Decomposing socioeconomic inequality in child vaccination: results from Ireland

Edel Doherty[1], Brendan Walsh[2], Ciaran O Neill[3]

[1] Centre for Pain Research and Discipline of Economics, J.E. Cairnes School of Business and Economics, National University of Ireland, Galway, Ireland

[2] Discipline of Economics, J.E. Cairnes School of Business and Economics, National University of Ireland, Galway, Ireland

[3] Corresponding Author: Discipline of Economics, J.E. Cairnes School of Business and Economics, National University of Ireland, Galway, Ireland

Background: There is limited knowledge of the extent of or factors underlying inequalities in uptake of childhood vaccination in Ireland. This paper aims to measure and decompose socio-economic inequalities in childhood vaccination in the Republic of Ireland

Methods: The analysis was performed using data from the first wave of the Growing Up in Ireland survey, a nationally representative survey of the carers of over 11 000 nine-month old babies collected in 2008 and 2009. Multivariate analysis was conducted to explore the child and parental factors, including socio-economic factors that were associated with non-vaccination of children. A concentration index was calculated to measure inequality in childhood vaccination. Subsequent decomposition analysis identified key factors underpinning observed inequalities.

Results: Overall the results confirm a strong socioeconomic gradient in childhood vaccination in the Republic of Ireland. Concentration indices of vaccination (CI=-0.19) show a substantial pro-rich gradient. Results from the decomposition analysis suggest that a substantial proportion of the inequality is explained by household level variables such as socio-economic status, household structure, income and entitlement to publicly funded care (34.2%, 25.2% 29.5% and 9.2% respectively). Substantial differences are also observed between children of Irish mothers and immigrant mothers from developing countries.

Conclusions: Vaccination was less likely in lower than in higher income households. Access to publicly funded services was an important factor in explaining inequalities.

Keywords: Childhood Vaccination, Inequalities, Concentration index, Ireland

INTRODUCTION

Many developed countries have well-established programmes of childhood vaccinations. On the whole, concerted efforts to eliminate communicable diseases among children have been highly successful. For example, the World Health Organisation (WHO) estimated that the total number of people contracting measles in Europe had fallen from approximately 850,000 in 1980 to 27,000 in 2010 [1]. To prevent an outbreak of vaccine preventable diseases ambitious targets have been set by the WHO and many national governments to achieve childhood vaccination rates of 95 percent. In order to achieve such high rates many countries have established specific programmes for vaccination in childhood. Despite this, vaccination rates often fall below the targets and uptake varies substantially between countries. Taking the EU-27 as an example, while the average vaccination rate achieved in 2010 was 95 percent for Diphteria, Tetanus and Pertussis, this varied from a high of 99 percent in a number of countries to much lower rates of 76, 83, 89 percent in Malta, Austria and Latvia respectively [2]. Moreover, the European objective of eliminating Measles and Rubella by 2010 was not achieved due to lower than required vaccination coverage prevailing in a number of countries [3]. With free movement of people across European countries, low achievement on vaccination in one country may have implications for other countries also.

A growing number of studies, using data for industrialised countries have shown considerable variability in childhood vaccination associated with a number of factors. Factors that have been examined previously relate to socio-economic and demographic characteristics such as household income, parental age, parental education, parental ethnicity, number of siblings, birth order, insurance status, parental and physician attitudes and structural factors, associated with the type and accessibility of healthcare services [4-16].While not every study observed a link between socio-economic circumstances and vaccination rates (which may reflect differences in healthcare systems across countries), there is an emerging consensus across studies that factors associated with lower socio-economic status contribute to lower vaccination rates. In some cases, socio-economic status was found to play a more prominent role in affecting vaccination rates than other contributors such as negative parental perceptions of vaccines [11].

Findings from the literature suggest that there are also particular groups of children within developed countries where targeted action may be required to overcome potential barriers to vaccination. However, to be effective, policies that target low uptake should be informed by an assessment of the factors driving potential inequalities in childhood vaccination. In this respect, the concentration index (CI) is a method used to quantify socioeconomic and other potential inequalities in health and health care, with applications across a number of health-related areas[17-19]. The CI shows how a health measure, such as vaccination, varies according to some measure of socioeconomic status, such as income, providing a single metric of any income related inequality. Further CIs can be decomposed at the individual level to allow elements which drive the income-related inequality to be identified separately [19]. This can be a useful tool in informing the development of appropriate policy responses

The present study seeks to quantify in a CI the extent of inequality in vaccination uptake and shed light on the role that socioeconomic and other factors play in explaining vaccination uptake in the Republic of Ireland. The paper uses data from the Growing Up in Ireland (GUI) study, collected during 2008-2009from families of approximately 11,134 infants. The paper quantifies the extent of the socioeconomic gradient in infant vaccination using a CI and decomposes the determinants of the inequality in infant uptake. One previous study conducted in Ireland found that there was inequality of access to the MMR vaccination based on approximately 550 observations from a cohort study [15]. However, this study did not decompose the socioeconomic gradient. As far as we are aware, this is the first paper to utilise the decomposition technique to quantify the main determinants of childhood vaccination in a developed country. The findings have implications for the formulation of policies which seek to address inequalities in childhood vaccinations in developed countries.

MATERIALS AND METHODS

Data Description

The GUI data includes approximately one-third of all nine-month old babies born in the state during the study period (2008-09). The sampling frame for the design was drawn from the Child Benefit Register. The purpose of the GUI project is to provide data that describes the lives of Irish children and thereby inform public policy and service delivery [20]. Further details of the survey, including the sampling procedures, are discussed elsewhere [20-21].

In Ireland, there is an immunisation programme for infants provided free of charge from when they are born until they are thirteen months old. Babies receive their first immunisation at birth in hospital (the BCG tuberculosis vaccine), after this, parents are asked to bring their baby to receive courses of vaccinations when the baby is two months, four months, six months, twelve months and thirteen months respectively. *At two months infants receive their first 6 in 1 vaccination (covering diphtheria, tetanus, whooping cough, hib (Haemophilus influenzae B), Polio and Hepatitis B) and the PCV (Pneumococcal Conjugate) vaccination. At 4 months infants receive their second 6 in 1 vaccination and the Men C (Meningococcal C) vaccination and at 6 months infants receive their final 6 in 1 vaccination and the PCV and Men C vaccinations.* These vaccinations are given primarily by General Practitioners (GPs) and are free for all infants born in Ireland. Prior to the two month vaccination, the Health Service Executive (HSE) writes to the infant's parents to remind them to arrange to visit the GP for their vaccination, for the four and six month vaccinations, it is up to parents to arrange these appointments (the HSE does not send reminder letters) [22]. In this paper we examine the uptake of the six month vaccination in order to understand factors driving non-uptake by infants at this stage (almost 99% of children had received at least one of the vaccine doses whereas 92% received their six month vaccination, this equates to a total of 896 infants in the sample who did not receive their 6 month vaccination). Since our data is from nine-month old babies, we cannot explore the uptake of the 12 and 13 month vaccinations (at 12 months infants receive the MMR and PCV vaccinations and at 13 months infants receive the Men C and Hib vaccinations). For our explanatory variables we include a range of characteristics that may contribute to uptake of vaccinations, and explain any potential socio-economic gradient. These variables include equivalised household income, which is used as the ranking variable in the construction of the concentration curves and indices (this scale takes a value of 1 for the first adult in the household, 0.66 for any subsequent adults and

0.33 for each child). Other variables included represent a range of socioeconomic variables, household variables, parental level variables, as well as a set of variables relating to the child. Table 1 shows the summary percentages for the variables used in our analysis.

Econometric Analysis

In modelling the probability of infants not receiving their six month vaccination a logit model was used, which is suitable for modelling binary outcome variables. The outcome variable takes a value of one if an infant did not receive their 6 month vaccination or zero otherwise. For our analysis we only present the results from a multivariate model where we control for a range of other explanatory variables. The inclusion of variables was based on findings from previous studies that examined factors associated with vaccination uptake and availability of variables in the GUI dataset. We present the results for the models where all our independent variables were entered simultaneously into the models. We note that some of our variables are likely to be correlated such as household social class, equivalised income and maternal education. As a result we also discuss some findings from univariate analyses where the variables were entered separately in the models.

Concentration Index

Concentration indices are commonly used as a means of quantifying socioeconomic inequalities. Using the concentration index, allows for more easily comparability with other studies which also use this methodology, regardless of populations, mean and distribution of the dependent variable and also mean and distribution of the socioeconomics income variable. One of the main benefits of the concentration index is the ability to be decomposed into a range of variables not just equivalised household income.

Inequalities in the uptake of childhood vaccinations have been studied previously; though most studies using concentration indices have been confined to developing countries [23-27]. The index quantifies the inequality in a measure that ranges between -1 and 1, with zero representing perfect equality.

Equivalised household income is used as the ranking variable in the construction of the concentration curves and indices. Continuous income thus provides more accurate indices compared to a categorical income variables with repetitive values across individuals [29].The concentration index (*CI*) can be represented by following, as was incorporated by Kakwani *et al*.[30]:

$$CI = \frac{2}{N\mu}\sum_{i=1}^{N} y_i R_i - 1$$

Here y_i denotes the dependent variable (had a vaccine or not), μ is the dependent's mean and $R_i$signifies the fractional rank of individuals along the income distribution. Individuals i move from 1 at the bottom of the distribution to N at the top of the distribution. The index can be more easily compared with other studies which incorporate this technique in their research in comparison to other inequality measures and regressions in particular. Concentration curves are a graphical representation of the *CI*, depicting the proportional resource use along the income distribution. Interpretation of the concentration index is different to that from normal regression analysis. Van Doorslaer and Koolman (2004) state that is an index of 0.10 (pro-rich) is calculated, a 10% redistribution of utilisation from the top half of the income distribution to the lower half would allow for perfect inequality.

Our dependent variable, whether the child had all three vaccinations or not, is a binary measure thus a normalisation is required to construct the *CI* to allow for quantification in the range -1 to 1.We incorporate the Wagstaff index, which normalises the standard concentration indices for binary variables. In the first study of childhood vaccination to use a *CI*, Wagstaff [31] incorporates this normalisation approach. Other normalisation approaches for binary variables are available [32]. We choose Wagstaff due to its use in vaccination previously, its use as a measure of relative rather than absolute inequalities, and because it also measures inequalities to a better degree when the mean of the variable is close to zero, with our mean ~8%.

$$CI_n = \frac{CI}{1-\mu}$$

The Wagstaff Index is then used in our decomposition analysis.

2.3 Decomposition Analysis

The decomposition allows for inequality to be partitioned into specific contributions (how much does each regressor contributes to or determines the overall inequality associated with individual determinants in an unpacking mechanism. The decomposition has become a feature of research since Van Doorslaer and Koolman [33]. The decomposition of the Wagstaff Index for binary variables has also been undertaken previously (Walsh et al., 2012). Determinants included with the decomposition analysis are chosen due to their impact both upon vaccination and/or income. For example, for a concentration of 0.10, if being in the highest social class provided a contribution of 0.05, this states that 50% of the observed income inequality is underpinned by differences in utilisation (and ranking in the income distribution) between those in the highest and lowest social class. The binary nature of the dependent variable means we utilise a Generalized Linear Model (GLM) with binomial link and probit family giving us average partial effects as has been used previously [34]. GLM allows for consistency of results for groups of dummy variables, regardless of the base category that is chosen [35].

$$\widehat{CI}_n = \sum \left(\frac{\beta_k \bar{x}_k}{\mu}\right) \widehat{CI}_k + \left(\frac{GC_\varepsilon}{\mu}\right)$$

Where β is the average partial effect from the GLM regression, $\bar{x}$ is the mean of the determinant and μ is the mean of the outcome variable (~0.08 in our analyses). $\widehat{CI}_k$ is the concentration index of each determinant k. Income in its logarithmic form is included within the decomposition again. The term $\frac{\beta_k \bar{x}_k}{\mu}$ represents the elasticity, which when multiplied by the regressor's concentration index $\widehat{CI}_k$ gives us the contribution of each variable. This contribution, when divided by the overall *CI*, presents the percentage contribution (the percentage the overall inequality explained by that regressor). Determinants will have no impact on inequality if they have no impact on the dependent variable or if the determinants are evenly distributed across the income distribution. The final expression represents the residual term and will equal zero if no systematic variation in unobserved heterogeneity across individuals in relation to their position in the distribution of the dependent variable is evident [36].

RESULTS

Table 1 presents odds ratios from a logit model exploring the determinants of the non-uptake of the six month vaccination in Ireland.[1]

Table 1: Multivariate Analysis of Determinants of Infant 6 Month Non-Vaccination

Variables	Odds Ratio	P-Value	95 % Confidence Interval	
Professional/Managerial Class (Social Class 1)	1.092	0.735	0.656	1.819
Non-manual/Skilled Manual (Social Class 2)	0.900	0.666	0.559	1.451
Semiskilled/Unskilled (Social Class 3)	1.148	0.586	0.699	1.887
Employed- Class unknown (Social Class 4)	2.743	0.101	0.822	9.150
Never Worked at all (Social Class 5)	Base Category			
Two parents two child household	0.808	0.329	0.527	1.239
Two parents one child household	0.265	0.000	0.163	0.432
One parent one child household	0.311	0.000	0.177	0.549
One parent two child household	Base Category			
Urban Location	0.981	0.844	0.811	1.187
Log Equivalised Household Income	0.713	0.010	0.550	0.924
Medical Card	0.816	0.141	0.623	1.070
Health Insurance	0.706	0.004	0.557	0.896
Baby Boy	1.096	0.321	0.914	1.314
Mother's Age	0.801	0.012	0.674	0.952

[1] Household Social Class is taken as the highest social class of both partners in the household [21]. The social class groups are defined on the basis of occupation so that people with similar levels of occupational skill are grouped together. Differences in educational attainment are not taken into account in the classification system. While the CSO uses a seven item classification system we used the combined classification for some classes derived in the GUI data, using a five item classification.

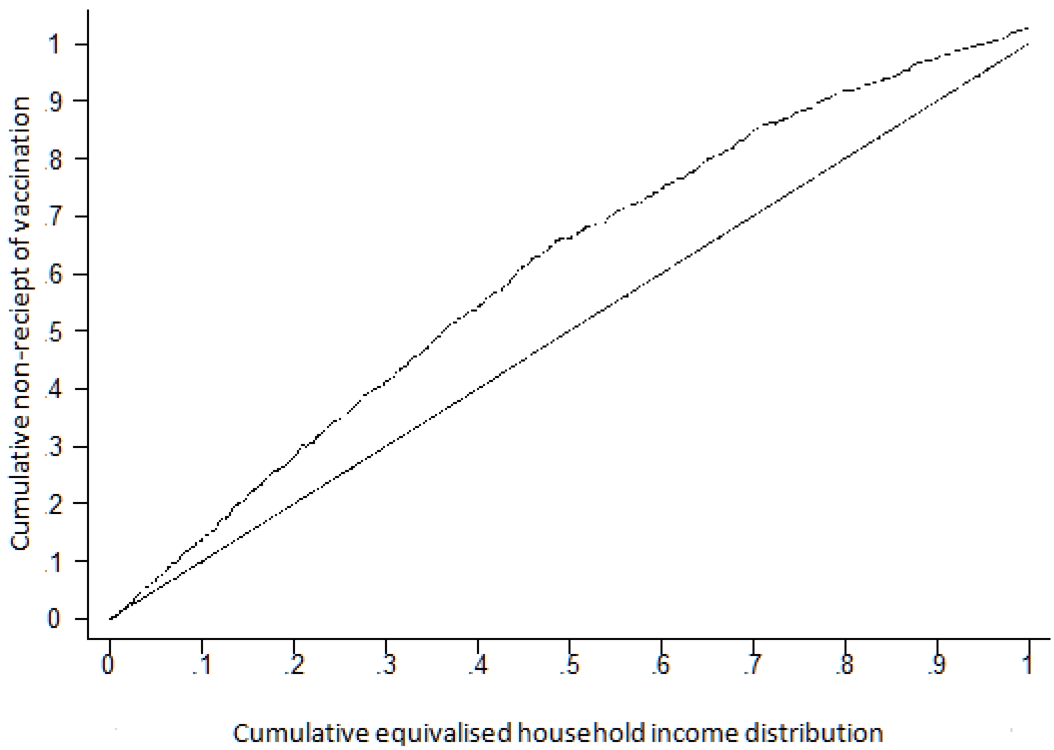
Mother's Age Squared	1.003	0.013	1.001	1.006
Mother Upper Secondary Education	0.949	0.707	0.721	1.248
Mother Degree or Equivalent Education	0.949	0.735	0.702	1.284
Mother Lower Secondary or Lower	Base Category			
Mother’s Ethnicity-White but not Irish	0.725	0.052	0.525	1.002
Mother’s Ethnicity- African	0.481	0.047	0.234	0.990
Mother’s Ethnicity- Asian	0.358	0.024	0.147	0.874
Mother’s Ethnicity – Mixed	0.568	0.465	0.125	2.588
Mother's Ethnicity- Irish	Base Category			
Mother can read English	0.699	0.128	0.441	1.109
Mother is Employed	0.827	0.100	0.660	1.037
Mother is Self-Employed	2.060	0.000	1.430	2.967
Mother is a student or in Training	0.827	0.555	0.441	1.551
Mother is unemployed or on Disability benefit	0.538	0.026	0.312	0.927
Mother is a homemaker	Base Category			
Mother smokes	1.259	0.000	1.124	1.410
Sample Size		(N = 9176)		

P-Values indicate statistical significance.

Results from Table 1 highlight a number of significant predictors of the non-uptake of infant vaccination at six months. In particular, household structure-relative to belonging to a single parent household with two or more children, health insurance, equivalised income, having a mother who is of Asian or African ethnicity or having a mother who is unemployed or on disability (10 percent level) negatively affects the likelihood that the infant did not receive their vaccination. On the other hand, having a self-employed mother or a mother who smokes significantly increases the probability that the infant did not receive their vaccination. While in separate univariate analyses, socio-demographic variables including household social class and maternal education, were significant, they do not remain so in the multivariate analysis shown in Table 1. This is likely because of collinearity between variables such as household social class, maternal education and household income. Despite this, we felt that the inclusion of all these variables in the multivariate model was important to capture the full effect associated with socio-economic status on vaccination uptake. Other variables, such as the child’s gender, living in an urban location, mother’s English literacy levels are not significant in either the multivariate or univariate analyses.

In order to investigate potential socioeconomic gradient in infant vaccinations, Figure 1 presents concentration curves for infants who have not received their six month vaccination. The curve shows the relationship between the cumulative share of household income on the horizontal axis and the cumulative share of non-vaccination on the vertical axis. The 45^{o} line represents the line of perfect equality (equivalent to a concentration index equal to zero), such that concentration curves lying above this line indicate 'pro-poor' inequality e.g. under- vaccination among infants is more prevalent amongst poorer households.

Figure 1: Concentration Curve of Non receipt vaccinations at 6 months



In order to quantify the extent of this inequality in vaccination in Irish infants, normalised concentration indices were calculated and are presented in Table 2 (corrected for heteroskedasticity and autocorrelation). The results show that significant inequalities are observed. In particular the interpretation of our results, using Van Doorslaer and Koolman explanation [31], suggest that a redistribution of ~19 % of vaccination from the richest half of the distribution to the poorest half would be needed to ensure equalise uptake across income groups.

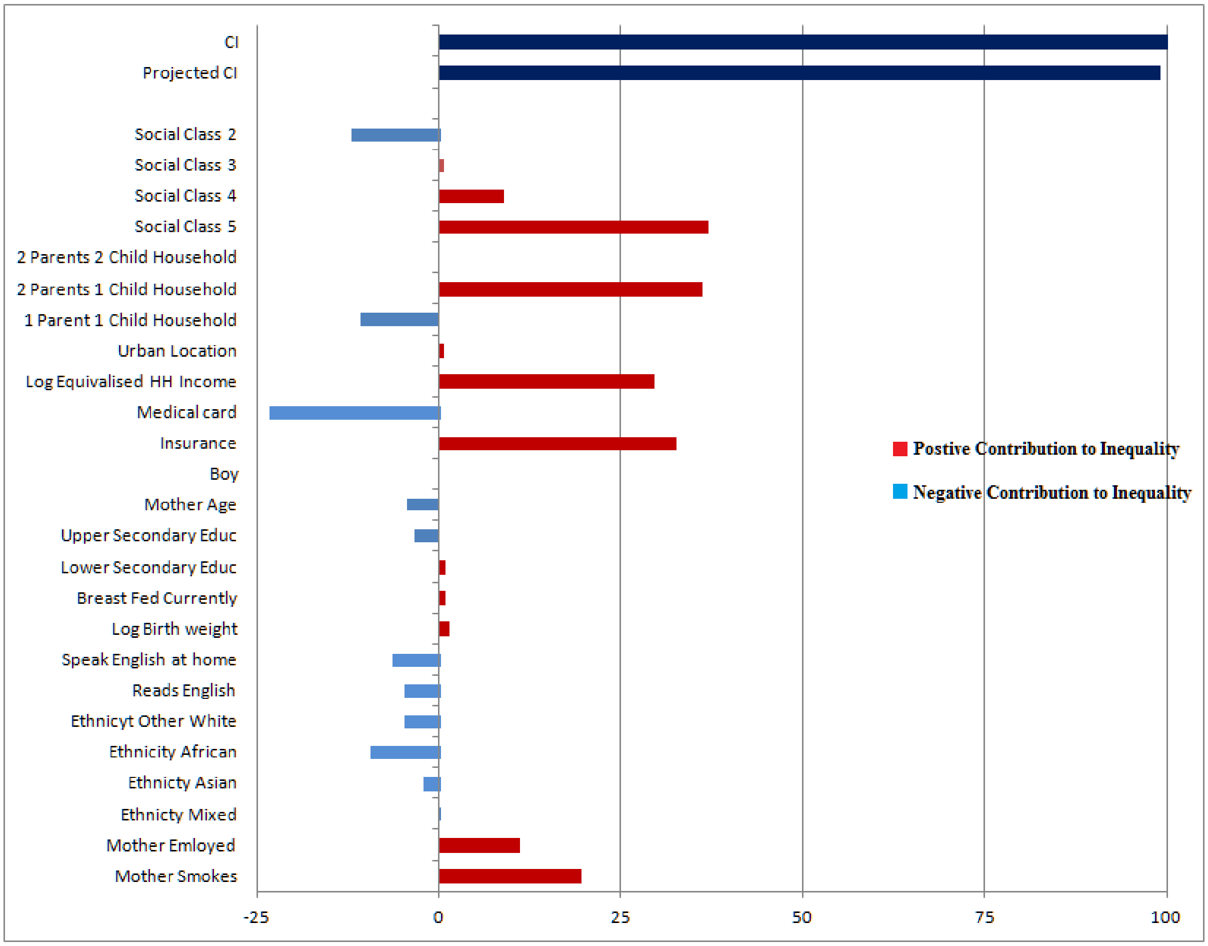
Table 3: Concentration index and Decomposition Analyses

Concentration Index	**- 0.194*** **	**100%**		
Projected Concentration Index	**-0.192**	**99.2%**		
Residual term	**-0.001**	**0.8%**		
	Contributions	**Percentage Contributions**	**Elasticises**	**Concentration Indices (Determinants)**
Decomposition Results				
Professional/Managerial Class (1)	Base	Base	Base	
Non-manual/Skilled Manual Class (2)	0.020	-11.9%	0.089	0.259
Semiskilled/Unskilled Class (3)	-0.001	0.4%	0.016	-0.053
Employed- Class unknown (4)	-0.017	8.8%	0.052	-0.328
Never Worked at all (5)	-0.072	36.9%	0.115	-0.628
Social Class Overall	**-0.070**	**34.2%**	-	-
One parent two children household	Base	Base	-	-
Two parents two children household	-0.000	0%	0.007	-0.022
Two parents one child household	-0.070	36.0%	-0.303	0.231
One parent one child household	0.021	-10.8%	-0.046	-0.460
Household Structure Overall	**-0.049**	**25.2%**	-	-
Urban Location	-0.000	0.5%	-0.055	0.016
Log Equivalised Household Income	-0.057	29.5%	-1.746	0.033
Uninsured	Base	Base	-	-
Medical Card	0.045	-23.3%	-0.081	-0.560
Private Health Insurance	-0.063	32.5%	-0.217	0.291
Medical Coverage Overall	**-0.018**	**9.2%**	-	-
Baby Boy	0.000	0%	0.023	0.002
Mother aged 35plus	0.008	-4.3%	0.066	0.129
Mother Degree	Base	Base	-	-
Mother Upper Secondary	0.005	-3.4%	-0.047	-0.100
Mother Lower Secondary	-0.001	0.06%	0.002	-0.501
Mothers Education Overall	**0.004**	**-2.8%**	-	-
Breast Feed Currently	-0.001	0.6%	0.099	-0.011
Log Birth weight	-0.002	0.9%	-1.760	0.001
Speak English at home	0.013	-6.4%	-0.054	-0.231
Mother Ethnicity - Irish	Base	Base	-	-

Mother’s Ethnicity - White but not Irish	0.009	-4.7%	-0.042	-0.215
Mother's Ethnicity- African	0.018	-9.3%	-0.032	-0.564
Mother's Ethnicity- Asian	0.004	-2.1%	-0.028	-0.147
Mother’s Ethnicity – Mixed	-0.000	0.2%	0.001	-0.311
Ethnicity Overall	**0.031**	**-16.3%**	**-**	**-**
Mother can read English	0.002	-1.2%	0.125	0.018
Mother Employed	-0.021	10.9%	-0.199	0.106
Mother Smokes	-0.038	19.4%	0.168	-0.223

Table 2 also presents the results from the decomposition analysis of contribution for non-vaccination among infants. Results are presented as the contribution of each individual variable to the overall inequality in the concentration index, with percentage contribution in parentheses. Overall the results suggest that the majority of the inequality in infant vaccination is explained by variables at the household level. Socioeconomic status, household structure and equivalised income contribute a large percentage to infant vaccination inequalities (34.2%, 25.2% and 29.5% respectively). Possession of a medical card (which entitles the mother to free public health care) reduces the inequality (-23.3%), while health insurance exacerbates it (32.5%) compared to household with no medical coverage. Factors such as mother’s age, education, English literacy levels and birth factors explain only a small percentage of the inequalities. On the other hand, mothers who have a non-Irish ethic background reduce the observed inequalities (-16.3%), while having a mother who is employed (relative to a homemaker) or a mother who smokes increases inequalities by 10.9% and 19.4% respectively. Figure 2 presents the analysis in graphical form also.

Figure 2: Graphical Representation of CI and Decomposition Analysis



DISCUSSION

This paper provides strong evidence of a large socioeconomic gradient in infant vaccination in the Republic of Ireland, confirming evidence from Ireland [15] and other countries [4-14,16]. It presents, for the first time, concentration indices of vaccination (CI=-19.44%) for Irish infants. The analysis allows us to decompose the socioeconomic inequalities into their specific determinants, facilitating a more in-depth analysis of under vaccination in childhood.

Factors such as household income, socio-economic status and household structure play a large role in explaining inequalities in infant vaccination in Ireland. Additionally, we find that having private health insurance increases inequalities in infant vaccination rates. While insurance will afford superior access to care generally in Ireland – relative to those without – this is a noteworthy finding given than infant vaccination is free in Ireland. Its significance may relate to differences in preferences for health and healthcare. Possession of a medical continued to play a role, possession of a medical card reducing inequalities. From a policy perspective these results suggest that families with infants who have neither health insurance nor a medical card may require targeted interventions to ensure these infants receive their full vaccination course. In the case of the GUI data, approximately 14% of families fall into this category.

Unlike some of the international literature [5,6-7,9,14], we do not observe that maternal age or education play a large role in explaining inequalities when other factors are controlled for. What are shown to be more important is the mother's ethnic origin, employment status and behavioural health. With regard to the ethnicity finding, our results suggest that public health campaigns targeted towards Irish mothers could be effective as a means to ensure greater infant vaccination uptake. What differentiates Ireland from many other developed countries is that many of the mothers of non-Irish ethnicity are likely to be first generation immigrants who may be less complacent towards vaccination than Irish mothers. The finding associated with employment status in the logit analysis point most likely to an effect of maternal time constraints, with self-employment mother's having a significant lower likelihood of having their infant immunised. That the mother's smoking behaviour is significant is in line with findings from other studies [15] and as with health insurance may relate to the role of the mother's preferences for health generally.

This study also incorporates concentration indices and decomposition analyses to measure inequalities in vaccination. While other inequality measures may be used as has been increasingly seen in the literature, the concentration index's ability to measure inequality easily just the dependent and ranking variable, measure inequality across the distribution rather than between groups and the ability to decompose inequality into specific regressors mean that the concentration indices may be the best measure in which to measure inequalities in healthcare utilisation.

CONCLUSIONS

Our results illustrate the advantages of using concentration indices and decomposition techniques to explore inequalities in childhood vaccination in the developed world. The results suggest that the factors associated with under vaccination of children and inequalities are multifaceted which may require coordinated policy responses at the household and parental level, particularly targeting mothers, to achieve national infant vaccination targets. In considering the results presented here, it is worth stressing that given the cross-sectional nature of the available data, the analysis may not have identified causal pathways. Furthermore, while factors such as parental and doctor attitudes have been shown to be important in other studies, including studies of Ireland [12,15-16], information on these were not available for the current study. Nevertheless, given the focus of this study in exploring contributors to inequalities in childhood vaccinations, the small residual found for the concentration index, suggest that we have captured the salient factors that contribute to inequality in infant vaccinations in Ireland.

ACKNOWLEDGEMENTS

Brendan Walsh is funded as part of a Health Research Board (Ireland) and National Cancer Institute (United States) Health Economics Fellowship. ***Growing Up in Ireland*** data have been funded by the Government of Ireland through the Office of the Minister for Children and Youth Affairs; have been collected under the Statistics Act, 1993, of the Central Statistics Office. The project has been designed and implemented by the joint ESRI-TCD ***Growing Up in Ireland*** Study Team.

REFERENCES

1. WHO. Immunization surveillance, assessment and monitoring: European Region, http://www.who.int/immunization_monitoring/data/data_EUR/en/index.html (Accessed 24th June, 2013)

2. OECD. "Childhood Vaccination Programmes" in Health at a Glance: Europe 2012, OECD Publishing, http://dx.doi.org/10.1787/9789264183896-49-en (Accessed 24th June, 2013)

3. WHO. Eliminating measles and rubella: framework for the verification process in the WHO European Region, 2012, http://www.euro.who.int/__data/assets/pdf_file/0005/156776/e96153-Eng-final-version.pdf (Accessed 24th June, 2013)

4. Bates AS, Wolinsky FD. Personal, financial, and structural barriers to immunization in socioeconomically disadvantaged urban children. *Pediatrics* 1998;**101**:591–6

5. Luman ET, McCauley MM, Shefer A, Chu SY. Maternal characteristics associated with vaccination of young children. *Pediatrics*2003;**111**:1215-1218.

6. Bobo JK, Gale JL, Thapa PB, Wassilak SG. Risk factors for delayed immunization in a random sample of 1163 children from Oregon and Washington. *Pediatrics* 1993;**91**:308-14.

7. Theeten H, Hens N, Vandermeulen C. et al. Infant vaccination coverage in 2005 and predictive factors for complete or valid vaccination in Flanders, Belgium: an EPI-survey. *Vaccine* 2007;**25**:4940-8.

8. Fiks AG, Alessandrini EA, Luberti AA, et al. Identifying factors predicting immunization delay for children followed in an urban primary care network using an electronic health record. *Pediatrics*2006;**118**:e1680-1686.

9. Miller LA, Hoffman RE, Barón AE, et al. Risk factors for delayed immunization against measles, mumps, and rubella in Colorado two year-olds. *Pediatrics*1994;**94**:213-219.

10. Allred NJ, Wooten KG, Kong Y. The association of health insurance and continuous primary care in the medical home on vaccination coverage for 19- to 35-month-old children. *Pediatrics*, 2007 ;**119**Suppl 1:S4-11

11. Danis K, Georgakopoulou T, Stavrou T, et al. Socioeconomic factors play a more important role in childhood vaccination coverage than parental perceptions: a cross-sectional study in Greece, *Vaccine* 2010; **28**: 1861-1869.

12. Santoli JM, Huet NJ, Smith PJ, et al. (2004). Insurance status and vaccination coverage among US preschool children, *Pediatrics*, 2004;**113:** Suppl:1959-64

13. Samad L, Tate AR, Dezateux C, et al. Differences in risk factors for partial and no vaccination in the first year of life: prospective cohort study. *BMJ* 2006; **332**:1312–3.

14. Swennen B, Van Damme P, Vellinga A, et al. Analysis of factors influencing vaccine uptake: perspectives from Belgium. *Vaccine* 2001;**20**:S5

15. Jessop LJ, Murrin C, Lotya J, et al. Socio-demographic and health-related predictors of uptake of first MMR vaccination in the Lifeway's Cohort Study. *Vaccine* 2010; **28**:6338-6343

16. Harrington PM, Woodman C, Shannon WF. Low vaccination uptake: Is the process the problem? *J Epidemio Commun Health 2000*;54:394-400

17. McGrail KM, Doorslaer EKA, van Ross NA, Sanmartin C. Income-related health inequalities in Canada and the United States: A decomposition analysis, *AM J Public Health* 2009; **99**:1856-1863

18. Nedjat S, Hosseinpoor AR, Forouzanfar MH et al. Decomposing socioeconomic inequality in self-rated health in Tehran *J Epidemiol Commun H* 2012;**66**:495-500.

19. Walsh B, Cullinan J. Decomposing inequalities in childhood obesity, NUI Galway Working Paper.

20. Greene S, Williams J, Layte R et al., Growing Up in Ireland: National Longitudinal Study of Children: Background and conceptual framework 2010, Published by the Department of Health and Children, Dublin, Ireland.

21. Quail A, Williams J, McCrory C et al. A Summary Guide to Wave 1 of the Infant Cohort (at 9 months) of Growing Up in Ireland 2011, Published by the Department of Health and Children, Dublin, Ireland

22. HSE. Your child's immunisation: a guide for parents 2013. http://www.immunisation.ie/en/ChildhoodImmunisation/PrimaryImmunisationSchedule/#d.en.15392 (accessed 12 August 2013)

23. Lauridsen J,Pradhan J. Socio-economic inequality of immunization coverage in India. *Health Econ Review*2011:1-11, doi: 10.1186/2191-1991-1-11

24. Barros ADJ, Ronsmans C, Axelson H et al. Equity in maternal, newborn, and child health interventions in Countdown to 2015: a retrospective review of survey data from 54 countries. *Lancet* 2012; **379**:1225-33

25. Joe W, Mishra US, Navaneetham K. Socio-economic inequalities in child health: recent evidence from India. *Glob Public Health* 2010; **5**:493-508.

26. Wattananon S, Tangcharoensathien V, Prakongsai P. Equity in maternal and child health in Thailand. *Bull World Health Organ* 2010;**88**:420-427

27. Victora CG, Fenn B, Bryce J, Kirkwood BR. Co-coverage of preventive interventions and implications for child-survival strategies: evidence from national surveys, *Lancet* 2005;**366**:1460-1466

28. Kruk ME, Prescott MR, de Pinho H, et al. Equity and the child health Millennium Development Goal: the role of pro-poor health policies. *J Epidemiol Commun H* 2011;65:327-333

29. Chen Z, Roy K. Calculating concentration index with repetitive values of indicators of economic welfare. *J Health Econ* 2009;**28**:169-175

30. Kakwani N, Wagstaff A, Van Doorlsaer E. Socioeconomic inequalities in health: measurement, computation and statistical inference. *J Econometrics*1997;**77**: 87-104.

31. Wagstaff A. The bounds of the concentration index when the variable of interest is binary, with an application to immunization inequality. *Health Econ* 2005;**14**:429-432

32. Erreygers G, Van Ourti T. Measuring socioeconomic inequality in health, health care and health financing by means of rank-dependent indices: A recipe for good practice. *J Health Econ* 2011; **30**: 685-694

33. Van Doorslaer E, Koolman. Exploring the differences in income-related health inequalities across European countries. *Health Econ* 2004;**13**: 609-628

34. Van Doorslaer, E, Wagstaff A, Bleichrodt H, et al. Income-related inequalities in health: some international comparisons, *J Health Econ*, 1997;**16**: 93-112.

35. Yiengprugsawan V, Lim LL, Carmichael G, et al. Decomposing socioeconomic inequality for binary health outcomes: an improved estimation that does not vary by choice of reference group. BMC Research Notes 2007; **3**: 57.

36. Jones AM, Lopez-Nicolas A. Measurement and Explanation of Socio-Economic Inequality in Health with Longitudinal Data. *Health Econ* 2004; **13**: 1015-1030.

37. Walsh B, Silles M, O’Neill C. The role of private medical insurance in socio-economic inequalities in cancer screening uptake in Ireland. *Health Econ* 2012; **21**: 1250-1256