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Wage inequality, the health system, and infant mortality in wealthy industrialized countries, 1970–1996

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Abstract

This pooled, cross-sectional, time-series study assesses the impact of health system variables on the relationship between wage inequality and infant mortality in 19 OECD countries over the period 1970–1996. Data are derived from the OECD, World Value Surveys, Luxembourg Income Study, and political economy databases. Analyses include Pearson correlation and fixed-effects multivariate regression. In year-specific and time-series analyses, the Theil measure of wage inequality (based on industrial sector wages) is positively and statistically significantly associated with infant mortality rates—even while controlling for GDP per capita. Health system variables—in particular the method of healthcare financing and the supply of physicians—significantly attenuated the effect of wage inequality on infant mortality. In fixed effects multivariate regression models controlling for GDP per capita and wage inequality, variables generally associated with better health include income per capita, the method of healthcare financing, and physicians per 1000 population. Alcohol consumption, the proportion of the population in unions, and government expenditures on health were associated with poorer health outcomes. Ambiguous effects were seen for the consumer price index, unemployment rates, the openness of the economy, and voting rates. This study provides international evidence for the impact of wage inequalities on infant mortality. Results suggest that improving aspects of the healthcare system may be one way to partially compensate for the negative effects of social inequalities on population health.

Keywords: Income inequality; Social epidemiology; Health determinants

Introduction

During the past decade there has been an on-going debate over the role of social inequalities as a determinant of population health. The debate continues, with much emphasis placed on what has become known as the "relative income hypothesis"—the proposition that the distribution of income in society is an important determinant of that population's health, independent of other social inequalities.

A recent review of the literature (Judge & Paterson, 2002) shows that definitive conclusions about the relationship between income inequality and health (at least in terms of cross-country comparisons) have been difficult to reach. Previous international studies have been limited in terms of the quality and comparability of income inequality data used, the time period for which the study was conducted, small sample size, and a lack of attention to health system variables.

This study seeks to test the relationship between another aspect of social inequality, i.e., inequality in wages and infant mortality rates (IMR) using data from 19 Organization for Economic Cooperation and Development (OECD) countries over the period 1970–1996. This study is meant to add to previous research in this area by using a longitudinal design, improving study

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power (through a larger sample size), testing an alternate measure of social inequality, and employing a more complete model of health determinants.

Social inequality and health

Several international comparisons have shown that social inequalities are associated with a number of health outcomes, at different points in time, and using a cross-section of a variety of countries (Wilkinson, 1992). By and large, cross-country studies demonstrating a relationship between social inequalities and health have the following characteristics: they use Gini coefficient measures of income inequality based on household surveys to measure social inequality, they generally examine a limited time period, and they often combine developing countries with wealthy industrialized ones (Judge & Paterson, 2002).

Results have varied depending on the study design, data used, years examined and countries included in the sample. One of the few consistent results is that among health outcomes, the infant mortality rate (deaths of children under 1 year expressed per 1000 live births in that year) has been found to be associated with social inequalities, especially in wealthy countries (Hales, Howden-Chapman, Salmond, Woodward, & Mackenbach, 2000; Judge, Mulligan, & Benzeval, 1998; Lynch et al., 2001). Although there is an on-going debate about the magnitude and significance of this association (see Deaton, 2001; Gravelle, Wildman, & Sutton, 2001; Judge & Paterson, 2002; Marmot & Wilkinson, 2001; Mellor & Milyo, 2001) researchers have postulated several pathways through which social inequalities might have an impact on health.

How are social inequalities and health related?

Several possible explanations have been offered for how social inequalities, such as the distribution of income, might affect individual and population health. One hypothesis is that social inequalities have a psychosocial impact on individuals that results in poorer health outcomes. The psychosocial explanation posits that ‘‘cognitive processes of social comparison’’ work to increase individuals’ levels of stress that concomitantly lead to poorer health status. Chronic stress, poor social support, and lack of control over one’s work are related to poor health and have a greater effect on those at the bottom of social hierarchies (Wilkinson, 1996, 1998; Marmot, 1999). This hypothesis is supported by data from the Whitehall studies of British civil servants that show a continuous social gradient in health—i.e., at each level in a social (or economic) hierarchy, individuals at any given level tend to exhibit poorer health than individuals in the next highest level of the hierarchy (Marmot et al., 1991).

The macro-level correlate of the psychosocial hypothesis is that social inequalities can disrupt macro-level social relations and that this disruption is unfavorable to population health. Social inequalities, such as the maldistribution of income, are thought to precipitate changes in society by creating a climate of mistrust, reduced cooperation, decreased social bonds, and reduced membership in voluntary organizations. There is evidence that such inequalities are associated with unfavorable social conditions, such as violent crime (see Chiu & Madden, 1998; Sampson, Raudenbbush, & Earls, 1997; Walberg, 1998). Several authors have variously termed this concept ‘‘social cohesion’’, ‘‘social trust’’ and ‘‘social capital’’. In spite of difficulties with the definitions and measurement of these concepts (see Woolcock, 1998; Lynch, Due, Muntaner, & Davey Smith, 2000; Macinko & Starfield, 2001), all suggest a social mechanism that is related to psychosocial stresses associated with the status and power differentials between groups. This explanation has been called ‘‘Neo-Durkheimian’’ because of its emphasis on the role of social relations and networks in determining both individual and population-level health (Muntaner & Lynch, 1999).

A third hypothesis, often used in refutation of the first two, posits that social inequality implies the existence of groups of individuals who suffer from poor living conditions, and that these ‘‘neo-material’’ factors lead to poor health. A ‘‘neo-material’’ explanation incorporates the individual-level health hypothesis but goes further claiming that, ‘‘health inequalities result from the differential accumulation of exposures and experiences that have their sources in the material world’’ (Lynch, Smith, Kaplan, & House, 2000). The effect on health is thought to be the result of harmful exposures, lack of resources, and systematic under-investment in human, physical, health and social infrastructure. Thus, this explanation incorporates both individual and contextual-level factors, but emphasizes that accumulated exposures resulting from poorer physical conditions, reduced quality of education, and fewer social services adversely affect the life chances and health outcomes of those at the lowest end of the social spectrum (Lynch et al., 2001).

There has been considerable criticism of the hypothesis that inequalities lead to poorer health. The critiques have focused on three main areas: measurement (especially of inequality), study design (especially regarding limited sample size), and interpretation (particularly regarding the curvilinear relationship between income and health).

One of the most comprehensive studies on income inequality and health to date is that by Mellor and Milyo (2001). This study examined the country-level relationship between income inequality (measured by the Gini coefficient and income ratios of the bottom 20th percentile to the top 20th percentile) and aggregate health outcomes (life expectancy at birth, infant mortality) across 30 countries over a four-decade span. It also examined 48 US states over five decades, using the Gini coefficient to measure income inequality and all-cause mortality, IMR, low-weight births, homicides, suicides, and six different specific causes of death as dependent variables.

At the international and state levels, the authors found that, contrary to previous literature, there was no consistent relationship between income inequality and health outcomes, including infant mortality. The analysis controlled for demographic variables such as median income, educational levels, and year-specific effects. The state-level analyses also controlled for percentage of population that is urban, black, and college educated. In the 54 regression equations reported, income inequality was significantly associated with poorer aggregate health outcomes in only 11 instances but was significantly associated with *better* health outcomes in 15. These results confirmed, in a more comprehensive way, a number of negative and contradictory findings reported in other works (see Lynch et al., 2001; Gravelle, 1999).

However, as Kawachi and Blakely (2001) point out, the Mellor and Milyo (2001) study raises almost as many questions as it attempts to answer. First, the household income data upon which the Gini data were based were not derived from a standardized source, such as the Luxembourg Income Study (LIS), but from many sources as compiled by the World Bank (Deininger & Squire, 1996). Therefore, there is no guarantee that the Gini data were comparable. Second, many of the regressions were performed with a mixed sample of poor and rich countries. Earlier studies (Rodgers, 1979; Waldmann, 1992) showed that the relationship between income inequality and health outcomes differs based on a country's level of socioeconomic development. Third, the analyses restricted to wealthy countries may not have detected significant predictors because they were limited by small ($n = 48$) sample size. Based on these analyses, it appears that the debate about the role of social inequalities on health is far from settled.

Conceptual framework

The conceptual framework for this study is operationalized in the following way. First, the most distal determinants of health in the model include national policies and culture. In this framework, national policies refer to policies outside the health sector that affect overall macroeconomics, international relations, and income redistribution. Culture refers to the broad set of beliefs and practices specific to one's national, subnational, religious, and/or ethnic identity that might contribute to different preferences for types of political and legal institutions, social participation, institutional development, lifestyle choices, and overall priorities. Both national policies and culture are conceptualized as antecedents to more proximal determinants of health.

More proximal health determinants include factors thought to influence health at both the macro- and the micro-levels. Of these, the most macro-level health determinants include the environment and demographics. Another macro-level factor exerting an important influence on health status is the national socioeconomic environment, the most common measure of which is Gross Domestic Product (GDP) per capita. GDP has consistently been found to be positively associated with better health outcomes (World Bank, 1993). Other variables used in this analysis include the openness of the economy in terms of international trade, the distribution of income by population shares, as measured by the Gini coefficient, and the distribution of wages among industrial sector wage earners, as measured by the Theil coefficient.

In this model, the health system serves as an interface between individuals and the larger political system in which they live. Health care is produced by system inputs (physicians, medicines, facilities) that interact with the population through various processes (medical consultations, surgeries, deliveries) and result in health outcomes (Donabedian, 1973).

Individual resources can be social, economic, or biological. Individual resources included in this framework include measures of social cohesion, such as the propensity of individuals to join voluntary organizations. Several of these variables have been linked to improved health status, at least at the aggregate level (Blakely, Kennedy, & Kawachi, 2001; Kawachi, Kennedy, Lochner, & Stith, 1997).

Psychosocial characteristics include interpersonal trust, one's sense of control, and overall satisfaction with life. Each of these variables has been found to be associated with individual health in previous studies (Berkman & Kawachi, 2000; Marmot & Wilkinson, 1999; Bosma, Schrijvers, & Mackenbach, 1999).

Economic resources include income, and the consumer price index—a measure of the relative price of a common basket of basic goods and services. Other individual resources include one's genetic makeup, although there are no international measures available to compare health risks or resiliencies conferred by heredity.

Behavioral factors include lifestyle choices that make up an increasingly significant percentage of health risks, particularly in industrialized countries (Murray & Lopez, 1997). Two of the most important factors are drinking and smoking, both of which have been linked with premature mortality (Dawson, 2000; Enstrom &

Heath, 1999; World Health Organization, 1997). Other important behaviors include participation in politics, which in this framework is measured by voting rates, a political protest scale, and the percentage of the population that is unionized. Various measures of political participation have been associated with income inequalities and health at the aggregate level (Blakely, Kennedy, & Kawachi, 2001; Muntaner et al., 2002).

Methods

This study is limited to wealthy members of the OECD. Although there are currently 30 member countries in the OECD, not all are included in the study. The World Bank has categorized the Czech Republic, Hungary, Korea, Mexico, Poland, Slovakia, and Turkey as "middle income" countries (World Bank, 1993). Since there is some evidence that health determinants may vary by level of socioeconomic development (Omran, 1971), these countries were excluded from the analyses. Other studies (Lynch et al., 2001; Wilkinson, 1992) have similarly excluded these countries. Iceland, Ireland, and New Zealand were not included because of missing explanatory variables. Switzerland was not included in the study due to both missing explanatory values and due to extreme outlying Theil values that were between 4 and 10 times higher than any other country in the sample. Because there is no reason to believe that Switzerland is the most unequal of OECD countries in terms of wage disparities, it is likely that these values were calculated in error.

Health outcomes, health system variables and macroeconomic data for this study are from the OECD *Health Data 2001* database (OECD, 2001). All economic variables (unless otherwise specified) are expressed in constant inflation-adjusted 1985 US dollars. Income per capita is additionally adjusted for purchasing power parity. Because of evidence of non-linearity, an income-squared term has also been included in multivariate models. Income and wage inequality measures come from the LIS and the University of Texas Inequality Project, respectively.

Missing data were adjusted for in several ways. First, only independent variables that appeared to be missing at random were imputed. Based on this criterion, less than 10 percent of all data used in the analysis were imputed. The vast majority of these imputed data represent data missing for 1 or 2 years within a 26-year time-series. Because the statistical analysis software uses listwise deletion (i.e., the entire unit of analysis will be dropped from the regression if any one data point is missing), failure to use even this relatively modest amount of imputed data could result in further biases due to artificial reductions in sample size.

Two techniques were utilized for imputing missing values. For those values that tended to increase over time, grand mean or regression imputation could introduce values that were too high if the missing data occurred early in the time-series, or too low if the missing data appeared late in the time-series. For this reason, missing values for number of physicians per 1000 population were imputed by using the midpoint between existing values in years immediately proceeding and following the missing value. For values that did not show any clear yearly pattern, but still increased over time, the within-country mean for each decade was used. Because of the lack of adequate predictor variables that were not included in the final model, regression imputation techniques were not utilized.

Prior to imputation, a dummy variable was created for each variable with missing values. Each of these dummy variables represents the pattern of missing values for imputed data and was included in preliminary regression analyses (Little & Rubin, 1987). In fixed-effects multiple regression analyses, these missing dummy variables were not found to be statistically significant.

Inequality measures

The unique inequality measure used in this study is the Theil Index derived from industrial sector wages, via the OECD Structural Analysis (STAN) database as calculated and complied by the University of Texas Inequality Project (2000). In this study, the Theil Index of wage inequalities is compared with the Gini coefficient of household income inequalities derived from the LIS. Both are considered measures of social inequality.

According to Conceição and Ferreira (2000),

> The Theil Index provides a measure of the discrepancies between the distribution of income and the distribution of population between groups. …The Theil index compares the income and population distribution structures by summing, across groups, the weighted logarithm of the ratio between each group's income and population shares. [If]…this ratio is one for some group, then [that]…group's contribution to inequality is zero. When all groups have a share of income equal to their population share, the overall Theil measure is zero. As an added benefit, the Theil index is sensitive to transfers of income from rich to poor. This sensitivity increases with the…[size of] the difference [in income] between rich and poor. (p. 13)

The LIS Gini is the most commonly used indicator of income inequality, and its inclusion permits comparison with other cross-national studies. However, there are several limitations to using the LIS Gini measures. First, reliable data from the LIS are available for only a few countries and for only 3 or 4 years. The resulting small sample size greatly limits the power of any analyses based on these data. Second, the Gini is often highly correlated with other economic measures, which could introduce multicollinearity into regression analyses. For example, in this study LIS Gini measures were highly correlated with GDP per capita (ρ ranged from 0.51 to 0.69; $p<0.01$ for each year). Third, there has been criticism of the LIS Gini measure's ability to detect changes in inequality over time (Wade, 2001).

The Theil measure used in this analysis has several properties that make it an attractive alternate to the LIS Gini. First, the data set used for the construction of the Theil Index is derived from industrial sector wages. These data are thought to be more reliable than the household surveys upon which the LIS Gini is based because industry is likely to keep better records than do most households (Galbraith, Conceição, & Kum, 2000). Second, the Theil data are available in long time-series for multiple countries, thus facilitating longitudinal analyses. Third, the Theil measure was not highly correlated with important covariates such as GDP per capita (ρ ranged from 0.25 to 0.41; $p>0.05$ for each year). Finally, because the Theil is based on wages among those who are employed (thus excluding those at both extremes of the income distribution), it may be less sensitive to the type of statistical artifact suggested by Gravelle (1999).

Health system measures

The second measure is related to the financing of the health care system. This indicator measures whether or not a country's health care system is primarily funded by taxes as opposed to social security or private insurance. Previous studies have postulated that tax-based health financing systems are on the whole more effective in reducing infant mortality than those financed primarily through social insurance or private means (Elola, Daponte, & Navarro, 1995). Other health system covariates include number of physicians per 1000 population, and public expenditures on health (in inflation-adjusted US dollars).

Health outcomes

The impact of health determinants can be expected to differ depending on the etiology of different health outcomes. However, the literature demonstrating a relationship between income inequality and health at the cross-country level has most consistently shown an association with IMR (the number of deaths of infants under 1 year of age per 1000 live births during the same year).

Social and political measures

Aggregated individual variables for the years 1986, 1990–1991, and 1995–1996 were derived from three different waves of the World Values Survey (WVS). The WVS consists of individual-level responses to a variety of standardized questions and response categories and has been administered in over 40 countries. Individual responses were weighed using the WVS variable "weight" in order to derive valid, nationally representative, and cross-country comparable estimates. Each wave was analyzed separately and the nationally representative proportions, means, and standard errors for each variable for each wave were then extracted for analysis with the other data sets. The total sample size for the subset of OECD countries analyzed was 20,149 for the 1986 wave; 29,136 for the 1990–1991 wave; and 10,252 for the 1995–1996 wave.

WVS variables included "interpersonal trust" measured by the weighted proportion in each country answering "yes" to the question, "Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people" (WVS question V27). The variable, "belonging to organizations" consisted of responses to a series of questions asking if an individual was a member of a variety of social, political, and religious voluntary organizations (WVS questions V28–V36). Only those individuals who responded they were "active members" were counted as a member. Responses were summed and divided by country sample size to gain a national estimate of the average number of organizational memberships per capita.

The variable, "political protest" was generated by summing individual responses to whether or not an individual would participate in political activities, including signing a petition, striking, boycotting a product or company, attending a demonstration, or occupying a building (WVS questions V118–V121). Responses were summed and national population averages calculated.

The variable, "control over life" was measured by the weighted proportion of individuals in each country answering how much freedom of choice they felt they had over how their life turned out (WVS question V66). Responses on a 10 point Likert scale were recoded to either no control (responses 1–5) or sense of control (responses 6–10) and national proportions calculated for each category. The variable, "life satisfaction" (V65) consisted of the weighted proportion of individuals responding to the question, "all things considered, how satisfied are you with your life as a whole these days?" Responses on a 10 point Likert scale were recoded to either not satisfied (responses 1–5) or satisfied (responses 6–10) and national proportions calculated for each category.

The variable, "good self-rated health" represents the weighted proportion of the population responding that their health status was either "good" or "very good".

Analyses

This study uses two main statistical techniques: Pearson correlation and fixed-effects multivariate regression. Pearson correlation was used with the Gini and WVS data because too few time periods were available to perform more elaborate analyses. Gini and WVS data were available only for the following 15 countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, the United Kingdom (UK) and the United States. Note that the 1996 wave of the WVS contained only 10 countries (Australia, Finland, Germany, Japan, Norway, Spain, Sweden, United Kingdom, United States). Changes in sample size are noted in results tables.

Fixed-effects multivariate regression analyses were carried out with the following 19 countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom, and the United States. Political variables (union membership and voter turnout) were available only for the subset of 19 countries mentioned above (excluding Greece, Luxembourg, Portugal, and Spain), so models testing these pathways have a limited sample size. All changes in sample size and composition are indicated in the text and in results tables. Moreover, all calculations of F-tests comparing nested models were performed using models of identical sample size and composition.

Multivariate regression analysis uses two-way fixed-effects (FE) regression. This technique accounts for correlation among error terms due to the presence of repeated measures on the same unit (country) and period- (year-) specific effects. Ordinary Least Squares (OLS) regression will not yield proper estimates on data containing repeat measures (Fisher & van Belle, 1993). The FE model uses a differencing estimator in order to remove the systematic variance in the error term. Including dummy variables for each year controlled for period effects. OLS regression is then used on the transformed model (Hsiao, 1986). This estimation technique yields results similar to the Least Squared Dummy Variable (LSDV) approach described by Sayrs (1989). The main alternative, a random effects (or random intercept) model relies on the assumption that regressors and error terms are uncorrelated. Application of the Hausman (χ^2) test revealed that this assumption was not valid for the data modeled in this study.

One advantage of the FE model is that it can control for time-invariant heterogeneity between countries (Hsiao, 1986). Examples of factors captured in the FE model include relatively stable aspects of national culture and historical patterns of social and economic relationships between groups that shape social institutions and policy systems. FE could also include fundamental value systems that influence citizens' outlook on life, their preferences for income redistribution, perceptions of health and illness, and factors shaping health-seeking behaviors.

The main disadvantage of the fixed-effects approach is that the conclusions reached are conditional on the current data. That is, results cannot be generalized to other countries not already included in the analysis (Hsiao, 1986). Because there are few wealthy OECD countries that are not already included in the analysis, this is not a particularly burdensome limitation.

Results

Table 1 presents descriptive statistics for the main outcome variable and the independent variables used in multivariate analyses. The table shows a decline in IMR from a mean of 16.6/1000 in the 1970s to 6.2/1000 in the 1990s. This decline was statistically significant for each decade.

The Theil index showed a slight increase from the 1970s to the 1980s, and a larger increase from the 1980s to the 1990s (higher Theil values mean higher levels of wage inequality). The change from the 1980s to the 1990s, and from the 1970s to the 1990s is statistically significant. Other economic variables (GDP, income, public expenditures, unemployment, open economy) showed statistically significant increases over time. For example, inflation-adjusted mean GDP increased by approximately 400 percent over the 26-year period. The Consumer Price Index decreased significantly over time.

In terms of political and social variables, mean union membership showed no significant change over time, but the proportion of the population voting in national elections declined significantly, but only when comparing levels in the 1970s to that of the 1990s. In terms of health system variables, the percentage of countries with tax-based health financing increased significantly from 1970 to 1980, but not from 1980 to 1990. Public expenditures on health doubled from 1970 to 1980 and doubled again from 1980 to 1990 levels. The number of doctors per 1000 population also increased over time. Both alcohol and tobacco consumption showed statistically significant decreases over time, although the change was significant for alcohol consumption only when comparing 1990 levels with previous decades.

Table 2 shows Pearson correlation coefficients for IMR and economic, political, social, psychological, and health variables. It is important to emphasize that these

Table 1
Descriptive statistics for IMR and independent variables, by decade

Variable	1970–1979 Mean	1970–1979 S.D.	1980–1989 Mean	1980–1989 S.D.	1990–1997 Mean	1990–1997 S.D.
IMR (deaths/1000 births)	16.63	7.65	9.66*	3.02	6.20**	1.51
Theil	0.0137	0.0005	0.0149	0.0005	0.0231**	0.003
GDP per capita	5592.67	2939.89	12126.7*	5031.06	22896.8**	7305.20
Public expenditures (% GDP)	20.47	3.95	21.02	6.02	23.61**	5.82
Income (ppp)	1763.99	5235.11	2943.80*	8957.98	4409.58**	13206.9
Unemployment (%)	1.48	0.94	3.22*	1.60	3.74**	1.77
Open economy (% GDP = trade)	60.01	34.57	63.27	42.90	73.46**	28.19
Consumer price index	8.48	3.97	6.17*	3.98	3.37**	1.86
Population in unions (%)	19.08	8.57	20.99	11.20	17.83	14.28
Voter turnout (% population)	0.84	0.10	0.82	0.11	0.79**	0.13
Healthcare finance system	0.50	0.50	0.63*	0.48	0.67**	0.47
Health expenditures ($/capita)	306.1		743.4*		1501.8**	
Physicians (per 1000 pop)	1.54	0.40	2.22*	0.64	2.83**	0.86
Alcohol use (liters/capita)	12.02	4.17	11.39	3.39	10.38**	2.67
Tobacco use (grams/capita)	2657.19	575.25	2419.79*	533.77	1982.14**	406.25

*Statistically significant difference compared to 1970s average ($p<0.05$).
**Statistically significant difference compared to 1980s average ($p<0.05$).

estimates are based on a sample of only 16 data points (15 for comparisons with Gini coefficients).

In 1986 and in 1994/1996, both Gini and Theil are statistically significantly associated with infant mortality. The magnitude of the association is strongest with Gini. GDP per capita is strongly negatively associated with IMR at every time period, and the percentage of people who said that they generally trust other people was negatively associated with IMR in 1986 and 1991, and was nearly statistically significant in 1994/1996 ($p = 0.066$). In terms of health determinants, public expenditures on health were negatively associated with IMR in every time period, and tobacco use was positively associated with infant mortality in 1994/1996 only.

The remaining sets of statistically significant relationships are to be found with inequality measures and other explanatory variables. The Gini coefficient was negatively associated with GDP per capita in 1991 and 1994/1996, and with total public expenditures in all three periods. The Gini coefficient was negatively associated with the extent to which economies are open to international trade, and with higher union membership. Gini coefficients were not associated with psychological or health system variables except for a strong negative association with public expenditures on health at each time period.

The Theil index shows a somewhat different pattern. Theil measures of wage inequality were not associated with GDP per capita, although they were associated with public expenditures per capita in 1991 and 1994/1996. The Theil measure showed no association with other economic variables except for a negative association with the openness of the economy in 1994/1996. The Theil was negatively associated with associational membership and with the percentage of the population unionized at each time period, and with the political protest scale for 1986 only. Theil measures were strongly negatively associated with psychological variables, including trust (every time period), sense of control over life (1986 only) and satisfaction with one's life (1986 and 1991).

Theil measures were associated with several health variables; they were negatively associated with the proportion of respondents in each country who reported self-rated good health in 1986, negatively associated with public expenditures on health in 1986, and positively associated with tobacco use in 1994/1996.

Table 3 shows results of multivariate analyses. Model 1 represents the restricted model containing only the Theil index and GDP per capita, against which all other models are tested. Model 2 contains variables pertaining to the health system. Physicians and healthcare financing were statistically significant and negatively associated with infant mortality. Public expenditure on health was positively associated with IMR, but of very low magnitude. Alcohol consumption was associated with higher IMR, although tobacco consumption was not. In the presence of the health system variables, the magnitude of the Theil Index coefficient is reduced. An F-test shows that model 2 (health system pathways) improves upon model 1.

Model 3 shows the association of Theil and IMR in the presence of economic variables. GDP per capita and

Table 2
Pearson correlations for IMR, income inequality, and health determinants

	1986			1991			1994/1996		
	IMR	Gini	Theil	IMR	Gini	Theil	IMR	Gini	Theil
	$n = 16$	$n = 15$	$n = 16$	$n = 16$	$n = 15$	$n = 16$	$n = 16$	$n = 15$	$n = 16$
Income inequality									
Gini	0.57*	1	0.50*	0.31	1	0.54*	0.81**	1	0.71**
Theil	0.45*	0.50*	1	0.36	0.54*	1	0.45*	0.71**	1
Economic									
GDP per capita	−0.69**	−0.38	−0.41	−0.56*	−0.66**	−0.25	−0.59**	−0.51*	−0.35
Public expenditures	−0.39	−0.69**	−0.39	−0.22	−0.78**	−0.38	−0.41	−0.67**	−0.49*
Income per capita (ppp)	−0.11	−0.24	−10.05	−0.29	−0.25	0.14	−0.16	−0.32	−0.01
Unemployment	0.26	0.66**	0.29	-0.08	0.48*	−0.02	−0.06	−0.08	−0.05
Openness of economy	−0.08	−0.51*	−0.16	0.30	−0.48*	0.01	−0.34	−0.64**	−0.47*
Consumer price index	−0.11	0.22	−0.15	−0.12	0.11	0.09	0.07	0.12	0.12
Political and social									
% Unionized	−10.32	−0.68**	−0.55*	−0.16	−0.69**	−0.55*	−0.58*	−0.61**	−0.50*
% Pop voting	0.05	−0.55*	−0.26	−0.07	−0.44	−0.20	−0.32	−0.41	−0.27
							$n = 9$	$n = 9$	$n = 9$
Belong to organizations	−0.29	−0.25	−0.77**	−0.21	-0.16	−0.69**	−0.02	−0.28	−0.58*
Political protest scale	−0.30	−0.25	−0.77**	−0.11	−0.18	−0.32	−0.14	−0.14	−0.08
Psychological									
							$n = 9$	$n = 9$	$n = 9$
Trust others	−0.62**	−0.41	−0.71**	−0.53*	−0.44	−0.54*	−0.40	−0.44	−0.58*
Control over life	−0.08	−0.07	−0.48*	0.03	−0.07	−0.42	0.13	−0.02	−0.28
Satisfaction	−0.27	−0.14	−0.69**	−0.12	−0.31	−0.56*	0.11	−0.20	−0.47
Health									
							$n = 9$	$n = 9$	$n = 9$
Good self-rated health	−0.36	−0.13	−0.57*	−0.15	−0.07	−0.46	0.03	−0.07	−0.34
							$n = 15$	$n = 15$	$n = 15$
Tax-based health financing	0.17	−0.08	−0.05	0.17	−0.07	0.02	0.01	−0.12	0.07
Public expenditures, health	−0.69**	−0.61**	−0.63**	−0.54*	−0.84**	−0.40	−0.60**	−0.54*	−0.42
Physicians per 1000	0.27	−0.11	−0.10	0.30	−0.29	−0.02	0.18	0.05	0.13
Alcohol use (liters/capita)	0.19	0.29	0.37	0.41	0.10	0.28	0.22	0.05	0.19
Tobacco use (grams/capita)	0.24	−0.01	0.13	−0.01	0.22	0.41	0.50*	0.46	0.53*

$^*p \leqslant 0.05$, $^{**}p \leqslant 0.01$.

income per capita (squared) are both negatively associated with IMR, while the openness of the economy is associated with higher IMR. The Theil Index remains significant and its magnitude is slightly increased. The F-test of nested models is statistically significant ($p < 0.001$), indicating that model 3 is superior to model 1.

Model 4 tests political pathways. Among this reduced sample of 15 countries (Greece, Luxembourg, Portugal, and Spain are excluded due to missing values), union membership is positively associated with IMR, while voting is not statistically significant. The magnitude of the Theil coefficient is lower than in model 1, and the F-test indicates that model 4 is superior to model 1 in explaining IMR.

Model 5 combines all covariates from models 2, 3, and 4. Because it includes political variables, this model tests only the reduced sample of 15 countries. Results should therefore be compared with those obtained from model 4. In model 5, GDP per capita, income-squared, tax-based healthcare financing, and the openness of the economy are all negatively associated with IMR. Union membership and alcohol consumption were positively associated with IMR. These results are similar to those obtained in model 4. The Theil coefficient is similar in magnitude to that of model 4 and is statistically significant. An F-test reveals that model 5 is superior to model 1.

Model 6 combines all variables (except political ones) presented in models 1, 2, and 3. It is based on the full

Table 3
Infant mortality and wage inequality—pathways

	Model 1[a]	Model 2[a]	Model 3[a]	Model 4[a]	Model 5[a]	Model 6[a]
	GDP only	Health system	Economic	Political	All pathways	All (except political)
Theil	188.500	120.210	205.751	137.229	136.586	137.078
(p-value)	(0.000)	(0.002)	(0.000)	(0.005)	(0.004)	(0.000)
GDP ($US/cap)	−0.088	−0.038	−0.087	−0.073	−0.060	−0.044
(p-value)	(0.000)	(0.005)	(0.000)	(0.000)	(0.000)	(0.001)
Income ($US/cap)			0.001		0.004	(0.000
(p-value)			(0.001)		(0.001)	(0.034)
Income^2 ($US/cap)			−0.0001		−0.001	−0.0001
(p-value)			(0.000)		(0.002)	(0.000)
Unemployment (%)			0.190		0.052	0.331
(p-value)			(0.129)		(0.649)	(0.005)
Open economy (%)			0.030		−0.067	0.025
(p-value)			(0.006)		(0.000)	(0.013)
Union density (%)				0.014	0.008	
(p-value)				(0.000)	(0.048)	
Voting (%)				0.004	−0.003	
(p-value)				(0.102)	(0.870)	
Public exp, health		0.005			0.002	0.000
(p-value)		(0.000)			(0.081)	(0.000)
Doctors (per 1000)		−0.935			0.000	−1.336
(p-value)		(0.014)			(0.382)	(0.000)
Healthcare finance		−3.106			−3.205	−2.300
(p-value)		(0.000)			(0.001)	(0.000)
Tobacco (per cap)		−0.006			0.000	0.000
(p-value)		(0.546)			(0.150)	(0.151)
Alcohol (per cap)		0.310			0.441	0.285
(p-value)		(0.000)			(0.000)	(0.000)
R^2 (within)	0.820	0.864	0.844	0.858	0.905	0.878
F (vs model 1)[b]	—	20.580	11.905	9.840	14.705	16.922
df	—	5,362	4,363	2,304	11,295	9,358
p-value	—	<0.001	<0.001	<0.01	<0.001	<0.001
N (total)	413	413	413	347	347	413
Total countries	19	19	19	15[c]	15[c]	19
Avg. obs./country	22	22	22	23	23	22

[a] Year dummy variables and intercepts not reported.
[b] All F-tests performed on Model 1, using equivalent sample size.
[c] Does not include Greece, Luxembourg, Spain or Portugal.

sample size of 19 countries. GDP per capita, income per capita (squared), physicians per 1000 population, and the method of healthcare finance are all negatively associated with IMR. Unemployment, public expenditures on health and alcohol consumption are positively associated with IMR. The Theil index was positively associated with IMR, and its magnitude was lower than that of models 1 and 3, but higher than that of model 2. An F-test reveals that model 6 is superior to model 1 in explaining variation in IMR.

Table 4 compares models with 1-, 5-, 10-, and 15-year time lags for both Theil and health financing covariates with a contemporaneous model. All time-lag models are compared to model 1 which contains only GDP per capita. As a point of reference, model 2 includes contemporaneous measures of Theil and GDP.

Model 3 presents 1-year lagged Theil values controlling for GDP per capita. In this model, Theil is significantly associated with IMR, and slightly increased in magnitude. Model 4 presents 5-year lagged Theil values with GDP per capita. The 5-year lagged Theil value is statistically significant and improves over model 1. Model 5 shows a 10-year lagged Theil with GDP per capita. The 10-year lagged Theil is statistically significant but reduced in magnitude (by about one-fourth) from model 2 containing a contemporaneous Theil. The 10-year lagged model 4 also improves over model 1. Model 6 contains a 15-year lagged Theil with GDP. The 15-year lagged Theil is not statistically significant.

Models 7–11 present different combinations of lagged Theil and lagged healthcare financing covariates,

Table 4
Infant mortality rate: time lags[a]

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Theil		188.510 (0.000)					125.250 (0.002)				
Theil (1-year)			193.820 (0.000)					75.500 (0.063)			
Theil (5-year)				65.580 (0.045)					17.410 (0.540)		
Theil (10-year)					50.030 (0.043)					30.040 (0.241)	
Theil (15-year)						−6.350 (0.823)					−11.218 (0.686)
GDP	−0.096 (0.000)	−0.088 (0.000)	−0.910 (0.000)	0.090 (0.000)	−0.067 (0.000)	−0.033 (0.001)	−0.050 (0.000)	−0.041 (0.001)	−0.069 (0.000)	−0.058 (0.000)	−0.031 (0.001)
Health fin.							−4.527 (0.000)				
Health fin. (1-year)								−2.750 (0.010)			
Health fin. (5-year)									−1.823 (0.000)		
Health fin. (10-year)										−0.947 (0.021)	
Health fin. (15-year)											−1.520 (0.004)
R^2 (within)	0.870	0.870	0.870	0.890	0.908	0.910	0.896	0.890	0.902	0.912	0.917
F vs (model 1)[b]	—	18.150	19.750	3.040	3.130	−0.919	44.690	45.620	10.170	4.000	−0.405
(df)	—	1.367	1.351	1.287	1.205	1.117	2.366	2.333	2.273	2.194	2.111
(p-value)	—	<0.001	<0.001	>0.05	>0.05	>0.1	<0.001	<0.001	<0.001	<0.05	>0.1
N	413	413	396	328	239	145	413	374	310	226	137

[a] Year dummy variables and intercepts not reported.
[b] All F-tests performed on Model 1, using equivalent sample size.

controlling for GDP per capita. As a point of comparison, model 7 presents contemporaneous measures of GDP, Theil and healthcare financing. Model 8 presents Theil and healthcare financing covariates each with a 1-year lag. In this model, healthcare finance is negatively associated with IMR, although reduced in magnitude from contemporaneous measures. Theil, however, is not statistically significant. Model 9 presents Theil and healthcare financing covariates each with a 5-year lag. Healthcare financing is negative and significant, although it is reduced in magnitude. The lagged Theil is not significant, although the model is superior to model 1. Model 10 shows 10-year lags. Healthcare financing is further reduced in magnitude, but still negative and significant. Theil is not significant. The F-tests reveal that this model is also superior to model 1. Model 11 shows results using a 15-year lagged Theil and a 15-year lagged healthcare finance covariate. Health finance is further reduced in magnitude and statistically significant, while Theil changes sign and is not significant. This 15-year lagged model does not improve over model 1 ($p > 0.05$).

A test of the robustness of the association between IMR and Theil was performed by re-running an FE model containing Theil, GDP per capita, healthcare finance, and year dummies, but excluding one country at a time (Sayrs, 1989). Earlier analyses suggested that the United States was largely responsible for the observed relationship between income inequality (using the Gini coefficient) and health (Judge & Paterson, 2002; Lynch et al., 2001). However, in this analysis, excluding any one country from the analysis did not alter the basic relationship between IMR and wage inequality. As presented in the results tables, however, different combinations of countries and years did show slightly different patterns in the statistical significance of other covariates.

Different combinations of log-transformed values for all expenditure data were also modeled. Log transformation of public expenditures on health and income per capita rendered these covariates statistically insignificant in multivariate models. These transformations did not change the basic relationship between Theil and IMR.

Further sensitivity tests included performing an omitted variable test on the full models presented in Table 3. None of the models passed this test ($p > 0.05$) suggesting that there may be explanatory variables that we have not included in our models. Although this result alone does not provide sufficient justification for rejecting the conclusions of our analyses, it does point to the need for identification and testing of additional explanatory variables to enrich the conceptual and analytic framework.

Additional sensitivity tests employing statistical models that adjust for heteroskedastic errors and panel level auto-regression. The results of these analyses were generally consistent with the results obtained using the FE models reported above.

Discussion

This study has provided evidence that the Theil measure of wage inequality is associated with IMR at fixed points in time, in bivariate time-series, and in multivariate time-series regressions that controlled for economic, political, and health system variables. Among the pathways tested, health system components—particularly the equity of healthcare financing—significantly reduced the magnitude of the wage inequality measure, suggesting that improving the health system may be one way to offset some of the negative impacts of some social inequalities, at least within the sample of countries studied.

Analysis of time lags revealed that wage inequality exerted both contemporaneous and lagged effects on infant mortality. Healthcare finance also exhibited both contemporaneous and lagged effects on infant mortality. Contemporaneous effects of the Theil index on IMR persisted in the presence of other covariates such as GDP per capita and the method of healthcare financing, but time-lagged Theil effects were diminished in magnitude and no longer significant while controlling for healthcare variables.

Analyses also suggest that although both the Theil and Gini are highly correlated, they may have slightly different relationships to economic, political, and psychosocial pathways. The Gini coefficient was more closely correlated with economic variables, while the Theil measure was more closely associated with political, social and psychological ones. This is perhaps because the Theil is based on the distribution of wages among the working population, whereas the Gini is based on household surveys of income from all sources and would also include those households that were outside of the labor market, including the very poor. Although previous studies (Kawachi & Kennedy, 1997) found there to be little difference in type of income inequality measure used and its relationship to population health, these earlier studies did not consider all of the countries under examination in this work, nor did they utilize alternate data sets such as the STAN database for wage data.

Not all health care measures were always associated with infant mortality. This is to be expected, however, because our outcome measure, the infant mortality rate, is composed of both neonatal and post-neonatal mortality. Primary care is more closely associated with post-neonatal (deaths after the first month) as opposed to neonatal mortality, which is more closely associated with specialty care (Starfield, 1998). Measures of physicians per 1000 population combine both primary care and specialist resources. This may partially explain the discrepancy between significant findings in physician supply between the reduced groups of 15 countries (in Table 3, model 5 physician supply was not a significant predictor of IMR) and the full sample of 19 countries (physician supply was significantly associated with lower IMR in Table 3, models 2 and 6). Nevertheless, the more consistent indicator given the models tested here appears to be the method of healthcare financing. This is consistent with other literature suggesting that tax-based healthcare financing was more effective than other methods in reducing infant mortality (Elola et al., 1995). Although this study could not directly test this hypothesis, research suggesting that income inequality and poverty were associated are higher post-neonatal mortality (Lynch et al., 2001) and rates of low birth weight (Conley & Springer, 2001) suggests that equitable access to basic medical care may be one potential mediating factor in the relationship between social inequalities and health outcomes (Mackenbach, Stronks, & Kunst, 1989).

Limitations

This study has several limitations. First, not all OECD countries or time periods were available. The analytical techniques used (fixed-effect regression) limit the conclusions only to those countries and years that were analyzed. There remains the possibility that using a different selection of countries or years could result in a different conclusion. This limitation is particularly apparent when examining inconsistencies in results obtained in Table 3. In model 5, e.g., the openness of the economy was found to be negatively associated with IMR, while in model 6, just the opposite effect was found. Unfortunately, the fixed-effects technique limits the extent to which we can compare these two models because they are conditional on the data used to estimate them.

Because this is an ecological study, it is also not possible to say which socioeconomic groups within each country suffer higher infant mortality due to social inequality. Although multi-level studies in other populations indicate that it is usually those at the lowest end of the socioeconomic spectrum that suffer most from the adverse effects of income inequality, it is also possible, as Judge and Paterson (2002) point out, that those at the higher end of the socioeconomic ladder may also suffer negative health effects due to high levels of social inequalities.

It would also have been ideal to be able to explore other social, political, and psychosocial pathways in time-series analyses. In single year correlations, infant mortality and wage inequality were both negatively associated with levels of trust, and the Theil measure was negatively associated with life satisfaction, sense of control, organizational membership, and political protest. Time-series analyses would allow for more reliable investigation of the intriguing potential pathways between wage inequality, health outcomes, and the social environment. However, such an analysis is limited by data availability.

A further limitation is that this study does not directly address causation. Although time lags were modeled, they did not unambiguously show that lagged income inequality or health care measures were more powerful predictors of infant mortality than contemporaneous measures of these health determinants. Further complications arise in assessing the direction of causality regarding economic and political pathways. For example, it is not surprising that union membership was negatively associated with the Theil measure of wage inequality, but the question remains as to whether union membership results in less inequality or whether joining unions is simply a reaction to perceptions of increasing inequality in wages among working populations.

There also remain problems with multicollinearity, particularly regarding economic and expenditure data. The net effect of each of these variables is difficult to parse out as each is highly collinear with GDP per capita. For example, richer countries spend more on health, but among wealthy OECD countries increased expenditure have generally not been found to be associated with better health outcomes (Anderson, Hurst, Hussey, & Jee-Hughes, 2000; Anderson & Hussey, 2001), although at least one study did find log health expenditures to be negatively associated with IMR (Conley & Springer, 2001). In bivariate correlations, public expenditures on health are negatively associated with IMR, but in models with GDP per capita, public expenditures on health became positively associated with IMR. The correlation between GDP and public health expenditures in this sample is as high as 0.90 in some years lending support to the idea that they are collinear, and that this may be driving at least part of the discrepancies between the year-specific and time-series analyses.

The Theil Index improves in many ways over the LIS Gini, but it could also be improved upon. For example, a major limitation is that the index as used here is based only on industrial sector data. Incorporating service sector wages could increase the validity of the wage inequality measure.

Although the analyses presented here control for economic resources at both the individual (income) and macro (GDP) levels, we cannot directly address the argument that the additional health effect of relative income (wage dispersion measured by the Theil Index) is not due to a statistical anomaly of the type suggested by Gravelle (1999), Gravelle, Wildman, & Sutton, 2001). The argument is that societies with higher income inequality also have larger numbers of poor people, so it is the level of poverty that really drives the relationship between income inequality and health rather than other processes such as psychosocial pathways (Gravelle, 1999). However, because the inequality measure used here (Theil) is based on inequalities in wages rather than in household incomes, it is logical to assume that in this analysis the size of the artifact would be much reduced, because, by definition, anyone without a job is not included in the income inequality calculation. This may explain why this study found statistically significant associations between Theil and levels of trust, while other studies using the same WVS data, but using the LIS Gini measure did not (Lynch et al., 2001).

A final limitation of this study is that it does not explicitly control for endogeneity. In particular, the Theil measure itself may be an endogenous variable. Although the fact that the time-lagged Theil values also had an impact on the outcome adds weight to our conclusions, this potential bias remains. However, controlling for such endogeneity through instrumental variable or other techniques introduces risks of its own, such as potentially reduced efficiency of error terms that make it more difficult to detect statistical significance (Kennedy, 2001). Future work should be directed at identifying suitable instruments for modeling and testing for this potential endogeneity properly.

Conclusions

There are several potential conclusions suggested by this research. First, an alternative measure of inequality, the Theil index, offers several advantages over the more commonly used LIS Gini coefficient. These include the fact that the Theil is available for many more countries and years than is the Gini; there is evidence that the Theil is based on more reliable data than are most Ginis; and the Theil is highly correlated with the Gini. At the same time, the Theil appears to exhibit other properties that make it particularly suitable for international comparisons such as the finding that it is not highly correlated with GDP per capita or with other commonly used economic measures. The measure's correlation with political and social variables also opens up the possibility of exploring alternate pathways connecting social and economic inequalities with health outcomes.

The second finding is that the Theil is associated with IMR within the sample of 19 wealthy OECD countries included in this analysis. This relationship holds even while controlling for the most powerful ecological predictor of infant mortality, GDP per capita. Although this finding does not resolve the many contradictory findings presented in the literature regarding the relationship between social inequalities and health, based on the number of countries, sample size, and covariates used in multivariate models, it does at least provide considerable evidence for such a relationship while addressing many of the more common critiques of previous studies.

Perhaps the most intriguing finding is that health system components—particularly equity of healthcare financing—significantly reduced the magnitude of the inequality measure. This study provides further international evidence that suggests that improving aspects of the healthcare system may be one way to compensate for the negative effects of social inequalities on health outcomes. This policy response is likely to be more amenable to decision makers than some of the other solutions to problems of social inequalities, such as the redistribution of income through more progressive taxes.

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