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Research Article

Neonatal Death and National Income in Developing Countries: Will Economic Growth Reduce Deaths in the First Month of Life?

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The relationship between national income and child mortality has been understood for many years. However, what is less well known is whether the association differs for neonatal mortality compared to postneonatal and early childhood deaths. Our study extends knowledge by analysing the relationship between gross national income (GNI) and neonatal, postneonatal, and early child mortality. The study draws on mortality estimates from Demographic and Household Surveys and World Bank data for GNI. It uses multivariate multiple regression analysis to examine the relationship between GNI and neonatal, postneonatal, and early child mortality rates (NMR, PNMR, and ECMR) using cross-sectional data from 65 countries and trend data from 49 countries. No significant relationship can be found between NMR and GNI for cross-sectional data once adjusted for region. The trend data confirms that increases over time in GNI are associated with lower reductions in NMR than other component rates. Thus, economic growth alone may have a weaker effect on reducing neonatal deaths than for older age groups; achieving improvements in neonatal mortality requires investment in maternal and new born health services alongside growth.

1. Introduction

Over the last few decades neonatal mortality (death of an infant before 28 days) has fallen at a slower rate than postneonatal or early childhood mortality (death of a child between the ages of 28 days and 12 months and between 12 and 60 months, resp.). As a result around 40% of all child deaths now occur in the first month of life [1]. Despite this high burden of mortality, relatively little is known about the relationship between wealth or economic growth and neonatal mortality at the national level.

The relationship between national income and overall child mortality (deaths in all children under the age of five) has been understood for many years. A strong negative relationship between national income level (using per capita gross domestic product or gross national income: GDP or GNI) and child mortality has been well documented in a number of studies using both cross-sectional and trend data that examines the association between change over time. One of the most frequently cited studies is Pritchett and Summers' analysis [2], which estimates the effect of wealth on infant and child mortality using regression methodology based on cross-country time series data. It found that an increase in GDP by 10% was associated with a reduction in child mortality of 4%. The study concludes that in 1990 alone over 0.5 million child deaths in developing countries could be attributed to poor economic performance during the 1980s. A more recent study which examines the association between change in GDP and child mortality over time using data from 15 Indian states found that the composition of GDP growth is also important: growth within the nonagricultural sector has a greater impact on mortality [3].

Evidence on the relationship between GDP and neonatal mortality is, however, extremely sparse. A broader study using principal component analysis suggests that contextual factors (income, female literacy, sanitation, and access to clean water) explain less of the variation between country mortality rates for neonatal mortality than for postneonatal and early child mortality [4]. Further limited evidence is available that shows income may be of greater importance for older children than neonates at the household level. Lawn et al. [5] found that the differences in mortality between richest and poorest quintiles were generally greater for postneonatal than neonatal deaths. Further evidence from UK historical data gathered from 1911 and 1932 in England and Wales demonstrates that while a class gradient did exist in neonatal mortality, it was considerably less steep for infant mortality [6].

Our study extends knowledge by analysing and presenting the relationship between gross national income (GNI) and the three separate component rates of child mortality: neonatal, postneonatal, and early childhood mortality using both cross-sectional and trend data.

2. Methods

2.1. The Data. Data for the neonatal mortality rate, postneonatal mortality rate, and early childhood mortality rate (NMR, PNMR, and ECMR) are taken from Demographic and Household Surveys (DHS). Where available, the trend data also draws on estimates from the World Fertility Surveys (WFS), which were the predecessor to DHS. In both cases the estimates are based on births occurring up to five years prior to the survey. The GNI data is taken from the World Bank database and is adjusted to constant 2010 US dollars. As the NMR estimates are from a five-year period prior to the survey the GNI is taken from the midyear.

The data for cross-sectional analysis includes estimates from 65 countries from 2000 onwards. Thirty-five of the countries were in Sub-Saharan Africa, with eleven in Latin America and the Caribbean, nine in South or South East Asia and the remaining ten in West and Central Asia, North Africa or Europe. There were 49 countries where at least two estimates are available for a period ranging from 6 to 32 years. Over half of these countries were in Sub-Saharan Africa (25), with a further 11 in Latin America and the Caribbean, seven in South or South East Asia, and six in West and Central Asia, North Africa, or Europe. The vast majority of countries used for both cross-sectional and trend analysis were low income or lower middle income countries based on the World Bank classifications.

DHS/WFS data are among the most commonly used source of direct estimates for child mortality. However, there are issues about data reliability, particularly for neonatal deaths, which are more likely to be underreported [7]. To maximise the data accuracy only estimates from the five years prior to the study have been used: as data is collected on deaths up to 20 years before the survey some studies have used individual datasets to provide information on trends over time. However, there is evidence that mortality data becomes less reliable for deaths that occurred at a longer period before the survey [7, 8]. Probably the greatest data issue is that the component rates used here will have relatively large standard errors compared to total under five mortality, which makes tracking changes over relatively short periods problematic. In order to reduce this concern, only data from the earliest and most recent survey were used even if more were available, so intervals were as long as possible. All intervals were at least six years, but in reality the vast majority of the datasets were more than 10 years apart, with a mean average difference of 18 years.

The limitations of GNI as a measure of living standards are fully accepted: in particular, it is not able to capture national fractionalisation or inequalities, and may be particularly inaccurate in countries where the informal economy or nonmonetised sectors are important. However, as the focus of this paper is economic growth rather than family-level wealth or socioeconomic wellbeing, GNI is the most valid measure. It is also fully recognised that a number of other socioeconomic factors such as education and public spending also impact on child mortality and these will be strongly correlated with GNI. However, as this study is specifically focussed on addressing the gap in evidence on the relationship between GNI and neonatal mortality, it does not attempt to unravel these links.

2.2. Analysis. Multivariate multiple regression was used to capture the association between the three component mortality rates and GNI per capita using cross-sectional data from 65 countries. Multivariate multiple regression is preferable to using separate ordinary least squares (OLS) analysis for each outcome variable as posttest estimation allows for the difference in coefficients across equations to be tested for significance. The models can either be expressed as three separate equations

$$\begin{aligned}\log(y1i) &= \beta_{01} + \beta_{11}\log(x_i) + \cdots + \beta_{1k}\log(x_k) + \varepsilon_{1i},\\ \log(y2i) &= \beta_{02} + \beta_{21}\log(x_i) + \cdots + \beta_{2k}\log(x_k) + \varepsilon_{2i},\\ \log(y3i) &= \beta_{03} + \beta_{31}\log(x_i) + \cdots + \beta_{3k}\log(x_k) + \varepsilon_{2i}\end{aligned} \quad (1)$$

or alternatively can be specified as a vector, that is

$$\log(\underline{Y}_i) = \underline{\beta}_0 + \underline{\beta}_1\log(x_i) + \cdots + \beta_k\log(x_k) + \underline{\varepsilon i}. \quad (2)$$

A double log model was used as the data are nonlinear and this provided the best fit. An advantage of the double log model is that the slope coefficient measures the average percentage reduction in mortality that is associated with a percentage increase in national income, thus making interpretation easier. Dummy variables for region were also added.

The examination of the relationship between GNI and mortality using cross-sectional data has the disadvantage that it cannot allow for country-specific factors that may affect the association. In order to address this, the study also examines the relationship between the change in mortality and the change in GNI for 49 countries, where more than one survey is available. The use of these data has the advantage that external variables that differ between countries are factored out. Again, a double log model is used to create three separate models, with log of average annual rate of change in per capita GNI per annum as the independent variable and the log of the average annual rate of change in the three component

Table 1: Descriptive statistics for cross-sectional data from 65 countries.

Mean NMR per 1000 live births (with standard deviation) and range	Mean PNMR per 1000 live births (with deviation) and range	Mean ECMR per 1000 live births (with deviation)	Mean GNI per capita (with deviation) in $
27.8 (11.7)	27.7 (17.7)	33.7 (31.4)	1084 (1066)
5–62	4–64	1–126	120–4210

Table 2: Results for multivariate multiple regression using natural log of gross national income (GNI) per capita as independent variable (with dummy variables for region) and natural log of neonatal, postneonatal, and early childhood mortality rates (NMR, PNMR, and ECMR) as dependent variable.

	Coefficient	*P* value	Confidence interval	
Log of NMR (R^2 = 0.39)				
Log of GNI	−0.09	0.10	−0.19	0.02
West/central Asia, North Africa, and Europe (reference)				
Sub-Saharan Africa	0.57	0.00	0.26	0.87
South/South East Asia	0.33	0.07	−0.03	0.69
Latin America/Caribbean	0.00	1.00	−0.33	0.33
Constant	3.44	0.00	2.67	4.21
Log of PNMR (R^2 = 0.53)				
Log of GNI	−0.21	0.01	−0.35	−0.07
West/central Asia, North Africa, and Europe (reference)				
Sub-Saharan Africa	0.99	0.00	0.58	1.40
South/South East Asia	0.12	0.61	−0.37	0.61
Latin America/Caribbean	0.10	0.66	−0.35	0.55
Constant	3.84	0.00	2.79	4.89
Log of ECMR (R^2 = 0.68)				
Log of GNI	−0.25	0.01	−0.43	−0.07
West/central Asia, North Africa, and Europe (reference)				
Sub-Saharan Africa	1.96	0.00	1.43	2.48
South/South East Asia	0.69	0.03	0.06	1.33
Latin America/Caribbean	0.33	0.26	−0.25	0.91
Constant	3.41	0.00	2.05	4.77

Data sources: mortality rates were taken from Demographic and Household surveys (DHS) and GNI adjusted to constant 2010 US dollars were taken from the World Bank Database.

mortality rates as the dependent variable. Postestimation testing was then carried out to produce a Wald *F* statistic and corresponding *P* value to establish if differences in the coefficients between models were significant. It is possible that countries that have achieved low levels of neonatal mortality may skew the findings of the relationship between income and NMR, as further reductions beyond a certain point for these countries may rely less on general development progress and health care and more on advanced curative services which are often unfeasible for developing countries. For this reason separate models were run for the cross-sectional data excluding countries with NMRs less than 20, and also for the trend model excluding countries with a baseline NMR of less than 20. All data were analysed using STATA 11.0.

3. Results

Descriptive statistics for the 65 countries with cross-sectional data available can be found in Table 1. As can be seen there is a very marked range in the component mortality rates, as well as for GNI per capita. The means for NMR, PNMR and ECMR were 27.7, 27.8, and 33.7 per 1000 live births, respectively, and the mean per capita GNI was $1084.

The results from the regression analysis of the 65 countries, where cross-sectional data is available can be seen in Table 2. The coefficient for the log of GNI is not significant for NMR, but reaches significance for both PNMR and ECMR: for PNMR a 10% increase in GNI is associated with a 2.1% decrease in PNMR and a 2.5% decrease in ECMR. The dummy variable for Sub-Saharan Africa is associated with a large and significant increase in mortality for all age groups, particularly in early childhood mortality. The R^2 is markedly larger for the equations for PNMR and ECMR than for NMR (0.39, 0.54 and 0.68 for NMR, PNMR, and ECMR, resp.). The addition of a variable for the log of the gini coefficient of equity was not significant and did not result in any significant change in the original model. When the model was reanalysed including only the 44 countries,

Table 3: Results of multivariate multiple regression using natural log of change in GNI over time as the independent variable (and dummy variables for region) and the natural log of the change in NMR, PNMR, and ECMR as dependent variables.

	Coefficient	P value	Confidence interval	
Log of difference in NMR (R^2 = 0.32)				
Log of GNI	−0.29	0.02	−0.53	−0.06
West/central Asia, North Africa, and Europe (reference)				
Sub-Saharan Africa	0.26	0.25	−0.19	0.71
South/South East Asia	0.29	0.15	−0.11	0.68
Latin America/Caribbean	0.01	0.98	−0.40	0.41
Constant	−0.39	0.04	−0.77	−0.01
Log of difference in PNMR (R^2 = 0.42)				
Log of GNI	−0.48	0.00	−0.76	−0.20
West/central Asia, North Africa, and Europe (reference)				
Sub-Saharan Africa	0.01	0.98	−0.53	0.55
South/South East Asia	0.16	0.50	−0.32	0.63
Latin America/Caribbean	−0.21	0.39	−0.70	0.27
Constant	−0.41	0.07	−0.87	0.04
Log of difference in ECMR (R^2 = 0.29)				
Log of GNI	−0.53	0.03	−1.00	−0.06
West/central Asia, North Africa, and Europe (reference)				
Sub-Saharan Africa	0.26	0.25	−0.19	0.71
South/South East Asia	0.29	0.15	−0.11	0.68
Latin America/Caribbean	0.01	0.98	−0.40	0.41
Constant	−0.39	0.04	−0.77	−0.01

Data sources: mortality rates were taken from Demographic and Household surveys (DHS) and GNI adjusted to constant 2010 US dollars were taken from the World Bank Database.

where NMR is over 20 per 1000, the pattern remains fairly similar with the coefficient for the log of GNI not significant for NMR, and for PNMR and ECMR an increase in GNI of 10% was associated with a decrease of 1.4% and 2.1%, respectively. Removing the poorest countries (e.g., GNI per capital less than $300 per capita) and the richest countries (GNI more than $3000 per capita) made very little difference to the model, and the coefficient for the log of GNI remains insignificant for NMR but significant for PNMR and ECMR.

When the regression results for the trend data were examined (see Table 3), the coefficient for change in GNI was significant for all component mortalities, but the results showed higher elasticities for postneonatal and early childhood mortality than for neonatal mortality: a 10% increase in GNI over time is associated with decreases of 2.6%, 4.8%, and 5.3% in NMR, PNMR, and ECMR, respectively. It can be noted that changes in GNI over time appear to have a greater impact on mortality than differences in GNI between countries at the same point in time for all component mortality rates. While confidence intervals are quite wide, postestimation testing of the hypothesis that the coefficients for log of change in GNI are equal in the equations for log of change in NMR and log of change in PNMR, and log of change in NMR and log of change in ECMR demonstrate the coefficients to be significantly different at the 5% level: $F(4, 44) = 4.42$ and $P = 0.004$. For these models the R^2 is actually greater for the equation for NMR than for ECMR (0.32, 0.42 and 0.29 for NMR, PNMR, and ECMR, resp.).

If the model includes only those 31 countries with estimates at least 15 years apart (where the differences are likely to be less affected by random fluctuations or sampling error) the coefficients are larger but the same pattern remains, with a 10% increase in GNI associated with decreases in 3.3%, 5.8%, and 6.1% in NMR, PNMR, and ECMR (all significant at the 1% level). Removing the five countries with a baseline NMR less than 20 per 1000 made almost no difference to the model. In nine of the countries (all in Sub-Saharan Africa) there was actually a fall in GNI during the time period. If these countries were removed from the model, the coefficients for all three groups increased, although again the patterns remained the same: a 10% increase in GNI was associated with decreases in 3.7%, 6.2%, and 6.9% in NMR, PNMR, and ECMR (NMR and PNMR significant at the 1% level and ECMR significant at the 5% level).

4. Discussion

This study suggests changes in GNI are associated with less impact on neonatal than postneonatal and early childhood mortality. Indeed, with the model controlled for region there appeared to be no significant association between NMR and GNI for the cross-sectional data. This may partially explain why progress in reducing deaths in the neonatal period has been poorer than for older ages. While improved child health services have undoubtedly contributed to the reduction of child mortality in some countries [9], a number of studies suggest that socioeconomic factors, which are often underpinned by an increase in GNI/GDP, have been important drivers of mortality reduction over the last few decades. For example, Filmer and Pritchett [10] concluded that the differences in infant and child mortality rates between countries can be overwhelmingly explained by a relatively small group of economic and social factors, with very little variation explained by public spending and health policy. Work by Rutstein [11] and Cornia and Mwabu [12] which looked at potential explanatory variables for reductions in child mortality over time suggest there has been no "magic bullet" in the reduction of child mortality, but socioeconomic factors such as women's education and literacy improved real average per capita household income, and environmental conditions (safe water supply sanitation and housing) have all played an important part in reducing child mortality, as well as improvements in health services and child nutrition.

These findings may well reflect the differing underlying causes of death for newborns and older children. Infectious diseases are the main cause of death in older children, while the main causes of neonatal mortality are intrinsically linked to the health of the mother and the care she receives during pregnancy and childbirth [4]. The improved household living standards that are usually implied by higher national income are likely to have a greater impact on infectious deaths (although it could be argued that improved maternal nutrition would also have a beneficial impact on newborn survival). On the other hand declines in neonatal mortality are associated with the development of effective maternal and primary health care services [4, 13], which are still lacking in many developing countries. These findings also mirror historical patterns in developed countries, where mortality in older children started to decline as a result of improved household conditions long before the development of effective health systems. However, neonatal mortality and in particular deaths in the first week of life did not fall markedly until effective maternal health services were in place.

If neonatal mortality is less affected by changes in GNI, it has implications for the extent to which increased wealth will reduce child mortality in different countries. For countries with lower overall child mortality, and therefore a higher proportion of neonatal deaths, the impact may be less than for countries with high overall mortality. This offers a novel perspective to the debate on the degree to which synergies between economic growth and the heath sector can contribute to the achievement of the Millennium Development Goals MDGs [3, 14]: benefit from synergies may well be focussed in countries where the majority of child deaths are in the postneonatal or early childhood period.

Further work is needed to establish the drivers for reduction in neonatal mortality at the national level. Research clearly shows that increased maternal education [15], lower fertility, and longer birth intervals [16] are associated with lower NMR, but there is limited substantive evidence to identify them as a key determinant of national level success in reducing newborn deaths. It is often difficult to differentiate the particular drivers of change as major improvements in health care often occur against a background of broader social development, and indeed these factors may work together synergistically rather than independently: for instance reductions in neonatal mortality in Chile and Qatar occurred concurrently with both improved health care and progress in education and broader socioeconomic wellbeing [17, 18]. However, it is generally accepted that sustained and significant reductions in neonatal mortality require the provision of a comprehensive and integrated package of preventative and curative maternal and child health services that provide a "continuum of care" during pregnancy, at delivery and in the critical first few days and weeks of a newborn life [19].

The potentially limited impact of economic growth on the reduction of neonatal mortality point to the importance of targeted, cost-effective health care interventions to be introduced if neonatal mortality is to be effectively lowered in developing countries.

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Conflict of Interests

The authors have declared that no competing interests exist.

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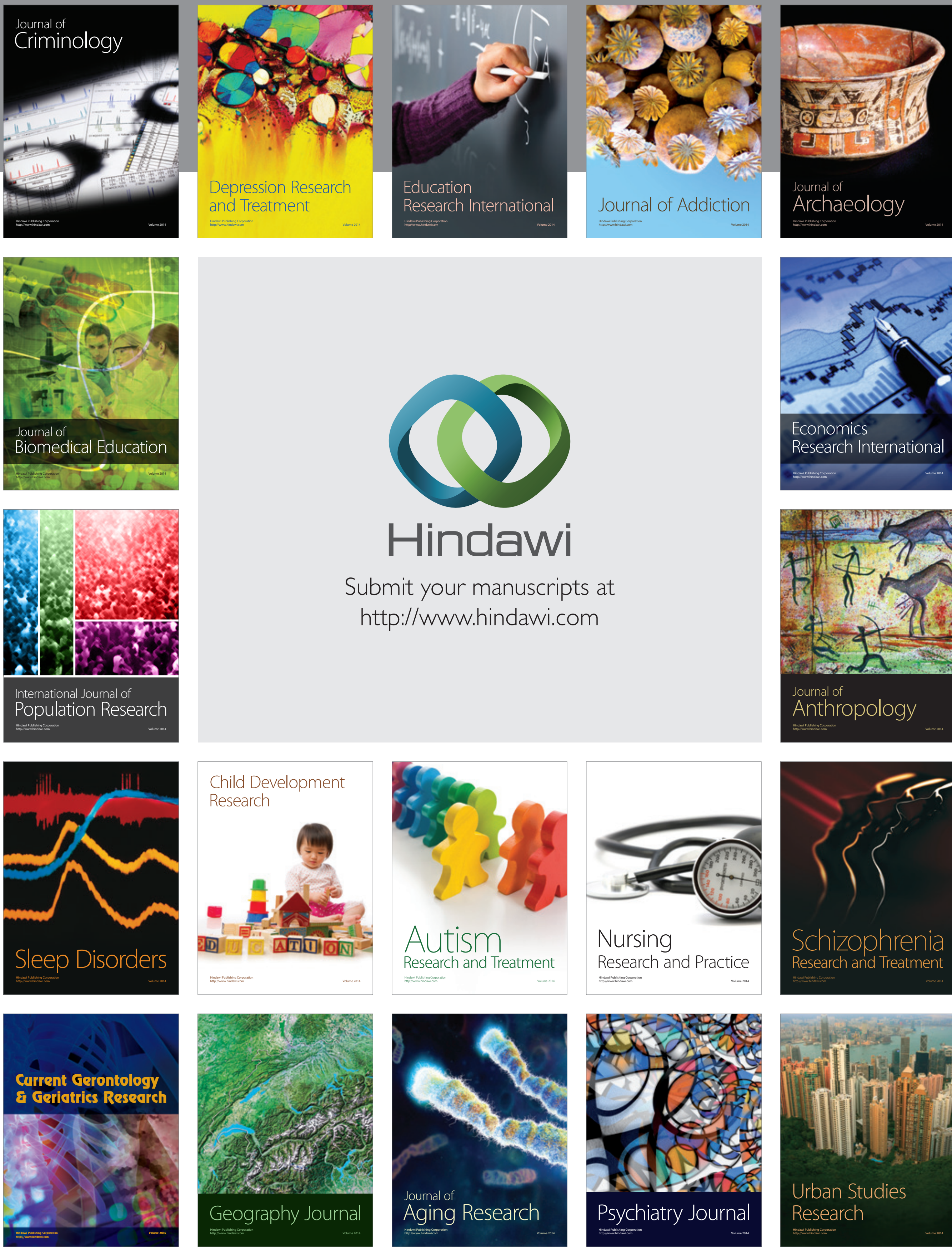
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