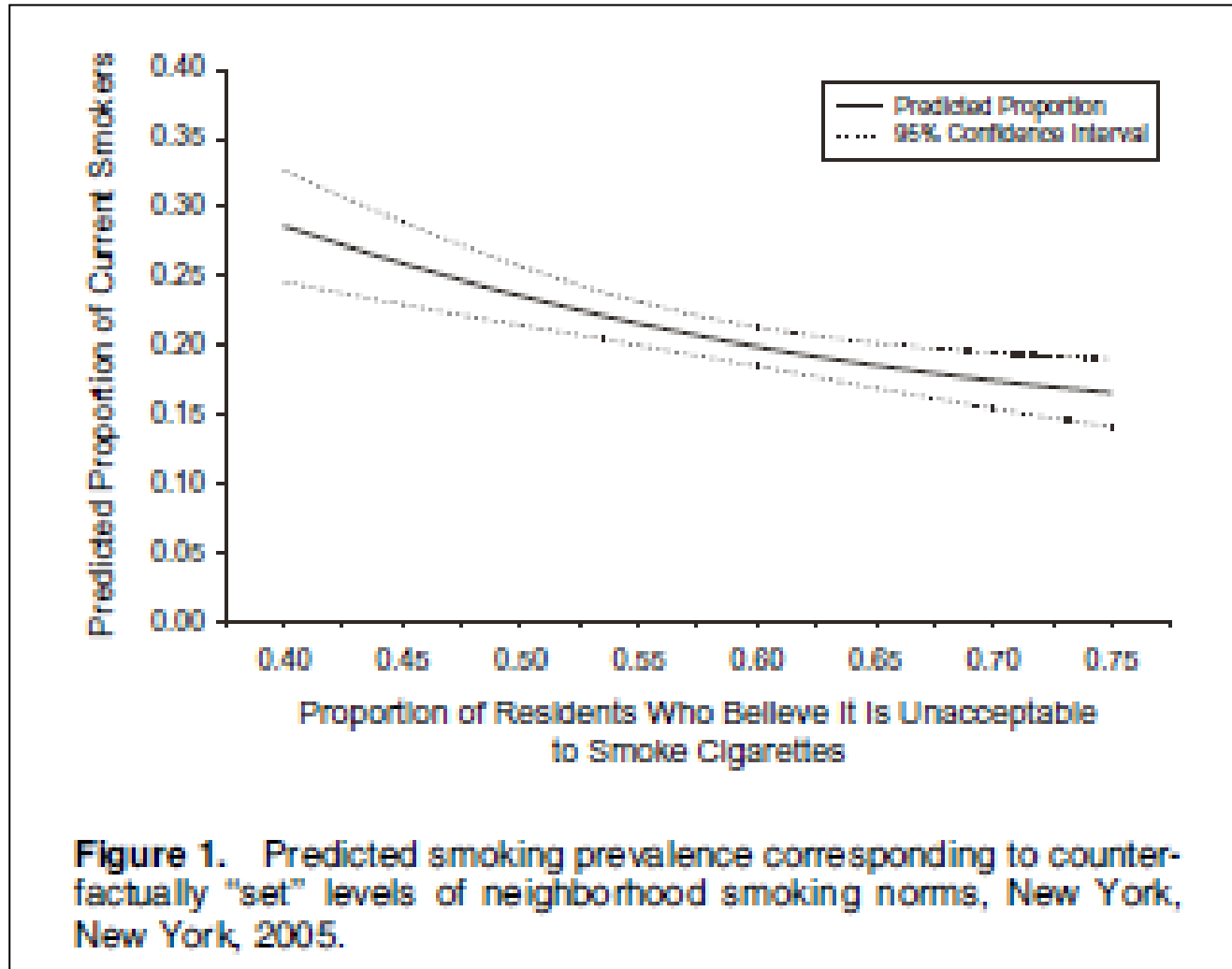
Ahern et al.



Counterfactual – Neighbourhood Norms

- Population average causal effect
 - difference under one intervention vs. another (or none) by estimating counterfactual exposures->outcomes
- Epidemiological association smoking/norms
 - estimate counterfactual - impute new pattern of neighbourhood smoking norms and derive smoking levels
- Prevalence estimates if norms “manipulated”
 - 17% (versus 29%) if all neighbourhoods prohibitive

Ahern et al.



Cook et al.



Three Conditions under Which Experiments and Observational Studies Produce Comparable Causal Estimates: New Findings from Within-Study Comparisons

Thomas D. Cook
William R. Shadish
Vivian C. Wong

Abstract

This paper analyzes 12 recent within-study comparisons contrasting causal estimates from a randomized experiment with those from an observational study sharing the same treatment group. The aim is to test whether different causal estimates result when a counterfactual group is formed, either with or without random assignment, and when statistical adjustments for selection are made in the group from which random assignment is absent. We identify three studies comparing experiments and regression-discontinuity (RD) studies. They produce quite comparable causal estimates at points around the RD cutoff. We identify three other studies where the quasi-experiment involves careful intact group matching on the pretest. Despite the logical possibility of hidden bias in this instance, all three cases also reproduce their experimental estimates, especially if the match is geographically local. We then identify two studies where the treatment and nonrandomized comparison groups manifestly differ at pretest but where the selection process into treatment is completely or very plausibly known. Here too, experimental results are recreated. Two of the remaining studies result in correspondent experimental and nonexperimental results under some circumstances but not others, while two others produce different experimental and nonexperimental estimates, though in each case the observational study was poorly designed and analyzed. Such evidence is more promising than what was achieved in past within-study comparisons, most involving job training. Reasons for this difference are discussed. © 2008 by the Association for Public Policy Analysis and Management.

INTRODUCTION

Comprehensive program evaluation depends on validly determining a program's causal impacts. Debate has been vigorous about the role experiments and observational studies should play in identifying such impacts. The main reason for preferring experiments is that, when perfectly implemented, they create intervention and control groups that do not initially differ in expectation and so do not differ on any measured or unmeasured variables. However, the regression-discontinuity design (RD) and instrumental variables (IV) also provide unbiased causal inference in theory. So additional technical justification for preferring experiments is required. It comes from experimental estimates being more precise than RD and IV estimates (Goldberger, 1972) and also from the experiment's assumptions being more transparent in research practice. IV's main assumption is that the instrument is only correlated with outcome through treatment. This assumption is well warranted when

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Within-Study Comparison of Causal Effect

- Experiment and Regression Discontinuity
 - Comparable causal estimates around RD cut-off
- Matched intact comparison groups
 - Comparable effect estimates where intact comparison groups with overlap on pre-test means and even slopes.
- Different populations, but known selection
 - Modelling of selection process can reduce bias

Two Background Papers

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Structure of Book

- Volume I – Background
 - Causal inference
 - Potential outcomes
 - “Evaluation research”
- Volume II – Analytical techniques
 - Matching methods
 - Propensity scoring
 - Causal diagrams
- Volume III – Temporal relations
 - Panel studies
 - Family studies
 - Instrumental variables
- Volume IV – Experimental analogues
 - Experimental paradigm
 - Regression discontinuity
 - Quasi-experiments, natural experiments

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Two Exemplar Papers

1. Matching/Propensity scores
2. Using panel data
3. **Fixed effects**
4. Instrumental variables
5. **A natural experiment**

Avendano



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Short report

Correlation or causation? Income inequality and infant mortality in fixed effects models in the period 1960–2008 in 34 OECD countries

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ABSTRACT

Income inequality is strongly associated with infant mortality across countries, but whether this association is causal has not been established. In their commentary in this issue of *Social Science & Medicine*, Regidor et al. (2012) argue that this association has disappeared in recent years, and question the premise of a causal link. This paper empirically tests the impact of income inequality on infant mortality in a fixed effects model that exploits the evolution of income inequality over a 38-year period, controlling for all time-invariant differences across countries. Data came from the Standardized World Income Inequality Database, containing yearly estimates for the period 1960–2008 in 34 countries member of the Organization for Economic Co-operation and Development (OECD), linked to infant mortality data from the OECD Health database. Infant mortality was modelled as a function of income inequality in a country and year fixed effects model, incorporating controls for changing economic and labour conditions. In a model without country fixed effects, a one-point increase in the Gini coefficient was associated with a 7% increase in the infant mortality rate [Rate ratio (RR) = 1.07, 95% Confidence Interval (CI) 1.04, 1.09]. Controlling for differences across countries in a country fixed effects model, however, income inequality was no longer associated with infant mortality (RR = 1.00, 0.98, 1.01). Similar results were obtained when using lagged values of income inequality for up to 15 years, and in models that controlled for changing labour and economic conditions. Findings suggest that in the short-run, changes in income inequality are not associated with changes in infant mortality. A possible interpretation of the discrepancy between cross-country correlations and fixed effects models is that social policies that reduce infant mortality cluster in countries with low income inequality, but their effects do not operate via income. Findings highlight the need to examine the impact of more specific social policies on infant mortality.

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Introduction

During the last decades, a wide array of studies has examined the association between income inequality and health in high-income countries. The rationale behind these studies is that income inequality, independent of individual income, is associated with population health, so that more equal societies have better health and lower mortality (Hale, Howden-Chapman, Salmon, Woodward, & Mackenbach, 1999; Kaplan, Pamuk, Lynch, Cohen, & Balour, 1996; Lynch et al., 2001; Navarro et al., 2003; Wilkinson & Pickett, 2011). Although income inequality is indeed consistently correlated with overall mortality across countries, whether this association is causal has been brought into question by a series of studies showing that in many instances, the association does not consistently hold when controlling for potential confounders (Mellor & Miyo, 2001). There is disagreement, however, on the right choice of confounders and methodological approaches, as this often determines the direction and strength of the association (Glymour, 2008; Kawachi & Blane, 2001; Mellor & Miyo, 2001; Zimmerman, 2008).

A noticeable exception is the association between income inequality and infant mortality. As suggested by Regidor et al. (2012) commentary in this issue of *Social Science & Medicine*, analyses based on data for the last decades of the 1970's and 1980's show a consistent association of income inequality and mortality, presumably as a result of welfare policies that promote income

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Fixed Effects – Inequality and Mortality

- Income inequality related to infant mortality
 - Strong ecological association income inequality with infant mortality across countries - but is it causal?
- Fixed effects controls variation across countries
 - Approach relies on changes in inequality within countries over time – 34 OECD countries over 38 years, Gini and IMR.
- Gini changes not associated with IMR changes
 - Possible that social policies reducing IMR cluster in relatively egalitarian countries, but their effects are not via income.

Avendano

Correlation: Inequality and infant mortality, 1963-2008

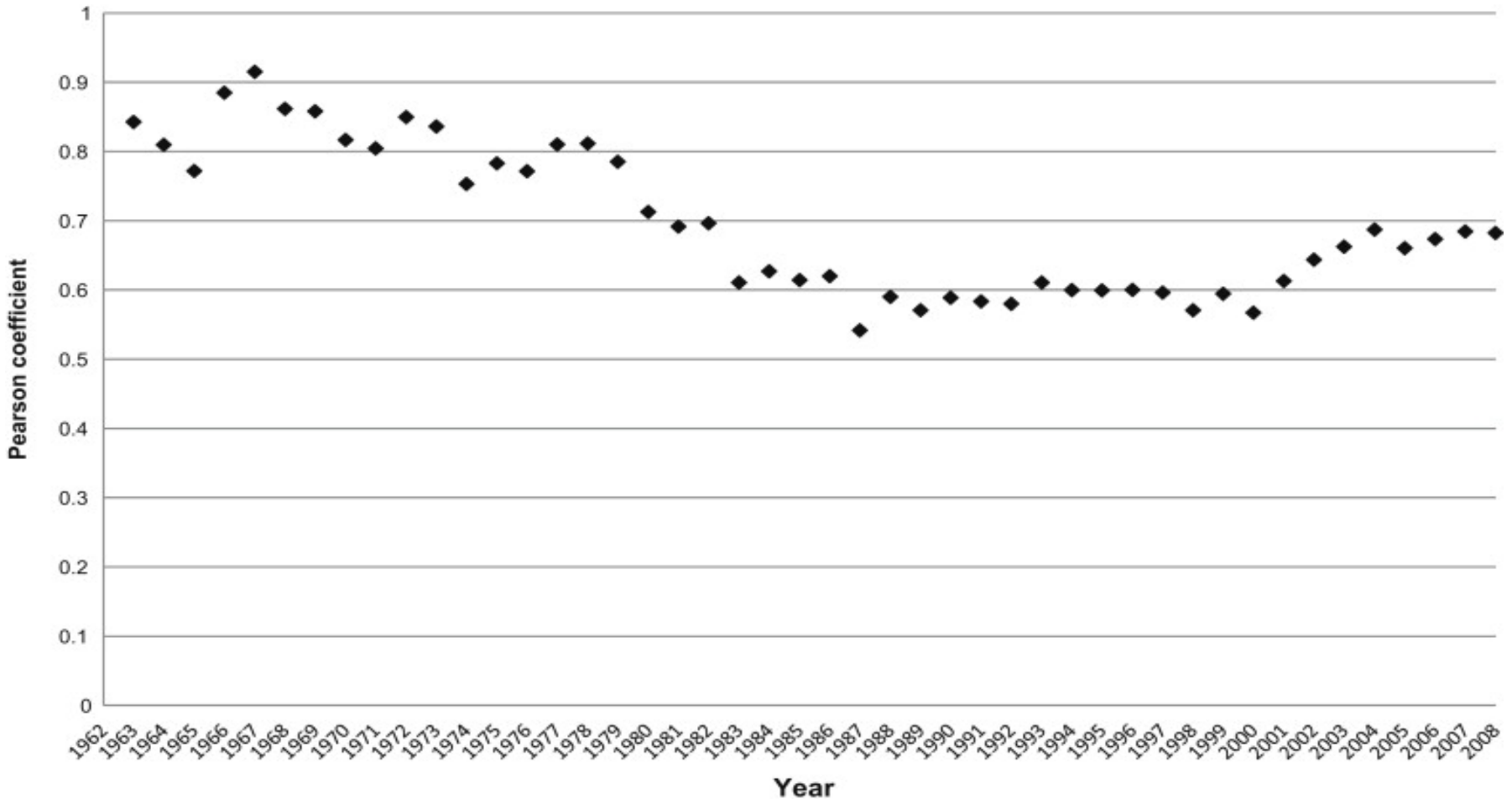


Fig. 2. Pearson correlation between household income inequality (Gini) and infant mortality rate for each year in the period 1963–2008 in 34 OECD countries.

Avendano

Year-to-year correlation: Income inequality and infant mortality, 1960-2009

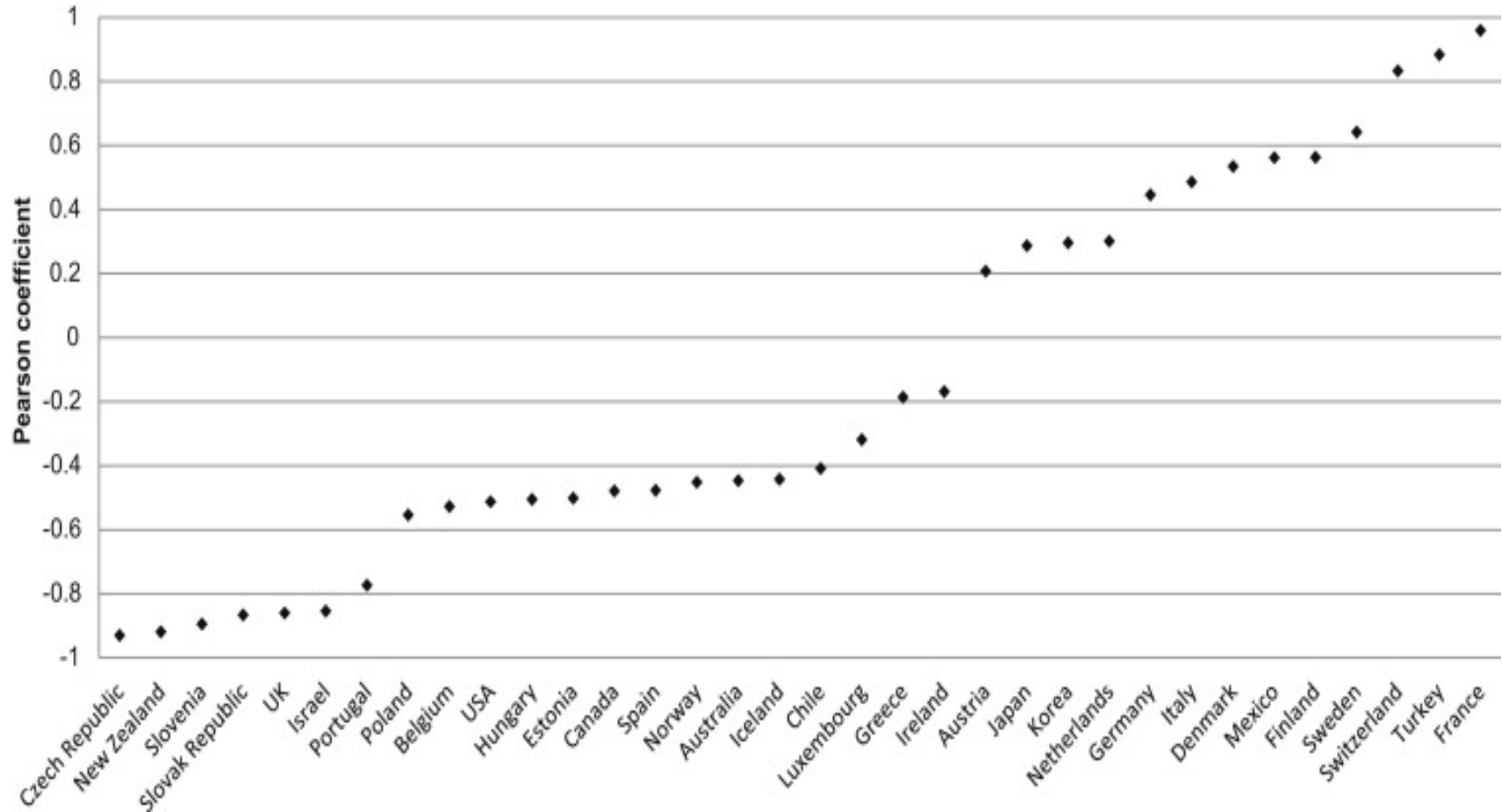


Fig. 3. Within-country year-to-year Pearson correlation between household income inequality (Gini) and infant mortality rates in 34 OECD countries for the period 1960–2008.

Strully et al.



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Effects of Prenatal Poverty on Infant Health: State Earned Income Tax Credits and Birth Weight

Kate W. Strully,^a David H. Rehkopf,^b and Ziming Xuan^c

Abstract

This study estimates the effects of prenatal poverty on birth weight using changes in state Earned Income Tax Credits (EITC) as a natural experiment. We seek to answer two questions about poverty and child wellbeing. First, are there associations between prenatal poverty and lower birth weights even after factoring out unmeasured potential confounders? Because birth weight predicts a range of outcomes across the life course, lower birth weights that result from poverty may have lasting consequences for children's life chances. Second, how have recent expansions of a work-based welfare program (i.e., the EITC) affected maternal and infant health? In recent decades, U.S. poverty relief has become increasingly tied to earnings and labor markets, but the consequences for children's wellbeing remain controversial. We find that state EITCs increase birth weights and reduce maternal smoking. However, results related to AFDC/TANF and varying EITC effects across maternal ages raise cautionary messages.

Keywords

infant health, poverty, Earned Income Tax Credit

In life course models of stratification, early-life environment is crucially important. Exposure to poverty and negative environments during critical stages of early life can negatively affect children's future developmental trajectories (e.g., cognitive and physical development), which may have lasting negative effects on educational attainment and adult earnings (Duncan and Brooks-Gunn 1997; Wagmiller et al. 2006). According to recent research, prenatal poverty and birth weight are important variables in life course processes of stratification (Conley, Strully, and Bennett 2003; Cramer 1995). As a measure of health at the start

of life, birth weight is a general indicator of a baby's in-utero environment and development, and maternal poverty during the prenatal period is a robust predictor of lower birth weights (Bennett 1997). Low birth weight can in turn predict a range of negative

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Natural Experiment – Welfare and Health

- Do work/income incentives affect infant health?
 - It is hypothesised that work/income schemes will raise incomes and employment for unmarried mothers with high school or less, and in turn improve infant health.
- Using a “natural experiment” design
 - Variation between US states in introduction of income/work incentives to estimate effects prenatal poverty/infant health.
- Labour market, incomes, birth weight, smoking
 - Schemes increased employment 19%, incomes 32%, increased infant birth weight, slightly reduced smoking

Model of Pathways

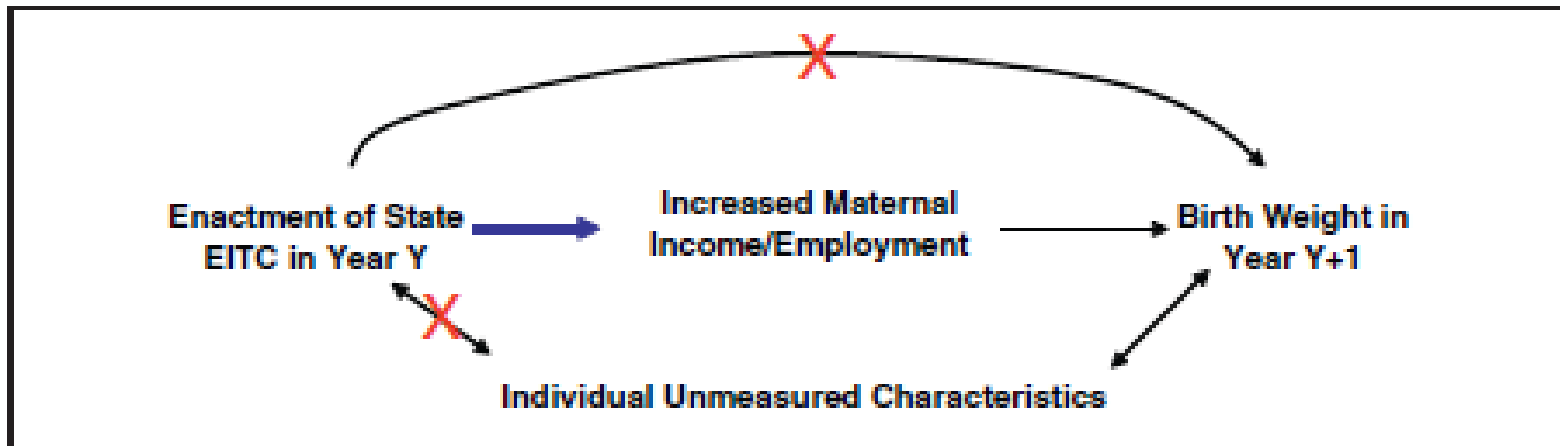


Figure 2. State EITCs as a Natural Experiment

Two Exemplar Papers

1. Matching/Propensity scores
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Concluding Thoughts

- Can insistence on causal purity go too far?
 - UK Cabinet Office advice on RCTs?
 - Smoking and lung cancer; climate change
 - Status of predictive and descriptive work?
- Evidence-based movement in policy
 - This requires credible, usable evidence
- Enhance role of the social sciences
 - Need conceptual and methodological credibility
 - Social sciences limited (see CoRES, MBIE, NSC)

National Science Foundation, 2012

