Environmental disclosure programs and birth weight: a meta- analysis

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Abstract

Environmental information disclosure programs are regulatory tools designed to reduce toxic emissions from polluting sites. These programs provide information on the most polluting sites and the type and quantity of their emissions, with the aim of protecting the environment and public health. Disclosed information is disseminated online through these programs' websites, and hence access to the internet is required in order to access this information.

This study evaluates the effectiveness of the most well-known international environmental information disclosure programs, namely TRI, E-PRTR, NPI, PROPER, EcoWatch, Greenwatch, NPRI, MVR, and AKOBEN. We compared the risk of low birth weight (LBW) before and after implementing these programs. We also considered the levels of internet accessibility in each country in which we evaluated the effectiveness of these programs. We conducted a meta-analysis to evaluate the effectiveness of these programs. We considered studies on the most well-known international environmental information disclosure programs and compared the risk of LBW before and after implementing these programs and also conducted a meta-regression to evaluate the factors influencing LBW risk.

Our analysis shows that in countries where these programs were in place, the risk of LBW had decreased for most programs except for the Toxic Release Inventory (TRI) and the European Pollutant Release and Transfer Register (E-PRTR), which had the opposite effect. The meta-regression results showed that maternal age and gestational duration significantly influence birth weight, with older mothers having a reduced risk of giving birth to LBW infants. Length of gestation is associated with decreased risk of LBW. Maternal education was negatively associated with birth weight, with mothers with higher education levels having an increased risk of giving birth to LBW infants. Time also showed a significant negative relationship with the incidence of LBW. Finally, a significant positive interaction was observed between the "program" and "internet" variables, suggesting that environmental disclosure may not reach certain vulnerable populations and that the presentation of information may play an important role in the effectiveness of these programs.

Keywords: Air pollution, birth weight, environment, meta-analysis, public information program.

JEL Classification Numbers: Q5, G53, I1, I18, K3.

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Introduction

Awareness of environmental pollution has grown in recent decades, due to the increasing environmental threats caused by industrialization, chemical production, energy consumption, and human activities. These activities have led to air, water, and soil pollution and have been associated with adverse health outcomes. As a result, there is a growing need to develop and implement measures, standards, and policies to reduce pollution and protect the environment.

Air pollution has been identified as a significant public health concern based on epidemiological evidence linking exposure to increased mortality, morbidity, and various respiratory and cardiovascular diseases, as demonstrated in the study by Brunekreef et al. (2002). Additionally, studies have also shown an association between maternal exposure to air pollution during pregnancy and adverse birth outcomes, including low birth weight (LBW), intrauterine growth retardation, preterm birth, and congenital malformations, as reported in studies such as Bobak and Leon (1992) and Dejmek et al. (1999). LBW, defined as a weight less than 2500g,[2] is often associated with preterm birth and is a crucial indicator of infant morbidity and mortality, as well as increased risk of chronic diseases in adulthood. Furthermore, studies have also shown that exposure to air pollution, even at low levels, can negatively affect infant mortality, as reported by Currie and Neidell (2005). The relationship between air pollution and these adverse outcomes has been the subject of numerous studies since the 1970s, with a consistent finding of a positive association between maternal exposure to air pollutants and these adverse outcomes.

Regulators have implemented various environmental regulatory policies, such as economic instruments and permit markets, to reduce the negative impacts of air pollution on human health and the environment. However, at the end of the 1980s, a new approach to environmental governance emerged, which emphasizes the provision of public information through environmental information disclosure programs as a means of reducing environmental risks and addressing the potential impacts of toxic substances on the environment, as reported in studies such as Graham et al. (2002). Environmental information disclosure programs aim to address the problem of asymmetric information between regulators and polluters, protect the right to a healthy environment for all, and involve civil society in environmental management. The information disseminated through these programs provides the public with knowledge about the levels and sources of air pollution and its potential health and environmental effects. This information can inform household decisions, such as relocating to areas with lower pollution levels or air toxicity.

Numerous countries worldwide have implemented environmental information disclosure systems, initiated by the United States in 1986 with the creation of the TRI. The

[2] LBW has been defined by WHO as weight at birth of < 2500 grams (5.5 pounds).

Netherlands and the Nordic European countries have taken a leading position in this field, surpassing other European countries such as Germany, France, and the United Kingdom. In addition, developing countries such as China, India, Indonesia, and the Philippines have also established disclosure systems to promote pollution control and improve environmental practices in response to traditional approaches deemed inadequate or unfeasible. The common goal of these different programs is to provide transparent information on polluting activities and stimulate the adoption of more environmentally friendly practices. However, the content, operation, and methods of communication with the public vary across countries' programs.

This study aims to assess and compare the effectiveness of different environmental information disclosure programs by examining their impact on infant health outcomes, specifically birth weight, an important indicator of newborn health. In addition, we will consider Internet accessibility levels, as this information is disseminated online through program websites. To do this, we will compare the impact of different environmental information disclosure programs on birth weight outcomes to determine their utility in raising household awareness of environmental quality and informing pregnant women about air quality, types, and sources of pollutants in their residential areas.

In the first section, we conduct a literature review of studies investigating the impact of toxic releases on birth weight outcomes. Studies that reported LBW were selected for use in meta-regression to analyze the effect of different explanatory variables on LBW outcomes. In the second section, we present the methodology and data used for the meta-analysis that investigates the impact of environmental disclosure programs on birth weight and compares the effectiveness of different environmental disclosure programs. In the third section, we present and discuss the results of our meta-analysis. Specifically, we present the results of the impact of different environmental disclosure programs on birth weight and then focus on the effects of two specific environmental disclosure programs, TRI and E-PRTR, on birth weight outcomes. In the fourth section, we conduct a meta-regression analysis using the random-effects (RE) and unrestricted weighted least squares (WLS) models to study the impact of different explanatory variables on birth weight outcomes. Finally, we conclude the study with a final section summarizing our findings and providing recommendations for policymakers and regulators on designing and implementing effective environmental governance strategies to protect public health.

1. Literature review

Multiple studies have examined the relationship between birth weight and air pollution levels. The first study on this topic was conducted by Williams et al. (1977), in which they analyzed the effect of air pollution in the most polluted areas of Los Angeles, California, on birth weight for the year 1973 using data from obstetric registers of births at the University of California at the Los Angeles Hospital. They found that the average birth weight of infants born in the most polluted areas was lower than those born in less polluted areas. Subsequent studies have also been conducted to investigate this relationship. For example, Ritz and Yu (1999) conducted a study to investigate the potential association between maternal exposure to carbon monoxide (CO) during pregnancy and LBW in infants born between 1989 and 1993 in California. Their findings revealed a positive relationship between maternal exposure to CO during pregnancy and an increased risk of LBW in infants. Another study, conducted by Salam et al. (2005) in California between 1975 and 1987, utilized data from the California Department of Health Services to assess the effects of several air pollutants, including O_3, NO_2, CO, and PM_{10}, on birth weight. The results indicated that higher gestational exposure to O_3, CO, and PM_{10} was associated with reduced birth weight by 47.2 g, 21.7 g, and 21.7 g, respectively.

Chay and Greenstone (2003a, 2003b) conducted studies to investigate the association between total suspended particulate matter (TSP) levels in the air across various counties in the United States and the incidence of LBW in infants. The study's utilized data from the Mortality Detail Files and National Natality Detail Files. The study findings revealed a statistically significant correlation between TSP concentration in the air and the percentage of infants with LBW. The results suggest that a decrease in TSP concentration from 93.1 to 75.6 between 1969 and 1974 led to an 8.3% to 7.6% reduction in the rate of low LBW newborns. Similarly, the decrease in TSP concentration from 69.4 to 59.8 between 1979 and 1984 reduced the LBW rate from 7.2% to 6.9%.

In a study by Maisonet et al. (2001), ambient CO and SO_2 were found to correlate positively with LBW in six cities in the northeastern United States. The data for birth weight was obtained from the National Center for Health Statistics. In Washoe County, Northern Nevada, Chen et al. (2002) investigated the association between the concentration levels of PM_{10}, CO, and O_3 in the air and LBW between 1991 and 1999. The birth data used in this study were obtained from the Bureau of Health Planning and Vital Statistics, Nevada State Health Division. The results of this study indicated that PM_{10} was associated with a decrease in birth weight of 10 g, while CO and O_3 were not associated with a decrease in birth weight. Ebisu and Bell (2012) also assessed the association between chemical pollutants in the air ($PM_{2.5}$, PM_{10}, CO, NO_2, O_3, and SO_2) and LBW in the northeastern and central Atlantic states. The results of this study suggested that maternal exposure to $PM_{2.5}$ had a negative impact on birth weight, while the effects of other chemical pollutants were less harmful than $PM_{2.5}$. Similarly, in Connecticut and Massachusetts, a study by Bell et al. (2007) examined the impact of maternal exposure to various pollutants PM_{10}, $PM_{2.5}$, SO_2, NO_2, and CO) on birth weight. The data used in this analysis were obtained from the Vital Statistics Division, Reproductive Statistics Branch of the National Center for Health Statistics. The results of this study indicated that maternal exposure to , NO_2, CO, PM_{10}, and $PM_{2.5}$ led to a decrease in birth weight, with the greatest decrease observed for exposure to CO and $PM_{2.5}$ (16.2g and 14.7g, respectively). In Texas, Geer et al. (2012) evaluated the influence of air pollution on birth weight between 1998 and 2004. The data for birth weight were obtained from the Texas Department of State Health Services, Vital Statistics. The study results indicate that a high concentration of SO_2 causes an average decrease in birth weight of 4.99 g, and a high concentration of O_3 causes a reduction in birth weight of 2.72 g.

Gray et al. (2010) studied the link between maternal exposure to PM_{10} and $PM_{2.5}$ and birth weight in North Carolina, United States, between 2000 and 2002. Data on births were obtained from the North Carolina State Center for Health Statistics. This study showed that an increase in PM_{10} concentration in the air led to a decrease of 5.3g in average birth weight, and an increase in $PM_{2.5}$ concentration led to a reduction of 4.6g in average birth weight. Bell et al. (2010) examined the association between maternal exposure to ambient $PM_{2.5}$ and birth weight in Connecticut and Massachusetts, United States, between 2000 and 2004. Data on births were obtained from birth certificate data from the National Center for Health Statistics. This study also showed a link between maternal exposure to $PM_{2.5}$ and LBW. Darrow et al. (2011) conducted a study to evaluate the effects of gaseous air pollutants (CO, NO_2, SO_2, O_3, PM_{10}, and $PM_{2.5}$) on birth weight in Atlanta, United States, between 1994 and 2004. Birth data were obtained from the Office of Health Information and Policy, Georgia Division of Public Health. The results of this study indicated that air pollutants were associated with an increased risk of LBW and a reduction in birth weight between 4g and 16g with increasing pollutant concentrations in the air. Savitz et al. (2014) examined the effects of $PM_{2.5}$ and NO_2 on birth weight in the city of New York, between 2008 and 2010. The data for birth weight were obtained from vital records in hospitals in New York. The results of this study showed that for every 10 $\mu g/m^3$ increase in $PM_{2.5}$ exposure, there was a decrease of 48.4g in birth weight, and for every ten ppb increase in NO_2 exposure, there was a decrease of 18g in birth weight.

In the Czech Republic, Bobak and Leon (1999) investigated the association between LBW and exposure to SO_2, TSP, and NO using birth data from the systematic birth registration published by the Czech Statistical Office between 1986 and 1988. This study showed a positive association between LBW and concentrations of SO_2 and NO. The following year, Bobak (2000) conducted a similar study using birth data recorded by the Czech National Birth Register in 1991 and found an association between maternal exposure to SO_2 and LBW, but no relationship between LBW and other contaminants was reported. In Oslo, Norway, Madsen et al. (2010) examined the link between maternal exposure to air pollution, temperature, and LBW using data from The National Birth Registry of Norway between 1999 and 2002. They found a reduction of 29.7g in birth weight for infants whose mothers were exposed to higher levels of NO_2 compared to those whose mothers were exposed to lower levels. In Rotterdam, Netherlands, Hooven et al. (2012) investigated whether infant health was affected by PM_{10} and NO_2 between 2001 and 2005. This study showed maternal exposure to PM_{10} and NO_2 was inversely associated with fetal growth and birth weight. High exposure to PM_{10} was also related to premature birth.

In Canada, Liu et al. (2003) examined the influence of air pollution on LBW using data obtained from the live birth database maintained by Statistics Canada for 1986 and 1998. The study found a relationship between maternal exposure to SO_2 during the first month of pregnancy and LBW. Gouveia et al. (2004) studied the relationship between air pollution exposure during pregnancy and weight at birth in Sao Paulo, Brazil, using data from the Birth Information System (SINASC) of the Ministry of Health in Brazil for 1997. They found that maternal exposure to PM_{10} and CO during the first trimester had adverse effects on newborns' birth weight, with a 23g drop in birth weight for a one ppm increase in exposure to PM_{10} and CO.

Ha et al. (2001) used data from the Korean National Birth Register of 1996-1997 to explore the correlation between gestational exposure to various air pollutants and birth weight in Seoul, South Korea. The research revealed that increased exposure to CO, NO_2, SO_2, and TSP reduced birth weight by 11.55 g, 8.41 g, 8.06 g, and 6.06 g, respectively. Lee et al. (2003) conducted a similar study in Seoul, South Korea, between 1996 and 1998. They replaced TSP with PM_{10} and obtained the same results as Ha et al. (2001), showing that LBW was associated with maternal exposure to these air pollutants. Shin et al. (2005) conducted a third study in South Korea, which analyzed data from 108,486 newborns in 2001. The results showed that the LBW rate was 7.2%. Lin et al. (2010) conducted a study comparing the birth weight of two Taiwanese cities between 1995 and 1997. They found that the prevalence of low-weight infants was higher in Kaohsiung, a petrochemical industrial city with higher air pollutant concentrations (2.4%), compared to Taipei, a non-petrochemical industrial city (2.1%).

Wang et al. (1997) conducted a study in Beijing, China, between 1988 and 1991 to investigate the link between maternal exposure to SO_2 and TSP in the air and LBW. This study showed an association between LBW and the two air pollutants, with a decrease of 7.3g in birth weight for every 100 ug/m^3 increase in SO_2 and a reduction of 6.9g in birth weight for every 100 ug/m^3 increase in TSP. In Japan, Yorifuji et al. (2015) used data on infant health obtained from The Japanese Vital Statistics in 2001 to study the relationship between maternal exposure to different air pollutants: SPM, NO_2, SO_2, and LBW. This study's results indicated a positive correlation between birth weight and air pollution exposure. In addition, the effect of SO_2 exposure was associated with risk throughout the gestation period, while the risk of exposure to SPM and NO_2 was higher in the first semester than in other semesters.

Finally, in Tehran, Iran, Araban et al. (2012) conducted a study to investigate the impact of air pollution on LBW in 2007. The study used data from infants born to mothers within a 5 km radius of an air pollution monitoring station during pregnancy. The study showed a significant impact of maternal exposure to CO on LBW; however, no significant impact was found for other gases such as PM_{10}, SO_2, NO_2, and O_3.

2. Method and data

A meta-analysis method was utilized to study the impact of environmental disclosure programs on birth weight. Meta-analysis is a statistical technique that combines the results of multiple studies to arrive at a more precise estimate of the effect of a particular intervention. This method was chosen for this study because it has been widely used in recent years to measure the effect of new treatments and provides a way to synthesize the results of different research studies that address the same question. In this study, the meta-analysis enabled the comparison of birth weight before and after the implementation of information disclosure programs in different years and countries, providing a comprehensive understanding of the effect of such programs on birth weight.

2.1. Environmental Disclosure Programs

In recent decades, various countries have implemented environmental information disclosure programs to complement legal and economic instruments to combat industrial pollution. The main objective of these programs is to involve civil society in environmental management and to encourage industries to reduce their toxic releases.

In this study, we aim to investigate the impact of environmental information disclosure programs on birth weight in several countries, including the United States, the European Union, China, Canada, Indonesia, the Philippines, South Korea, Australia, and Ghana. To assess the effect of these programs, we will compare birth weight in these countries between two time periods: before and after the implementation of environmental information disclosure programs. Additionally, we will conduct separate data analyses for the two environmental information disclosure programs E-PRTR and TRI, to measure the effect of E-PRTR on the number of LBW newborns for each member country of this program and the same for the TRI for all states of the United States. This will provide a comprehensive understanding of the impact of environmental information disclosure programs on birth weight in these countries.

- **In the United States: The Toxic Release Inventory program**

Toxic Release Inventory (TRI)[3] is a database maintained by the Environmental Protection Agency (EPA) that contains information on the release and management of certain toxic chemicals by industrial and federal facilities in the United States. The Emergency Planning and Community Right-to-Know Act (EPCRA) established the TRI program in 1986. Facilities that meet specific criteria must report information on the release of certain

[3] Source: https://www.epa.gov/toxics-release-inventory-tri-program (accessed January 2023)

chemicals to the environment and their management through recycling, energy recovery, and treatment.

- **In Europe: The European Pollutant Release and Transfer Register**

The European Pollutant Release and Transfer Register (E-PRTR)[4] is a European Union (EU) program that requires industrial facilities to report annually on the releases of specific pollutants to the air, water, and land, as well as off-site transfers of waste and pollutants in wastewater. The program is established under the EU's PRTR Regulation (Regulation (EC) No 166/2006), aiming to improve the transparency and accessibility of information on pollutant releases and transfers to the public. The E-PRTR is a publicly available database that contains information on the releases and transfers of pollutants from industrial facilities across the EU Member States.

- **In Indonesia: PROPER**

Program for Pollution Control, Evaluation, and Rating (PROPER) is a program implemented by the Indonesian government to evaluate and rate the performance of industrial facilities in terms of their compliance with environmental regulations. The Ministry of Environment and Forestry runs the program and aims to reduce pollution by encouraging industrial facilities to improve their environmental performance. PROPER was launched in 1995, and it evaluates industrial facilities based on several criteria, including compliance with legal requirements, pollution prevention and control, and community involvement. Facilities that meet specific performance standards are awarded a rating, and those that receive higher ratings are eligible for various incentives and recognition from the government. The program has been credited with helping to reduce pollution and improve environmental performance in the industrial sector in Indonesia (Afsah et al., 2013).

- **In Ghana: Akoben**

Akoben[5] is an environmental rating system used in Ghana to evaluate and rate the performance of industrial facilities in terms of their compliance with environmental regulations. The program is run by Ghana's Environmental Protection Agency (EPA) and aims to reduce pollution by encouraging industrial facilities to improve their environmental performance. It was launched in 2007. It is based on the African Quality of Life (AQL) model, which considers several environmental, health, and social factors. The program evaluates industrial facilities based on several criteria, including compliance with legal requirements, pollution prevention and control, and community involvement. Facilities that meet specific performance standards are awarded a rating, and those that receive higher

[4] Source: https://ec.europa.eu/environment/industry/stationary/e-prtr/legislation.htm (accessed November 2022)

[5] Source: http://www.epaghanaakoben.org/ (accessed November 2022)

ratings are eligible for various incentives and recognition from the government. The Akoben rating system is a tool that allows companies to evaluate their environmental performance and identify areas for improvement.

- **In Philippines: Ecowatch**

Ecowatch[6] is an environmental monitoring and reporting system used in the Philippines to evaluate and track the performance of industrial facilities in terms of their compliance with environmental regulations. The program is run by the Department of Environment and Natural Resources (DENR) and aims to reduce pollution by encouraging industrial facilities to improve their environmental performance. Ecowatch, launched in 2015, is a web-based system allowing the DENR to monitor industrial facilities in real-time. It tracks data on various environmental indicators, including air and water quality, waste management, and energy consumption. Facilities are required to submit regular reports to the DENR through the Ecowatch system, and the data are made available to the public through the DENR website. The program aims to improve transparency and accountability in the industrial sector by making it easier for the government to monitor compliance with environmental regulations and for the public to access information about the environmental performance of individual facilities.

- **Canada: The National Pollutant Release Inventory**

The National Pollutant Release Inventory (NPRI)[7] is a program in Canada that requires certain industrial facilities and mines to report annually on the releases, disposals, and recycling of specific pollutants to the air, water, and land. The program is managed by Environment and Climate Change Canada (ECCC) and is established under the Canadian Environmental Protection Act (CEPA). The NPRI program was launched in 1992, providing Canadians with information on pollutants in their communities. The NPRI is a publicly available database that contains information on the releases, disposals, and recycling of contaminants from industrial facilities and mines across Canada. The data is collected annually, and the facility must report on its releases of over 600 pollutants, including greenhouse gases, toxic chemicals, and particulate matter. The information is then made available to the public through the NPRI website. The program is intended to promote pollution prevention by providing information to industry, government, and the public about pollution releases and by encouraging facilities to reduce their emissions of pollutants. The NPRI also helps to inform policy-making and the development of regulations and supports research and monitoring activities.

[6] Source: https://www.ecowatch.com/oil-spill-philippines-2646399186.html (accessed November 2022)

[7] Source: https://www.canada.ca/en/services/environment/pollution-waste-management/national-pollutant-release-inventory.html (accessed December 2022)

- **Australia: The National Pollutant Inventory**

The National Pollutant Inventory (NPI)[8] is a program in Australia that requires certain industrial facilities to report annually on the emissions of certain pollutants to the air, water, and land. The program is managed by the Australian Government Department of the Environment and Energy, and was established under the National Environment Protection Measure (NEPM). The NPI program was launched in 1998, providing Australians with information on pollutants in their communities. The NPI is a publicly available database containing information on pollutant emissions from industrial facilities across Australia. The data is collected annually, and the facility must report on its emissions of over 300 pollutants, including greenhouse gases, toxic chemicals, and particulate matter. The information is then made available to the public through the NPI website.

- **South Korea: Monthly Violations Report**

During the rapid economic expansion of the 1970s and 1980s, the South Korean government was hesitant to strictly enforce its environmental regulations, fearing that it would harm economic performance and the competitiveness of industrial facilities. On the other hand, pressure on the government to improve environmental protection in the country was increasing (Dasgupta et al., 2006). In this context, the Monthly Violation Report (MVR) was first released in March 1984 by the Environmental Administration in the form of information documents distributed to journalists. The MVR describes a list of facilities that violate South Korean laws and regulations related to the environment. These violations include, among others, emissions standards violations and pollution control equipment failures. The Ministry of Environment classifies emitting facilities into five categories. However, while the ministry inspects all facilities in categories 1 to 5, it only discloses the names of companies from categories 1 to 3, even though most facilities belong to categories 4 and 5 (Long et al., 2003).

- **China: GreenWatch**

China's State Environmental Protection Agency (SEPA) is interested in public disclosure because China's pollution problem remains severe, despite long-standing attempts to control it with traditional regulatory instruments. Since 1998, supported by the World Bank's InfoDev Program, the present authors have been working with SEPA to establish GreenWatch, a public disclosure program for polluters. Adapted from Indonesia's PROPER, the GreenWatch program rates firms' environmental performance from best to worst in five colors—green, blue, yellow, red, and black. The media disseminates the ratings to the public (Wang et al., 2004).

[8] Source: https://www.dcceew.gov.au/environment/protection/npi (accessed January 2022)

2.2. Internet

To examine the influence of environmental disclosure programs on birth weight, we have considered the internet accessibility levels in each country, a crucial parameter for evaluating the accessibility of these programs for individuals. In addition, online platforms are often used to disseminate information related to these programs. Thus, it is pertinent to investigate the correlation between internet accessibility levels and the impact of environmental information disclosure programs on birth weight. The data on the level of internet access in each country were collected from The World Bank.[9]

To explore the relationship between internet accessibility levels and birth weight, we categorized the data into several categories based on the internet accessibility levels in each country, ranging from less than 10% to less than 90%. This classification allowed for a comparison of the impact of environmental information disclosure programs on birth weight in countries with differing levels of internet accessibility. Additionally, we compared the period when internet access was unavailable to determine the influence of internet access on birth weight. This methodology comprehensively examined the relationship between internet accessibility levels, environmental information disclosure programs, and birth weight. Moreover, it helped determine if implementing these programs had a greater effect in countries with higher internet accessibility levels.

2.3. Birth weight data

The number of births and LBW data were collected from public health institutions in nine countries and Europe. The data sources included Vital Statistics of the United States, Australia's Mothers, and Babies, the World Health Organization,[10] Canada.ca,[11] the Indonesia Demographic and Health Survey (IDHS)[12], the Korean Statistical Information Service (KOSIS)[13], and The World Bank.

To investigate the impact of environmental information disclosure programs on birth weight, we conducted a meta-analysis of LBW data in the presence and absence of such programs. In addition, we considered varying internet accessibility levels to assess the impact of the programs, as internet access is required to access the disclosed information

[9] Source: https://data.worldbank.org/ (accessed January November 2022)

[10] Source: https://www.who.int/(accessed January September 2022)

[11] Source: https://www.canada.ca/fr.html(accessed January September 2022)

[12] Source: https://dhsprogram.com/(accessed January September 2022)

[13] Source: https://kosis.kr/eng/(accessed January September 2022)

online. This approach enabled us to compare the number of LBW births before and after the implementation of the programs based on the different internet accessibility levels in the countries of interest. This also enables us to examine whether implementing these programs has had a greater impact in countries with higher internet accessibility levels.

3. Meta-analysis results

In this section, we present a meta-analysis intended to evaluate the efficacy of environmental disclosure programs in reducing environmental impact incidence, specifically regarding birth weight. This analysis's primary objective is to investigate these programs' effectiveness and compare their impacts. Initially, an overall analysis of the effect of all birth weight disclosure programs is conducted, followed by a more targeted assessment of the effect of the E-PRTR program in each member state and the effect of the TRI program on the US states.

3.1. Environmental information disclosure programs and low birth weight

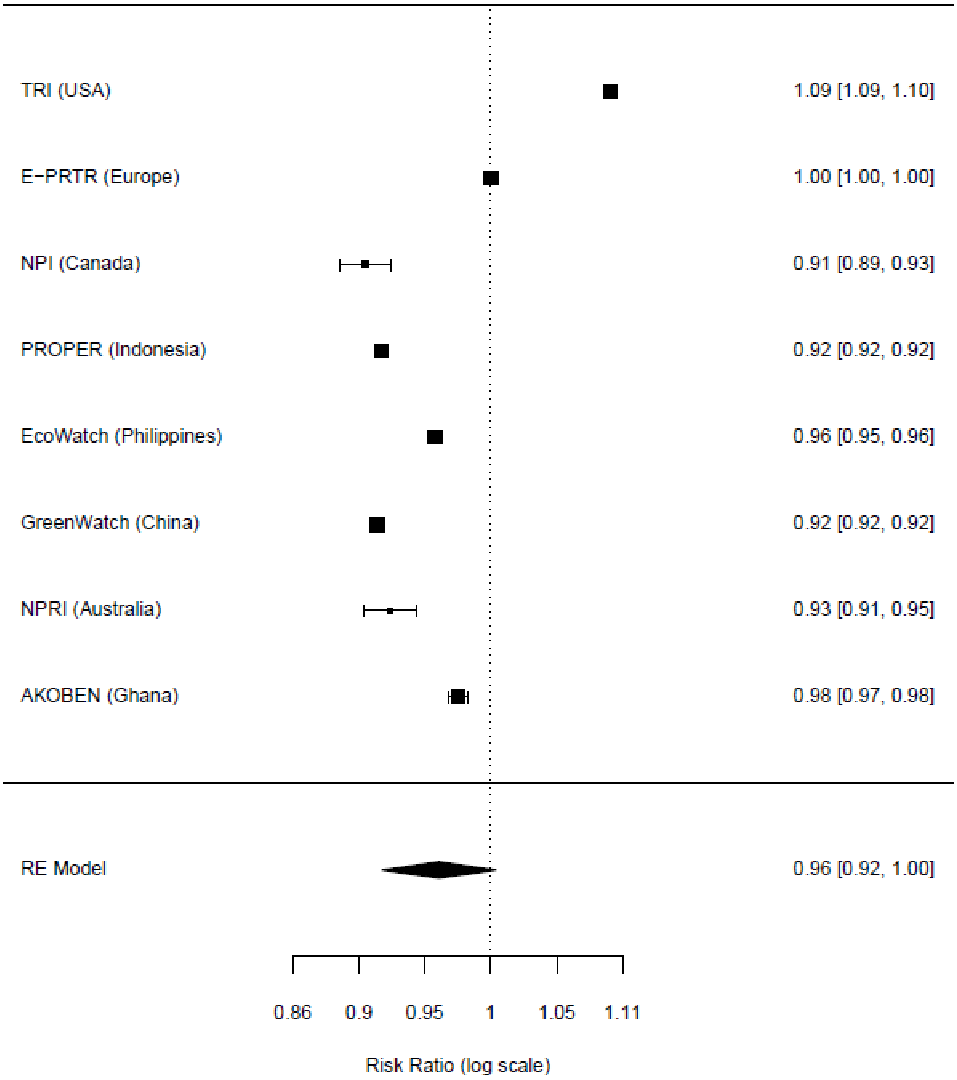
In this sub-section, we aim to examine the effects of various environmental disclosure programs on birth weight while considering the evolution of internet accessibility levels. Specifically, we aim to compare the impact of these programs on birth weight across countries with different levels of internet penetration to determine whether the program's effectiveness varies with the availability of information online. This analysis explores the relationship between internet accessibility levels, environmental disclosure programs, and birth weight.

We used the risk ratio (RR) to evaluate the association between implementing environmental disclosure programs and the incidence of LBWs. RR represents the ratio of risk between the exposed group and the unexposed group (Kim, 2017). Specifically, in this study, RR is employed as a metric to measure the degree of association between the likelihood of LBW after implementing information disclosure programs and the probability of LBW before implementing such programs while considering internet accessibility levels.

$$RR = \frac{\text{risk of LBW after the implementation of programs}}{\text{risk of LBW before the implementation of programs}} = \frac{X/(X+Y)}{Z/(Z+W)}$$

An RR equal to 1 indicates no association, an RR greater than 1 indicates an increased risk of LBW, and an RR less than 1 indicates a reduced risk of LBW. The number of LBWs and normal birth weights after the program's implementation is denoted as X and Y, respectively, while the number of low and normal birth weights before the program is designated as Z and W, respectively. Thus, X+Y represents the total number of births after implementing the information disclosure program, and Z+W represents the total number of births before the program.

Figure 1: Effect of environmental disclosure programs on the number of LBW, considering levels of internet accessibility greater than 10 %



Note: This forest plot (Figure 1) shows the risk ratios in log for each program (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of all information disclosure programs on the number of LBW (N = 8: information disclosure program).

According to Figure 1, implementing environmental disclosure programs in a population with internet accessibility levels above 10 % is associated with a 4 percentage points[14] (pp) reduction in the incidence of LBW newborns, as demonstrated by a hazard ratio of

[14] Percentage points refer to the difference between two percentages expressed as a whole number.

0.96. In addition, six environmental disclosure programs, conducted in Canada, Indonesia, the Philippines, China, Australia, and Ghana, exhibited statistically significant reductions in the incidence of LBW newborns following program implementation compared to pre-implementation rates. Conversely, the implementation of the E-PRTR program in Europe showed no significant change in LBW incidence (with a ratio of 1). In contrast, in the United States, implementing similar programs was associated with a significant increase in LBW incidence (9 pp).

Table 1: Correlation between environmental disclosure program and LBW, while considering varying levels of internet accessibility

LBW/internet users (%)	LBW USA	LBW EU	LBW Canada	LBW Indonesia	LBW Philippines	LBW S.K.	LBW China	LBW Australia	LBW Ghana	Total[15]
10 %	*+9*	*0*	*-9*	*-8*	*-4*	*-*	*-8*	*-7*	*-2*	*- 4*
20 %	*+11*	*+17*	*-7*	*-11*	*-5*	*+44*	*-10*	*-7*	*-4*	*+ 2*
30 %	*+12*	*+17*	*-5*	*-11*	*-5*	*+46*	*-12*	*-7*	*-5*	*+ 2*
40 %	*+12*	*+17*	*-4*	*-16*	*-6*	*+46*	*-13*	*-6*	*-*	*+ 2*
50 %	*+16*	*+16*	*0*	*-17*	*-6*	*+48*	*-14*	*-5*	*-*	*+ 3*
60 %	*+18*	*+16*	*+2*	*-*	*-6*	*+55*	*-*	*-5*	*-*	*+ 12*
70 %	*+22*	*+16*	*+9*	*-*	*-*	*+59*	*-*	*-6*	*-*	*+ 18*
80 %	*+21*	*-*	*+11*	*-*	*-*	*+88*	*-*	*-5*	*-*	*+ 24*

Note: S.K. is South Korea

Table 1 illustrates the correlation between various environmental disclosure programs and the incidence of LBW in relation to the levels of internet accessibility. The forest plot containing the additional percentages of internet usage can be found in the appendix, specifically Figures 1.1, 1.2, 1.3, 1.4, and 1.5.

Table 1 reveals a general trend towards an increase in the proportion of infants with LBW, ranging from -4 pp to +24 pp. However, a more in-depth analysis of individual programs indicates a decrease in LBW in several countries. For instance, implementing the PROPER environmental disclosure program in Indonesia was linked to a 17 pp reduction in LBW infants. Similarly, in the Philippines, the EcoWatch program was associated with a 6 pp reduction in LBW infants, while in China, the GreenWatch program was associated with a 14 pp reduction in such deliveries. Moreover, the NPI program in Australia was linked to a 5 pp reduction in LBW pregnancies, and the AKOBEN program in Ghana was associated with a 5 pp decrease in vaginal deliveries resulting in LBW infants.

However, in Europe and the United States, LBW has increased despite the implementation of environmental information disclosure programs and an increase in the

[15] LBW variation, expressed in percentage points relative to the period before the implementation of information disclosure programs

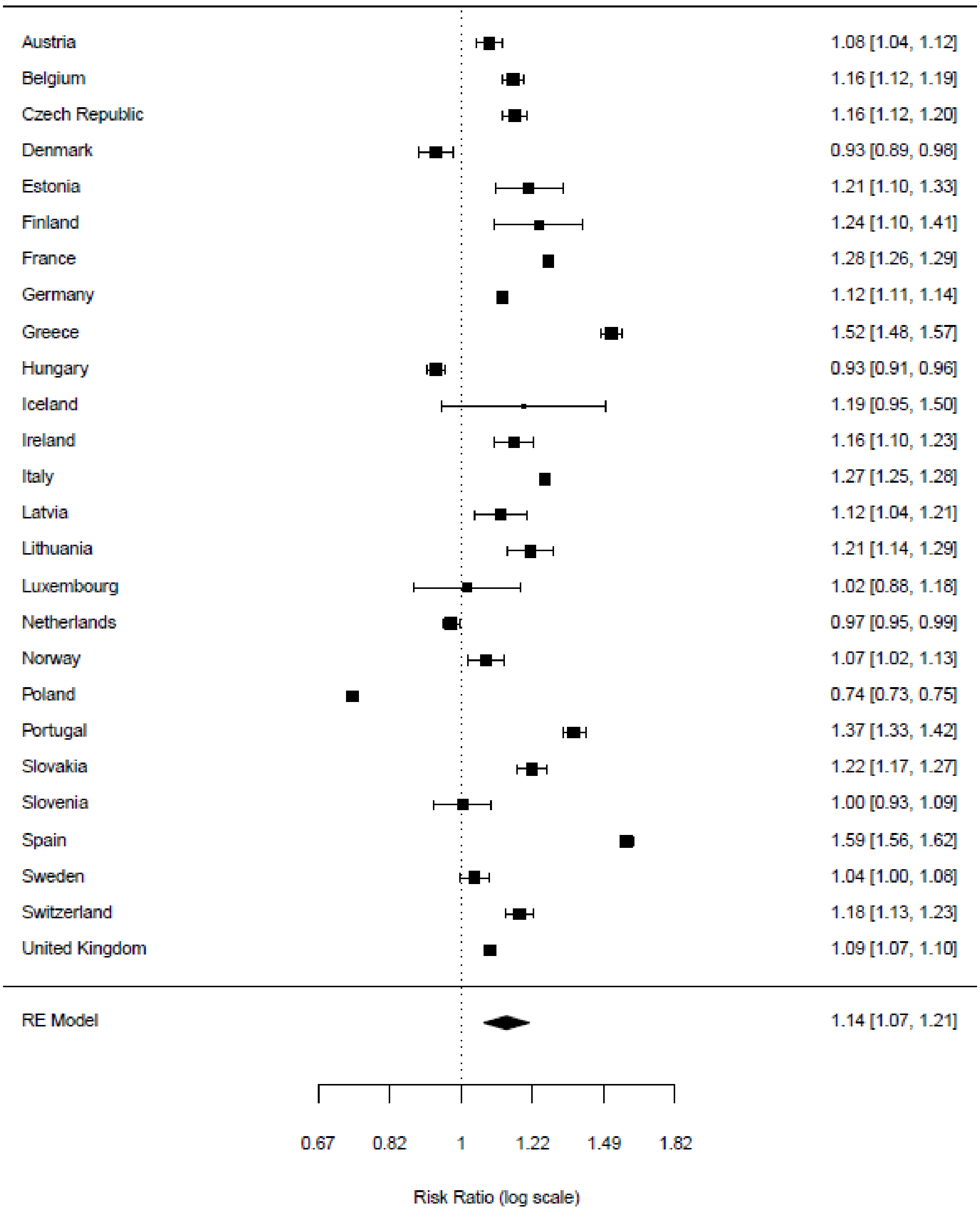
levels of internet accessibility compared to the pre-implementation of the E-PRTR and TRI programs. In Europe, the number of LBW has increased by +16 pp, while in the United States, it has increased by +21 pp. Therefore, there has not been the expected decrease in LBW in Europe and the United States with the implementation of information disclosure programs and an increase in the levels of internet accessibility, even though, since this information is disclosed online, the public can better learn about the quality of the environment in their place of residence.

Concerning the South Korea results, it was found that there was a considerable rise in the incidence of LBW even though it was already relatively high before the implementation of the MVR program. Our findings suggest that the issue in Korea is not related to environmental quality but rather stems from two factors. Firstly, LBW infants are omitted from national statistics, as birth registration is not mandatory for infants who pass away shortly after birth. Secondly, our study may have overestimated the fetal and neonatal mortality rate due to a higher response rate among tertiary care hospitals and general hospitals than hospitals and private obstetric clinics. The Health Insurance Review Agency report indicates that almost half of all deliveries occur in local private clinics, with only 8% in tertiary care hospitals. As a result, data obtained from tertiary care hospitals dealing with more high-risk pregnancies may inflate the incidence of fetal and neonatal mortality (Shin et al., 2005).

3.2. E-PRTR and low birth weight

The E-PRTR is a European registry providing environmental information from industrial facilities in the European Union's member states, Iceland, Norway, and Switzerland. The previous section's results have shown that the E-PRTR did not have the expected effects on LBW. However, given the involvement of several European countries in the program, we conducted an analysis to determine if the impact of the E-PRTR is consistent across all member states. We aim to evaluate whether this program produces consistent results in all participating countries.

Figure 2: Effect of E-PRTR on the number of LBW, considering levels of internet accessibility greater than 10 %



Note: This forest plot (Figure 2) shows the risk ratios in log for each country (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of E-PRTR on the number of LBW for European countries (N = 26: information disclosure program).

Implementing the E-PRTR environmental disclosure program, when considering a population with a greater than 10% level of internet accessibility, results in a 14% increase in LBW infants, as evidenced by a risk ratio of 1.14. Figure 2 illustrates that the number of

LBWs has increased in most European countries following the implementation of E-PRTR. However, there are four exceptions: Denmark, Hungary, Netherlands, and Poland, where the number of LBWs has decreased compared to pre-implementation. Table 2 presents the correlation between the E-PRTR and the number of LBWs while considering the levels of internet accessibility for each country included in the E-PRTR. The data is presented in terms of odds ratios and can be found in the appendix (2.1, 2.2, 2.3, 2.4, 2.5, 2.6, and 2.7) for further analysis.

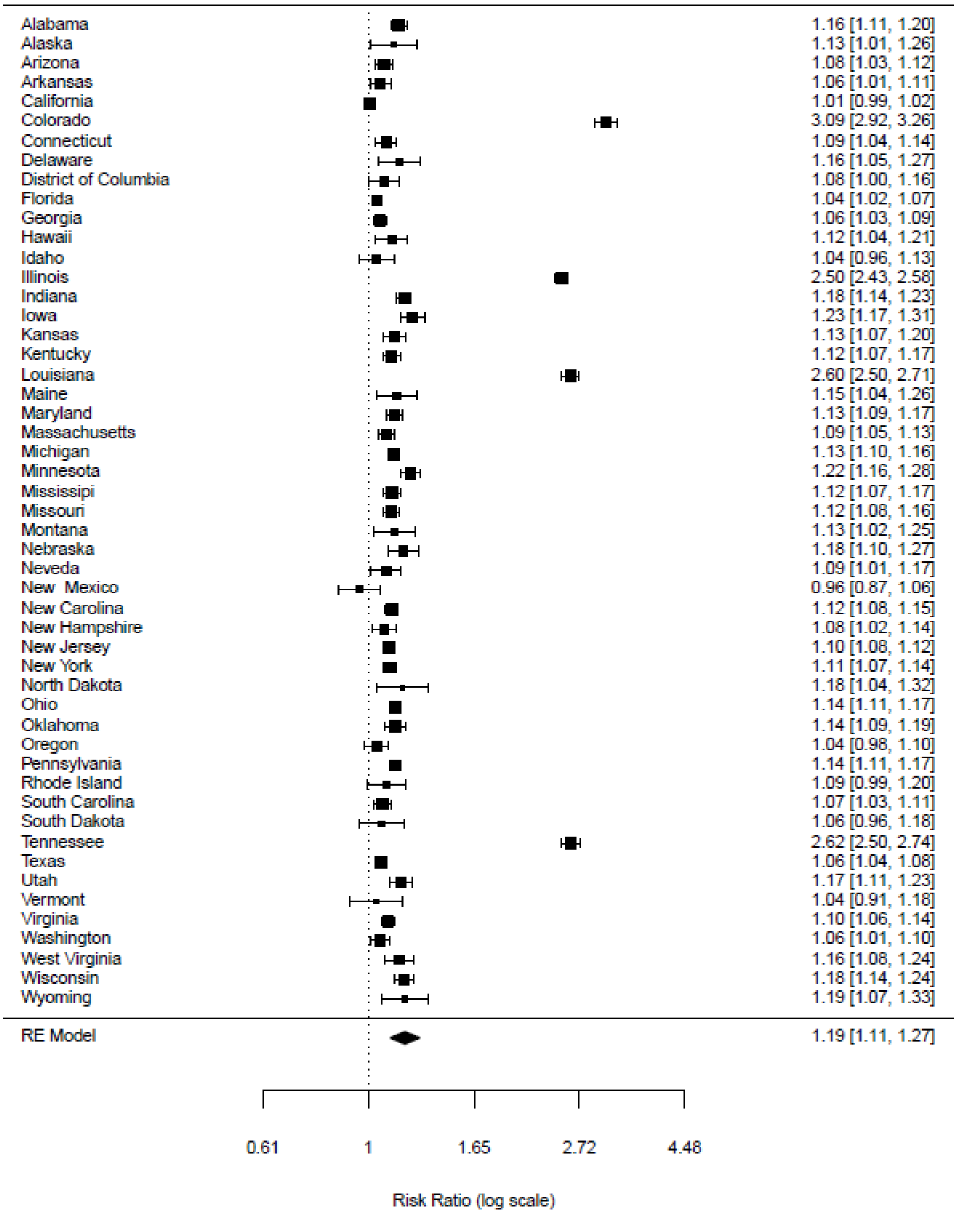
Table 2: Correlation between E-PRTR and birth weight, while considering varying levels of internet accessibility

States/internet users (%)	10 %	20 %	30 %	40 %	50 %	60 %	70 %	80 %
Austria	+8	+10	+12	+20	+19	+24	+24	+17
Belgium	+16	+16	+16	+11	+12	+12	+11	+11
Czech Republic	+16	+20	+25	+36	+48	+43	+50	+50
Denmark	-7	-7	-6	-5	-2	-4	-4	-3
Estonia	+21	+21	-1	0	-2	+1	+1	0
Finland	+24	+23	+22	+22	+23	+21	+20	+20
France	+28	+27	+27	+27	+26	+27	+26	+26
Germany	+15	+14	+12	+45	+19	+52	+45	+21
Greece	+52	+50	+49	+48	+66	+48	+48	-
Hungary	-7	-9	-9	-9	-11	-9	-7	-4
Iceland	+19	+19	+19	+21	+34	+23	+23	+23
Ireland	+16	+17	+18	+18	+17	+19	+24	+35
Italy	+27	+27	+25	+25	+27	+24	+24	-
Latvia	+12	+12	+9	+8	+2	+4	+1	0
Lithuania	+21	+21	+21	+19	+18	+17	+16	+15
Luxembourg	+2	+2	-6	-13	-28	-14	-13	-6
Netherlands	-3	-3	-3	-3	-8	-9	-14	-14
Norway	+7	+7	+7	+7	+7	+8	+9	+9
Poland	-26	-25	-24	-25	-28	-28	-25	-25
Portugal	+37	+37	+39	+45	+46	+57	+35	-
Slovakia	+22	+23	+23	+23	+29	+35	+40	+35
Slovenia	0	+2	+2	+6	+5	+10	+10	10
Spain	+59	+66	+69	+72	+64	+82	+87	+88
Sweden	+4	+4	+4	+4	+2	-1	-1	-2
Switzerland	+18	+18	+18	+18	+22	+20	+24	+27
United Kingdom	+9	+9	+10	+10	+13	+10	+10	+6
All	+14	+14	+13	+15	+14	+16	+17	+13

3.3. TRI and low birth weight

EPCRA established the TRI program to inform the general public about the United States toxic industrial releases. Similar to the analysis conducted for the E-PRTR program, it is essential to investigate the impact of TRI across all US states as the program is implemented nationwide. Such an analysis will enable us to determine if the outcomes are consistent across all states', notably concerning the apparent increase in the number of LBW incidents after the implementation of TRI.

Figure 3: Effect of TRI on the number of LBW, considering levels of internet accessibility greater than 10 %



Note: This forest plot (Figure 3) shows the risk ratios in log for each US (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates TRI's effect size on the number of LBW for the United States (N = 51 States).

The implementation of the TRI program, similar to the E-PRTR program, did not have the expected effects on the number of LBW cases. According to Figure 3, LBW increased by 19 pp with a risk ratio of 1.19 compared to the period before the implementation of the TRI program, where the levels of internet accessibility were higher than 10%. This increase was observed throughout the United States. Table 3 shows that the number of LBW cases increased sharply in some states of the United States, such as Colorado, Illinois, Louisiana, and Tennessee.

Table 3 displays the correlation analysis results between TRI and the count of LBW cases while considering the levels of internet accessibility in the United States. The risk ratios for these associations are presented in Appendix Figures 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, and 3.7.

Table 3: Correlation between TRI and birth weight, while considering varying levels of internet accessibility

States/internet user (%)	10 %	20 %	30 %	40 %	50 %	60 %	70 %	80 %
Alabama	+16	+15	+15	+21	+23	+24	+29	+28
Alaska	+13	+21	+23	+16	+20	+23	+16	+22
Arizona	+8	+11	+10	+13	+9	+14	+14	+18
Arkansas	+6	+4	+11	+7	+7	+11	+14	+10
California	+1	+2	+3	+3	+6	+9	+14	+14
Colorado	+9	+11	+3	+94	+11	+15	+16	+14
Connecticut	+9	+10	+17	+12	+17	+13	+22	+18
Delaware	+16	+19	+14	+18	+35	+28	+26	+22
District of Columbia	+8	+1	-1	-10	-13	-17	-16	-33
Florida	+4	+7	+7	+6	+12	+13	+15	+16
Georgia	+6	+9	+6	+7	+11	+11	+18	+21
Hawaii	+12	+10	+13	+15	+28	+33	+23	+32
Idaho	+4	+13	+9	+21	+11	+17	+18	+26
Illinois	+50	+47	+5	+49	+55	+59	+66	+63
Indiana	+18	+20	+23	+14	+19	+22	+13	+28
Iowa	+23	+24	+24	+19	+29	+28	+33	+31
Kansas	+13	+13	+14	+13	+14	+20	+16	+13
Kentucky	+12	+11	+15	+17	+22	+24	+32	+29
Louisiana	+60	+68	+66	+72	+75	+81	+96	+80
Maine	+15	+16	+14	+18	+23	+27	+23	+38
Maryland	+13	+15	+14	+16	+18	+19	+20	+12
Massachusetts	+9	+20	+19	+21	+29	+31	+36	+29
Michigan	+13	+13	+15	+16	+18	+20	+23	+26
Minnesota	+22	+23	+22	+28	+31	+31	+40	+37
Mississippi	+12	+15	+15	+21	+27	+30	+39	+30
Missouri	+12	+14	+16	+13	+19	+19	+17	+29
Montana	+13	+11	+23	+9	+21	+20	+27	+39
Nebraska	+18	+32	+23	+28	+35	+30	+32	+32
Nevada	+9	+11	+10	+5	+9	+17	+19	+23

New Mexico	-4	+17	+14	+26	+27	+25	+26	+29
New Carolina	+12	+15	+17	+13	+17	+19	+24	+18
New Hampshire	+8	+11	+7	+15	+15	+21	+25	+29
New Jersey	+10	+12	+12	+11	+13	+13	+17	+14
New York	+11	+12	+12	+11	+14	+14	+17	+17
North Dakota	+18	+27	+34	+31	+28	+33	+29	+35
Ohio	+14	+17	+17	+20	+26	+26	+33	+32
Oklahoma	+14	+12	+11	+16	+24	+21	+27	+22
Oregon	+4	+7	+5	+10	+13	+20	+19	+28
Pennsylvania	+14	+15	+15	+17	+24	+22	+26	+23
Rhode Island	+9	+17	+20	+13	+25	+35	+28	+26
South Carolina	+7	+7	+11	+12	+16	+17	+18	+11
South Dakota	+6	+1	+6	+13	+30	+21	+27	+23
Tennessee	+62	+60	+68	+73	+72	+77	+79	+72
Texas	+6	+7	+9	+9	+13	+16	+24	+24
Utah	+17	+16	+19	+16	+13	+15	+17	+26
Vermont	+4	+5	+10	+2	+8	+18	+4	+15
Virginia	+10	+11	+14	+14	+14	+18	+23	+16
Washington	+6	+7	+9	+6	+11	+15	+20	+22
West Virginia	+16	+20	+17	+21	+30	+26	+38	+40
Wisconsin	+18	+21	+24	+23	+25	+29	+32	+40
Wyoming	+19	+27	+26	+17	+19	+26	+29	+20
USA	+19	+22	+22	+22	+27	+29	+31	+31

4. Meta-regression analysis

In this section, we conduct a regression analysis to investigate the relationship between the level of implementation of environmental information disclosure programs and birth weight outcomes. Two econometric models, random effects (RE) and unrestricted least squares (WLS), are employed to perform the analysis. The RE model considers the dissimilarities between individual studies in the analysis. In contrast, the WLS model permits the estimation of the overall impact of the environmental information disclosure program. The regression analysis involves a meta-regression centered on the outcome variable, birth weight outcomes, and a meta-regression examining the factors that may influence this outcome variable.

We now present all the explanatory variables that we have chosen to use for our regression.

4.1. Explanatory variables

In the meta-regression analysis, we incorporated several covariates to investigate the effect of disclosure programs on birth weight, which is the dependent variable. A binary variable represents the presence or absence of an environmental disclosure program during data collection for each study. Additionally, the level of internet access is included as a continuous variable, as it can affect the accessibility of environmental information, including toxic industrial releases reported by such programs. Finally, a discrete variable, "time", is also incorporated, representing the year in which newborn health data, such as birth weight, was collected. This variable is included due to its potential association with technological advancements, economic developments, and changes in the healthcare system, which may impact the mother's lifestyle and, consequently, the newborn's health outcomes.

In this analysis, we incorporated several covariates, namely maternal age, length of gestation, and maternal education, to evaluate their potential influence on birth weight. While other sociodemographic factors such as maternal smoking or alcohol consumption and marital status may also impact birth weight, we opted to include maternal age, length of gestation, and maternal education due to their widespread usage in the studies integrated into our meta-regression and their consistent significance in the majority of these studies. The following explains the association between these three variables and birth weight:

- Maternal age significantly affects fertility decline, increased risk of miscarriage, and adverse impacts on maternal health and pregnancy outcomes. These outcomes include preterm birth, congenital disabilities, and birth weight. Therefore, in the analysis, maternal age is a continuous variable.

- Length of gestation is a crucial factor that influences the development and growth of the fetus in utero. Infants born at term, which corresponds to a gestational age of 37 to 42 weeks, have had sufficient time to fully develop their organs and body systems, resulting in a weight that falls within the expected range. Conversely, preterm infants born before 37 weeks of gestation may have an insufficiently developed body and LBW, increasing the risk of health complications and mortality.

- Maternal education is an important variable in our study because women with higher levels of education tend to have better access to healthcare and benefit from better nutrition and a healthier lifestyle, which can influence their baby's birth weight. Furthermore, women with higher levels of education are often more aware of the risks associated with pregnancy. They are more likely to follow medical advice and health recommendations during pregnancy, which can also positively impact their child's health at birth. Finally, women with higher levels of education often have better access to information, which can help them better understand and make informed decisions regarding their health and well-being.

In our analysis, the maternal age, length of gestation, and maternal education are continuous variables.

Overall, this analysis aims to study the effect of environmental information disclosure programs on birth weight outcomes, taking into account the potential impact of these additional covariates, with a specific focus on the online accessibility of information and the potential impact of the industrial releases whose information disseminated by the programs.

Our reference model for the MRA is specified as follows:

$$y_j = \beta_0 + \beta_1 x_{1j} + \beta_2 x_{2j} + \ldots + \varepsilon_j$$

Where y_j is the proportion of LBW (in log) and β_0 is the intercept. The variables x_i specify different variables that were taken into account, such as maternal age, the mother's education level, environmental disclosure program, etc. ε_j in this basic model specifies the variation between groups.

Two methods were used to estimate this model:

- The random-effects (RE) model is a widely used approach in meta-regression that assumes that the observed effects in individual studies are random and vary around a common estimate of the overall effect. The RE model accounts for heterogeneity across studies by including a random variance term. This approach allows each study to contribute to the overall effect estimate, with the contribution of each study weighted based on its precision. More precise studies receive greater weight than less precise studies. While the RE estimator accommodates the variability between the variables of interest and the groups, it is sensitive to the possibility of publication bias (Higgins et al., 2009).

- To solve the publication bias problem, another model has been proposed by Stanley and Doucouliagos (2015, 2017), which is the unrestricted least squares (WLS) model. The publication bias is smaller with the ULS method than with the random effect method. The WLS model is a type of meta-regression model that allows for both within-study and between-study heterogeneity. Unlike the fixed-effects (FE) and random-effects (RE) models, which assume a constant effect size across all studies, the WLS model allows for the possibility that the effect size may differ across studies. In the ULS model, each study is allowed to have its own intercept and slope coefficients, which are estimated simultaneously with the overall effect size.

Insufficient data on certain variables such as the sex of newborns, mother's ethnicity, mother's alcohol consumption, and mother's smoking limits our ability to calculate their effects on the incidence of LBW. As a result, we have directed our attention toward factors such as maternal age and length of pregnancy, which are known to impact LBW rates. Additionally, we have investigated variables related to environmental disclosure programs, including attendance at such programs, levels of internet accessibility, and maternal education.

Table 5: Results of the meta-regression (the dependent variable is the proportion of LBW)

	RE EQN. (1)	WLS EQN. (1)	RE EQN. (2)	WLS EQN. (2)	RE EQN. (3)	WLS EQN. (3)
Intercept	*1.1598*** (0.0028)*	*1.8817**** (<.0001)*	*4.3378**** (<.0001)*	*4.3070**** (<.0001)’*	*4.0617 **** (<.0001)*	*4.4590**** (<.0001)*
Maternal age	*-0.0046** (0.0153)*	*-0.0104**** (3.04e-07)*	*-0.0022 (0.2388)*	*-0.0046**** (0.0004)*	*-0.0022 (0.0057)*	*-0.0051**** (0.0003)*
Length of gestation	*-0.0262** (0.0101)*	*-0.0406**** (3.38e-06)*	*-0.0252*** (0.0026)*	*-0.0357**** (<.0001)*	*-0.0255 *** (0.0026)*	*-0.0373 ***** (0.0015)*
Maternal education	*0.0033 (0.1467)*	*0.003976** (0.0487)*	*0.0016 (0.4286)*	*0.0043**** (0.0008)*	*0.0017 (0.3798)*	*0.0039*** (0.0148)*
Time			*-0.0016**** (<.0001)*	*-0.0014**** (<.0001)*	*-0.0015**** (<.0001)*	*-0.001438**** (<.0001)*
Program			*-0.0004 (0.9646)*	*-0.0073 (0.33)*		
Levels of internet accessibility			*0.0005*** (0.9646)*	*0.0003** (0.02)*		
Program x Levels of internet accessibility					*0.0005*** (0.0050)*	*0.0002** (0.0206)*

Notes: Robust standard errors in parentheses. Multiplication (x) is used to indicate an interaction variable ***p<0.001, **p<0.01, *p<0.05, and ‘p<0.1. (N=47).

The meta-regression analysis conducted in this study aimed to investigate the relationship between environmental disclosure programs, levels of internet accessibility in the country, maternal age, maternal education, and time on the incidence of LBW.

The results presented in Table 5 reveal that maternal age and gestational duration significantly influence birth weight. Specifically, our analyses revealed that older mothers had a reduced risk of giving birth to infants with LBW, except for RE EQN. (3) and RE EQN. (3) models. Furthermore, it was observed that gestational duration is negatively associated with the probability of having infants with LBW. In other words, as gestational duration increases, the risk of giving birth to an infant with insufficient weight decreases.

These results align with previous studies that have identified advanced maternal age as a protective factor against LBWs (Strobino et al., 1995). Possible explanations for this observation include older mothers’ greater maturity, better health, and access to quality healthcare. Additionally, the inverse relationship between gestational duration and birth weight is consistent with the idea that newborns require sufficient time to reach their optimal weight and development. This underscores the importance of pregnancy monitoring and managing factors influencing gestational duration.

Our study results also revealed a significant negative association between maternal education level and birth weight of newborns (WLS EQN. models). Specifically, we found that mothers with higher education levels had an increased risk of delivering infants with LBW. In addition, our analyses showed that as maternal education age increased, the proportion of LBW also increased. Several mechanisms have been proposed to explain this association, including lifestyle habits, socioeconomic factors, health knowledge, and health-seeking behaviors. For example, mothers with higher education levels may be more likely to work full-time, have a stressful lifestyle, and make different health decisions due to their knowledge and beliefs. Additionally, they may have easier access to quality prenatal care, but this may not necessarily translate to better fetal health outcomes.

Our analysis revealed a significant positive relationship between the time variable and the incidence of LBW. In other words, we observed a decreased proportion of infants with LBW over time. This trend can be attributed to several factors, such as socioeconomic progress, medical advancements, and improvements in sanitary conditions.

Socioeconomic progress has likely contributed to reducing the incidence of LBW by improving the living conditions of pregnant women. Unfavorable socioeconomic conditions, such as poverty and lack of access to clean water, food, and healthcare, have been associated with an increased incidence of LBW. Medical advancements have also played an important role in reducing the incidence of LBW. Technological advances have enabled better management of pregnancy and childbirth complications and more effective monitoring of fetal growth. Furthermore, improvements in sanitary conditions have contributed to reducing maternal infections and diseases that can affect birth weight.

The analysis results revealed an unexpected interaction between the "program" and "internet" variables, which significantly and positively affected the incidence of LBW. This finding is surprising, as the initial hypothesis was that environmental disclosure programs would reduce the proportion of children born with growth retardation.

One possible explanation for this interaction is that the environmental information provided by the programs may only reach some vulnerable populations. Indeed, these populations may lack internet access or need help to understand the information conveyed. This could result in not changing their behavior or not taking the necessary measures to protect the health of their unborn child.

It is also relevant to note that information provided by disclosure programs, such as E-PRTR in Europe and TRI in the United States, may need to be more comprehensible to the general public. Furthermore, it is important to mention that most studies used in the meta-regression were based on data from the United States and Europe, with few studies conducted in other countries. Therefore, the results may not be generalizable to different contexts. However, studies on environmental information disclosure programs conducted in Asia have shown more positive results in the meta-analysis. These programs have successfully and effectively disseminated information by using more comprehensible methods for the public, such as using colors to indicate the level of pollution from industry. For example, the PROPER program disseminates information using a simple system to assess environmental performance, identify superior and inferior performances, and give color-coded ratings to facilitate communication through the media. The rating system classified environmental performance into five symmetric categories, two indicating inferior performances, one demonstrating compliance with minimal emission standards but non-compliance with stricter requirements, and two displaying superior performances.

Conclusion

International environmental information disclosure programs are becoming increasingly common worldwide. These programs aim to raise public awareness about environmental risks and provide information on pollutant emissions. While these programs are considered important measures for environmental protection and public health, their effectiveness must be thoroughly evaluated.

In this study, we evaluated the efficacy of several environmental information disclosure programs by examining the risk of LBW before and after implementing these programs. We conducted a meta-analysis by examining studies on the most well-known international environmental information disclosure programs, such as TRI, E-PRTR, NPI, PROPER, EcoWatch, Greenwatch, NPRI, MVR, and AKOBEN. We compared the risk of LBW before and after implementing these programs. We also performed a meta-regression to assess factors influencing the risk of LBW. Our analysis showed that in countries where these programs were in place, the risk of LBW had decreased for most programs, except TRI and E-PRTR, which had the opposite effect. The meta-regression results showed that maternal age and gestational duration significantly influence birth weight, with older mothers having a reduced risk of giving birth to LBW infants. Length of gestation is associated with a decreased risk of LBW. Maternal education was negatively associated with birth weight, with mothers with higher education levels having an increased risk of giving birth to LBW. Time also showed a significant negative relationship with the incidence of LBW. Finally, a significant positive interaction was observed between the "program" and "internet" variables, suggesting that environmental disclosure may not reach certain vulnerable populations and that information presentation may play a crucial role in the effectiveness of these programs.

Our findings suggest that implementing environmental information disclosure programs may reduce the risk of LBW in many countries. However, the observed inverse effect for the European pollutant registers TRI and E-PRTR highlights the need for a more thorough evaluation of the effectiveness of these programs and their impact on public health. In addition, information on LBW may be reported more accurately in the United States and

Europe, which may not be the case in other countries, potentially explaining why we found that other programs impacted the proportion of LBW in other countries. Further research is needed to understand the reasons for these mixed results and to identify strategies to improve the effectiveness of environmental information disclosure programs in reducing the risk of LBW and other adverse health effects.

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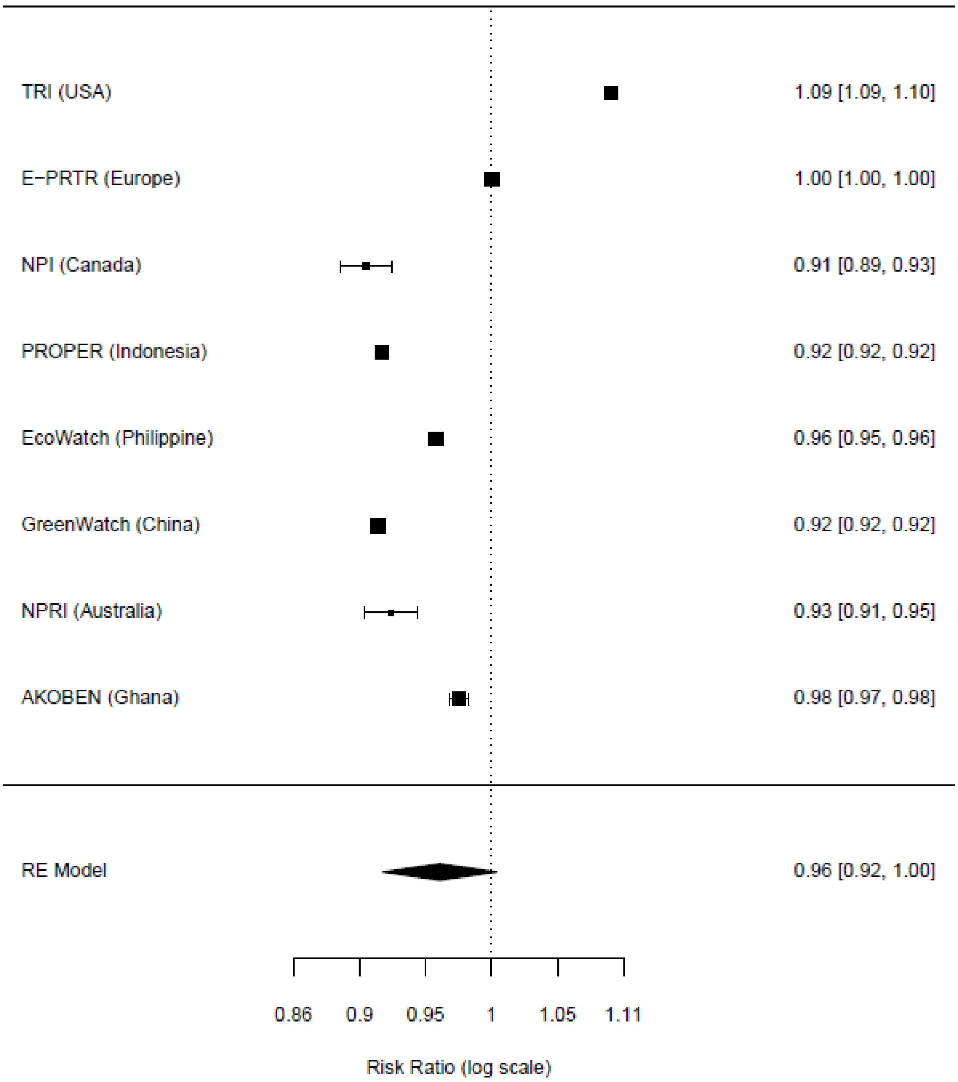
Appendix

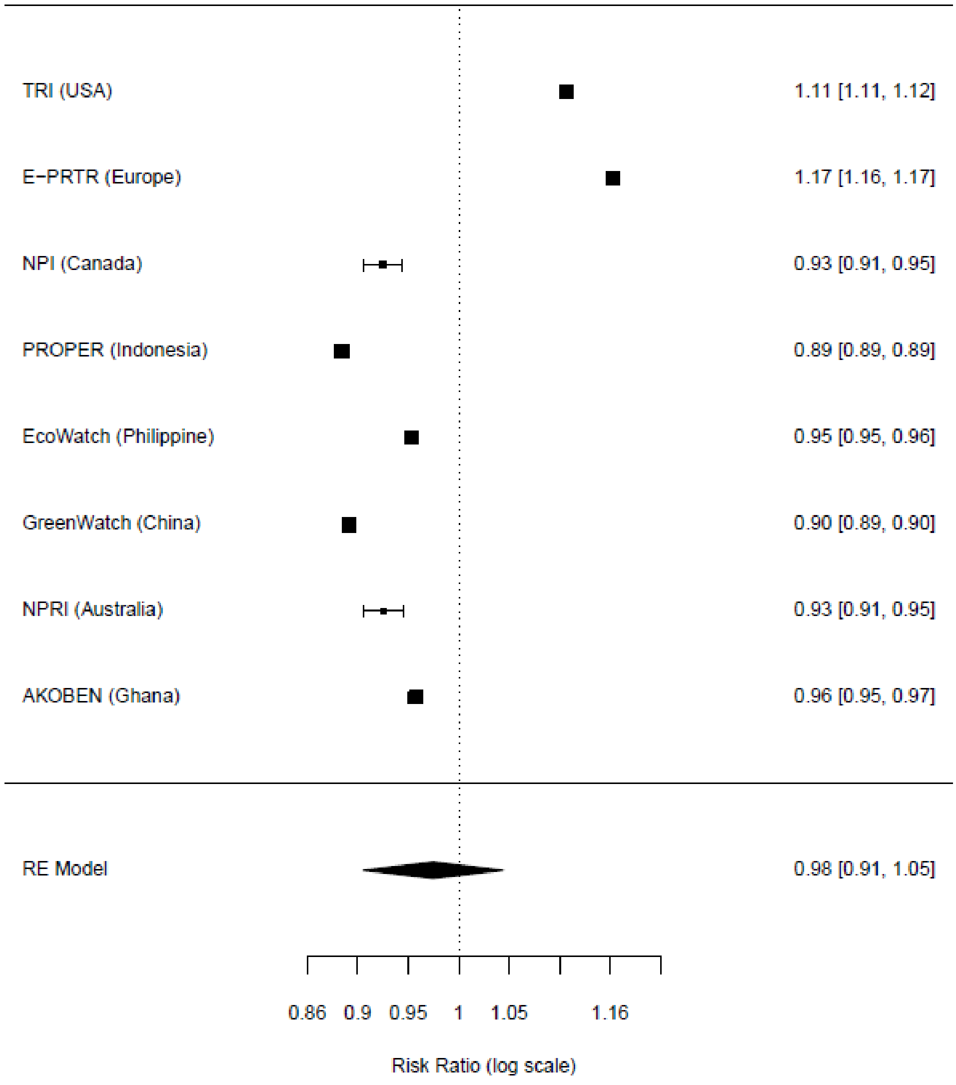
Appendix: Additional figures

Figure 1.1: Effect of environmental disclosure programs on the number of LBW, considering levels of internet accessibility greater than 20 %



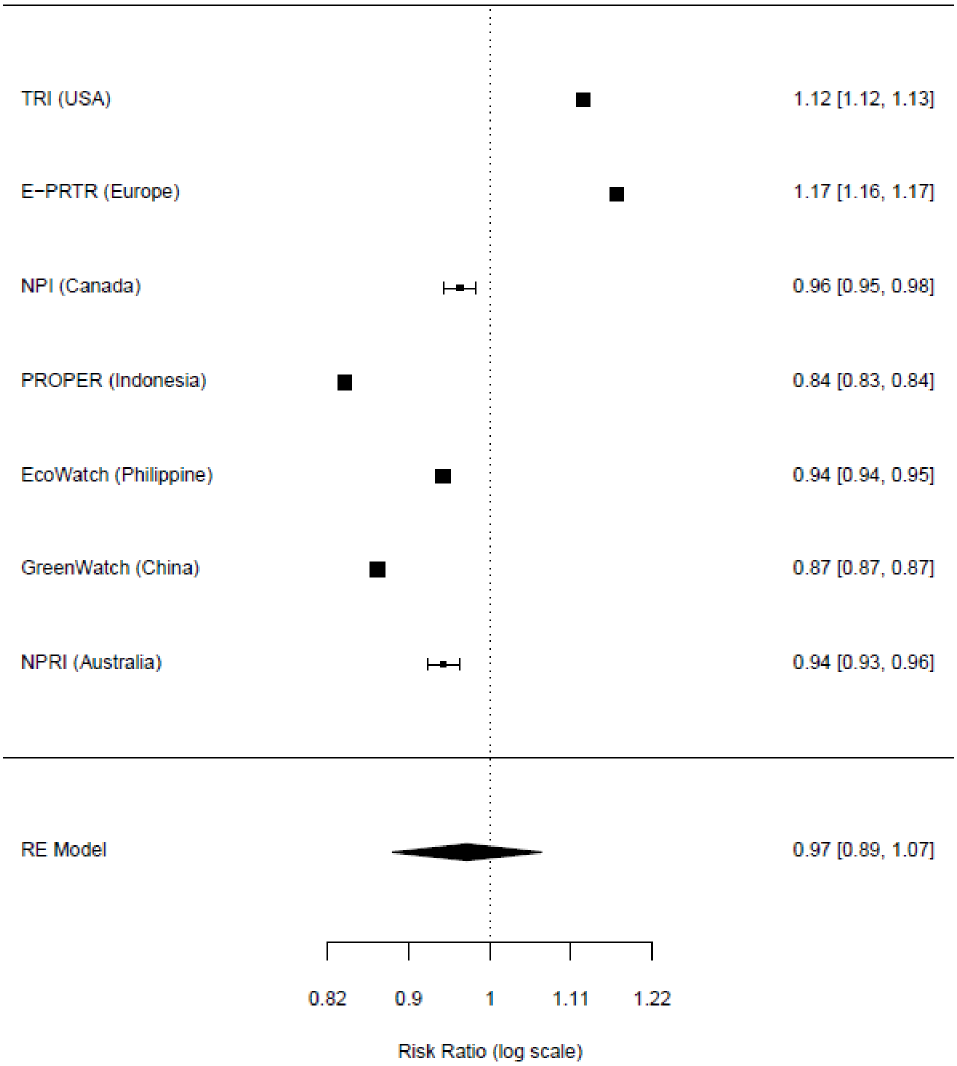
Note: This forest plot (Figure 1.1) shows the risk ratios in log for each program (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of all information disclosure programs on the number of LBW (N = 9: information disclosure program).

Figure 1.2: Effect of environmental disclosure programs on the number of LBW, considering levels of internet accessibility greater than 30 %



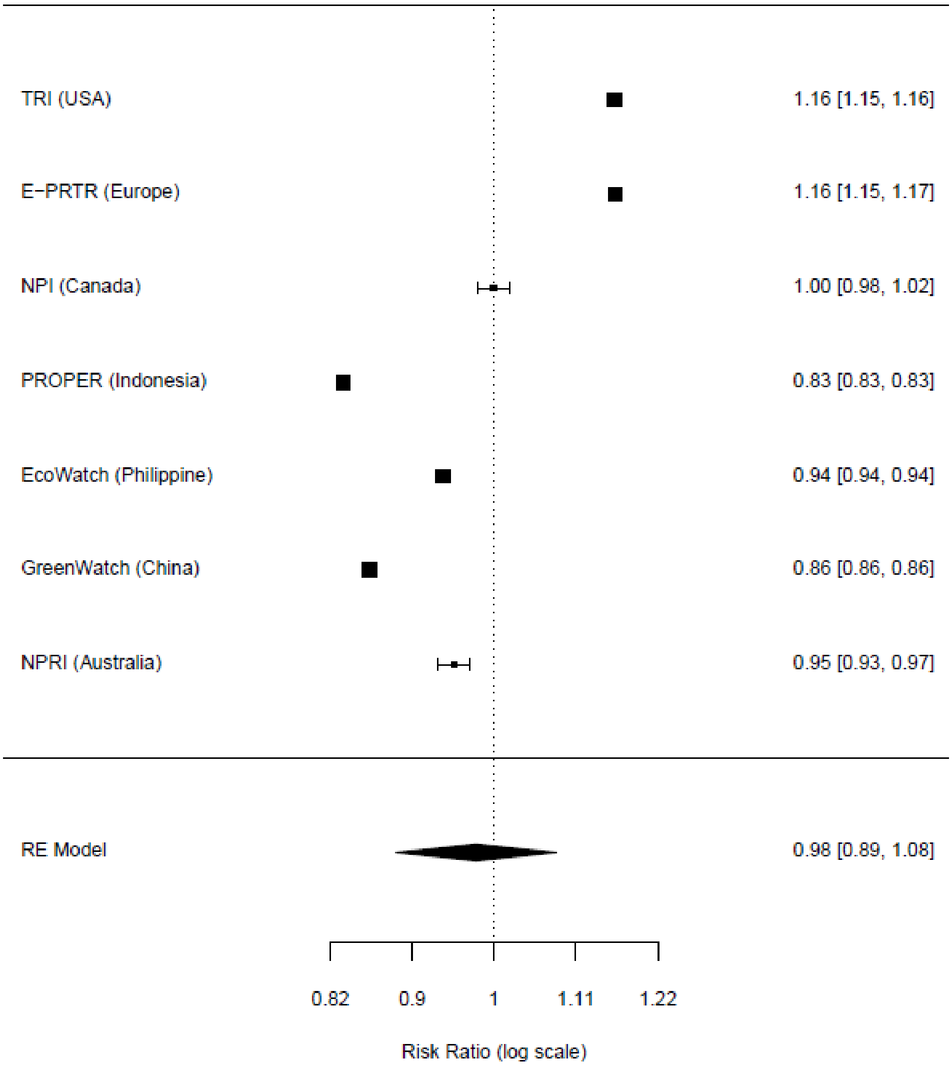
Note: This forest plot (Figure 1.2) shows the risk ratios in log for each program (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of all information disclosure programs on the number of LBW (N =8: information disclosure program).

Figure 1.3: Effect of environmental disclosure programs on the number of LBW, considering levels of internet accessibility greater than 40 %



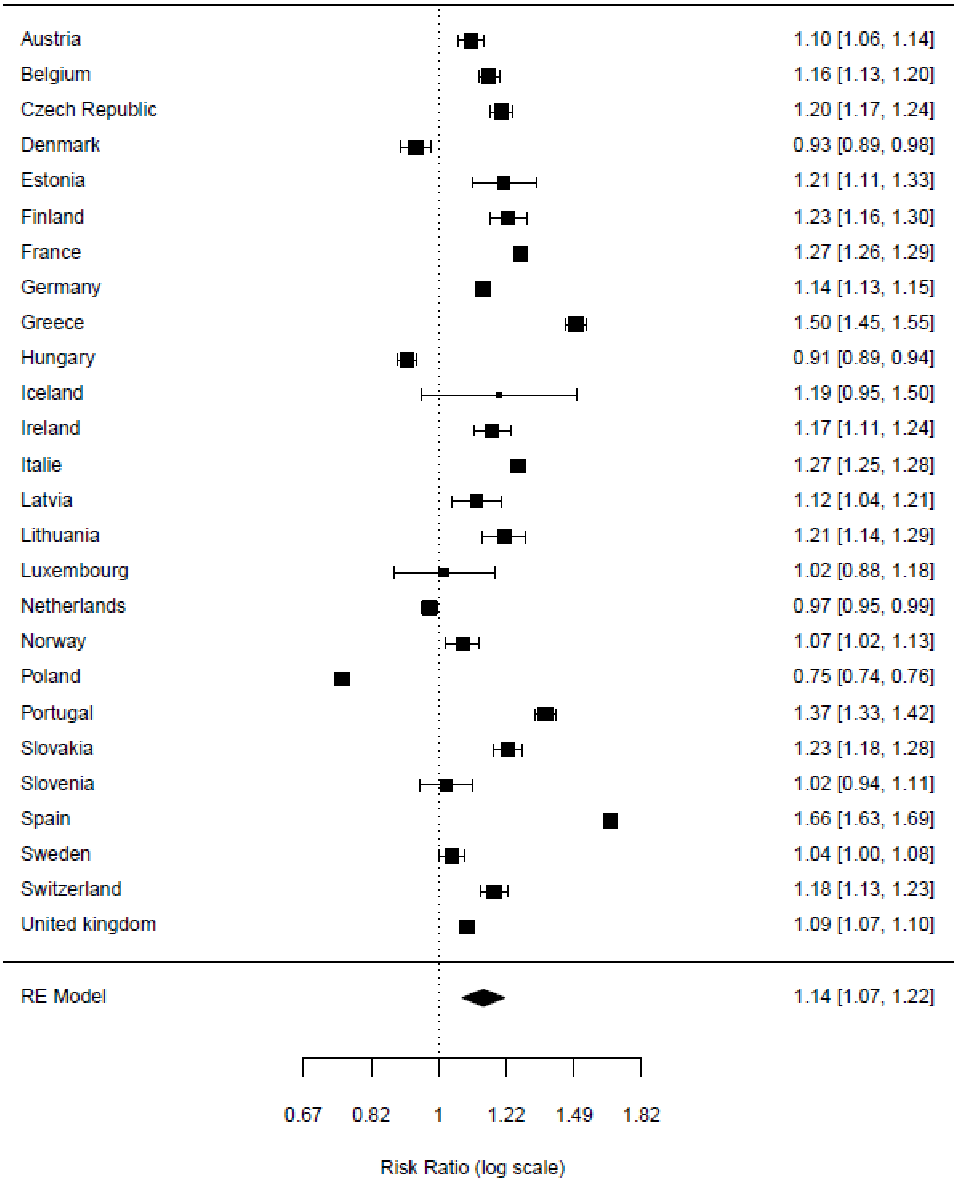
Note: This forest plot (Figure 1.3) shows the risk ratios in log for each program (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of all information disclosure programs on the number of LBW (N =7: information disclosure program).

Figure 1.4: Effect of environmental disclosure programs on the number of LBW, considering levels of internet accessibility greater than 50 %



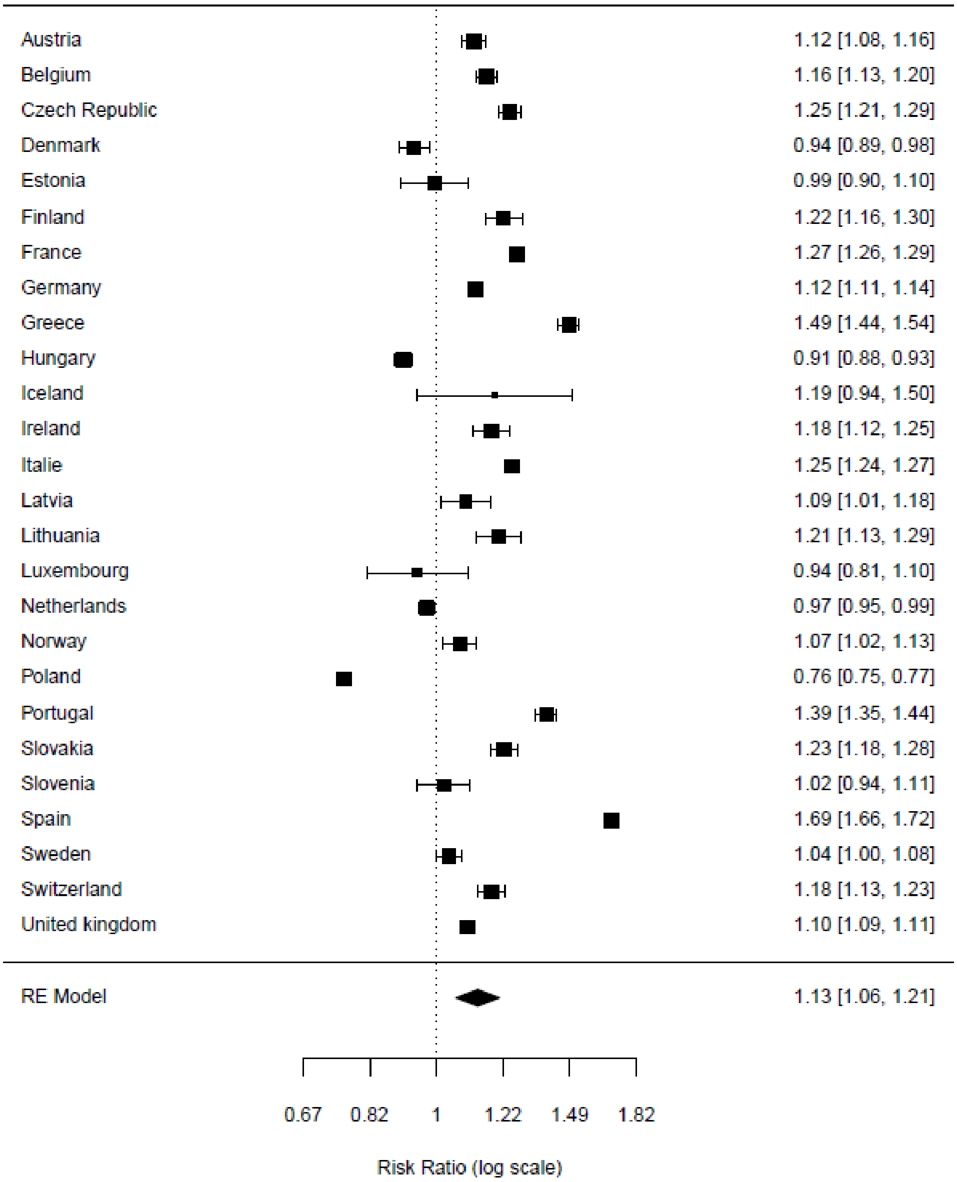
Note: This forest plot (Figure 1.4) shows the risk ratios in log for each program (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of all information disclosure programs on the number of LBW (N =7: information disclosure program).

Figure 2.1: Effect of E-PRTR on the number of LBW, considering levels of internet accessibility greater than 20 %



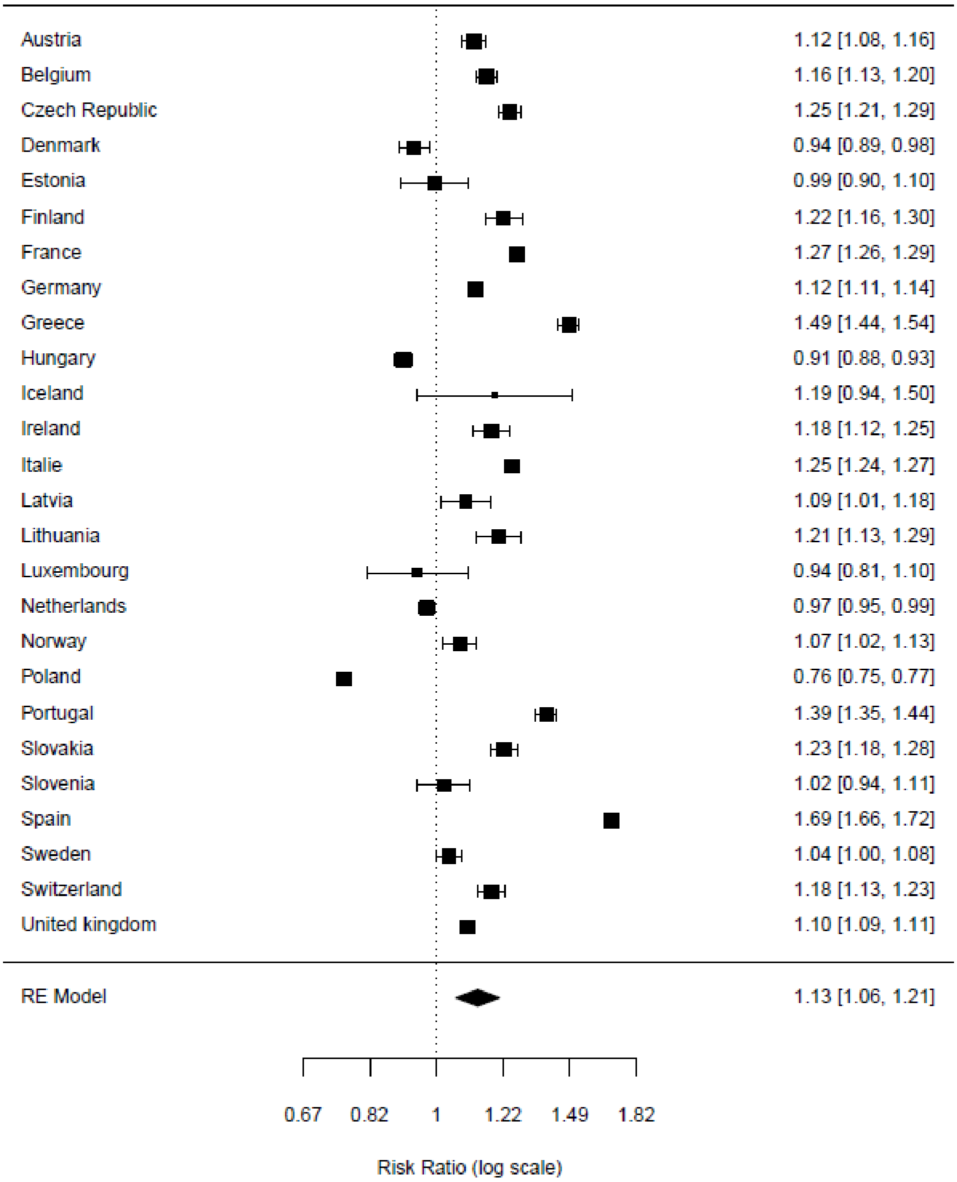
Note: This forest plot (Figure 2.1) shows the risk ratios in log for each countries (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of E-PRTR on the number of LBW for European countries (N = 26: information disclosure program).

Figure 2.2: Effect of E-PRTR on the number of LBW, considering levels of internet accessibility greater than 30 %



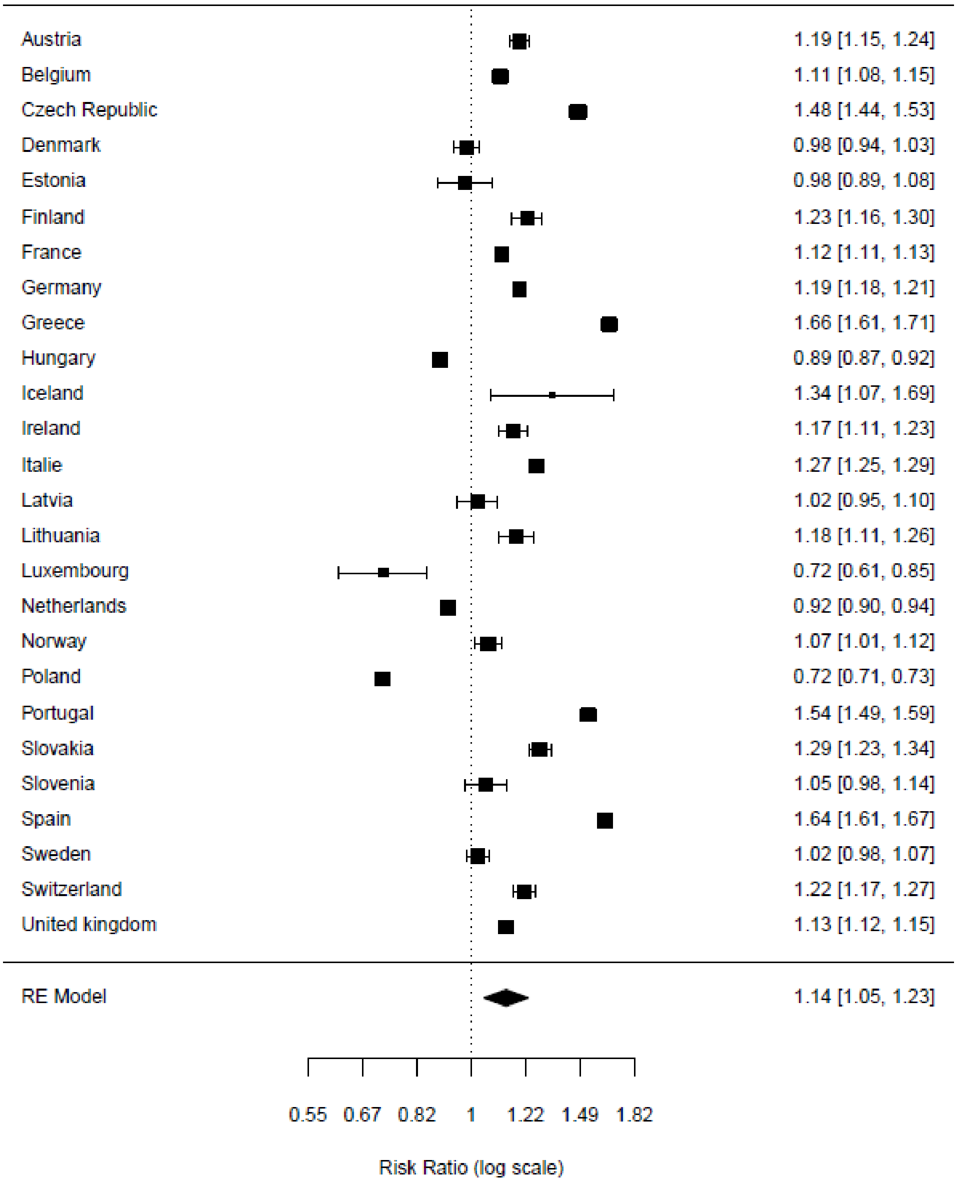
Note: This forest plot (Figure 2.2) shows the risk ratios in log for each countries (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of E-PRTR on the number of LBW for European countries (N = 26: information disclosure program).

Figure 2.3: Effect of E-PRTR on the number of LBW, considering levels of internet accessibility greater than 40 %



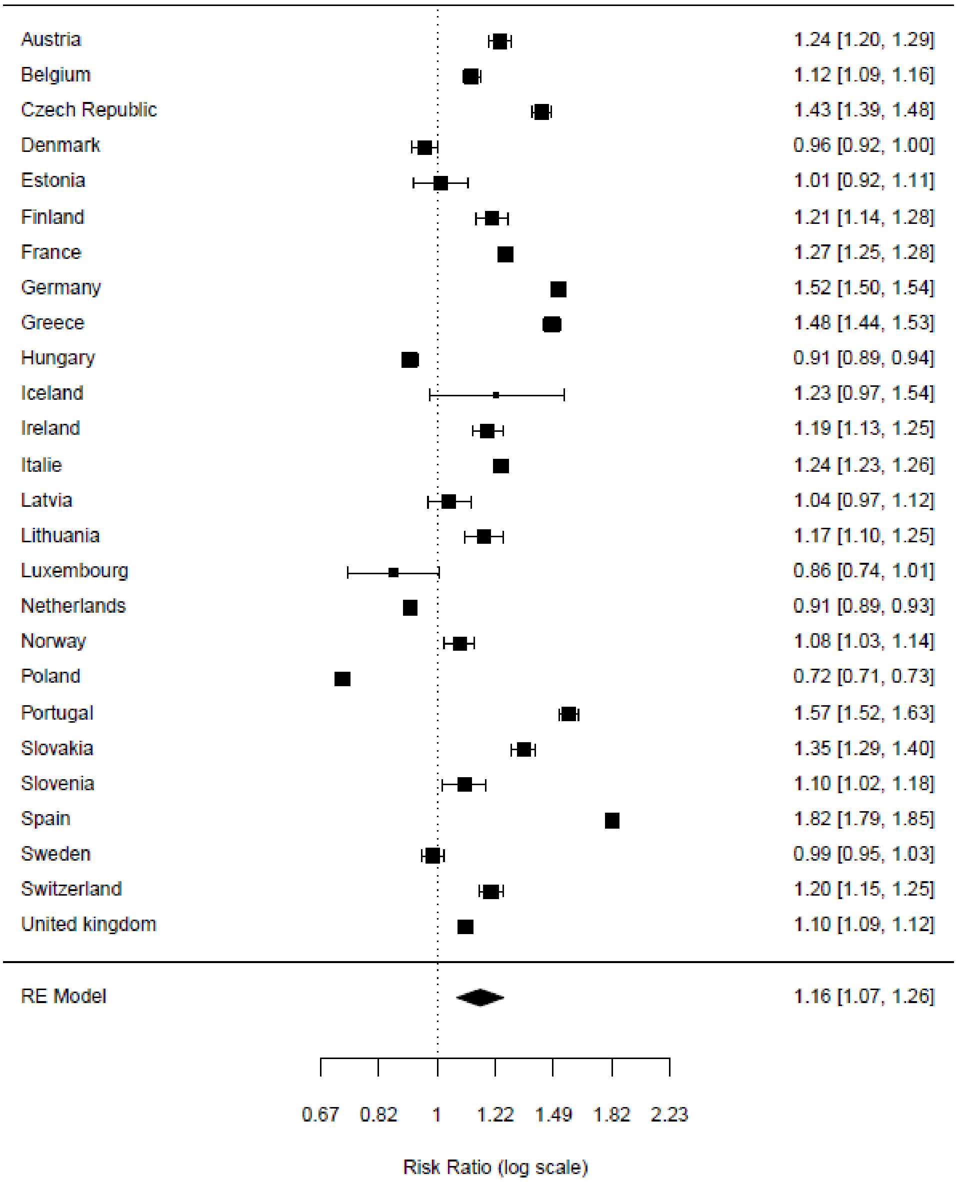
Note: This forest plot (Figure 2.3) shows the risk ratios in log for each countries (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of E-PRTR on the number of LBW for European countries (N = 26: information disclosure program).

Figure 2.4: Effect of E-PRTR on the number of LBW, considering levels of internet accessibility greater than 50 %



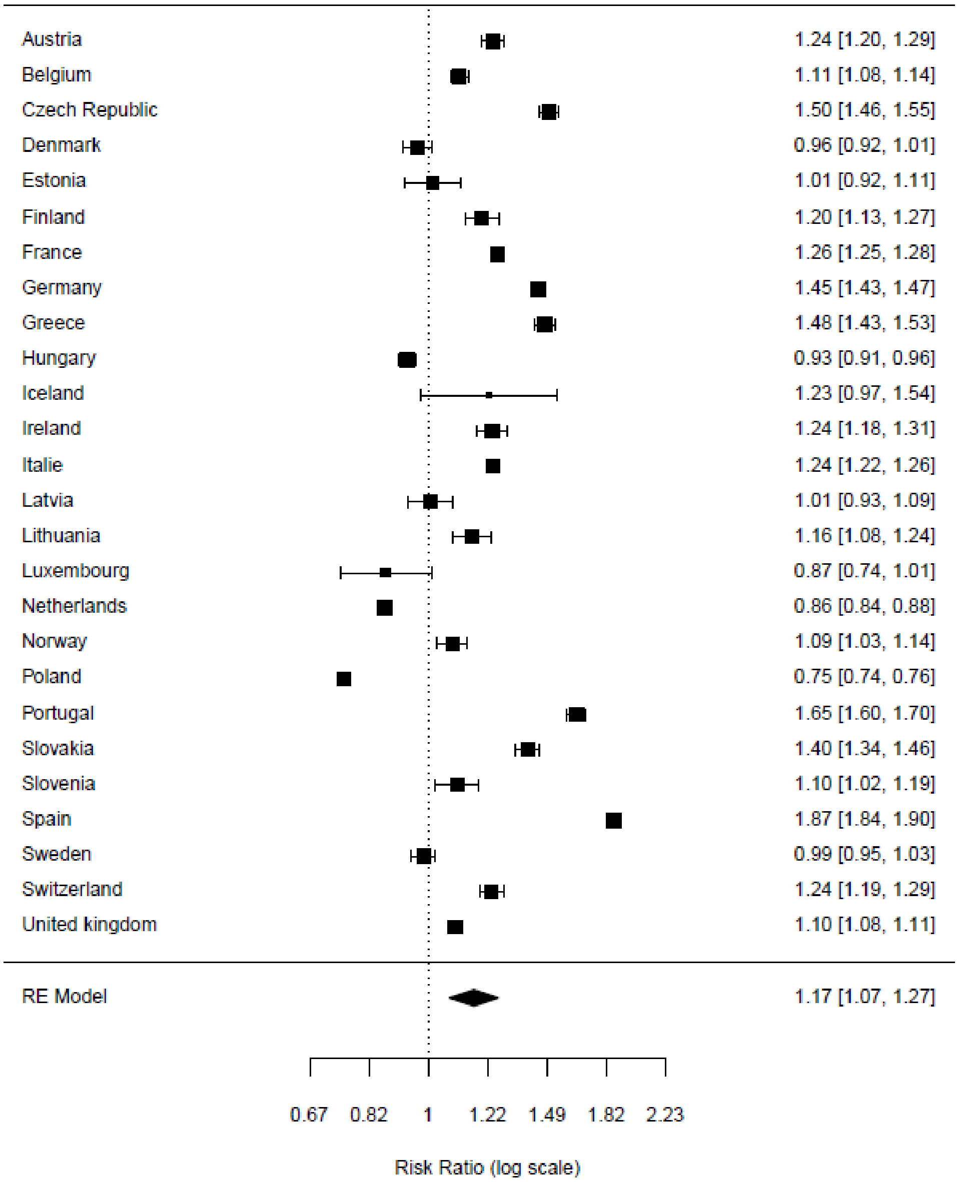
Note: This forest plot (Figure 2.4) shows the risk ratios in log for each countries (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of E-PRTR on the number of LBW for European countries (N = 26: information disclosure program).

Figure 2.5: Effect of E-PRTR on the number of LBW, considering levels of internet accessibility greater than 60 %



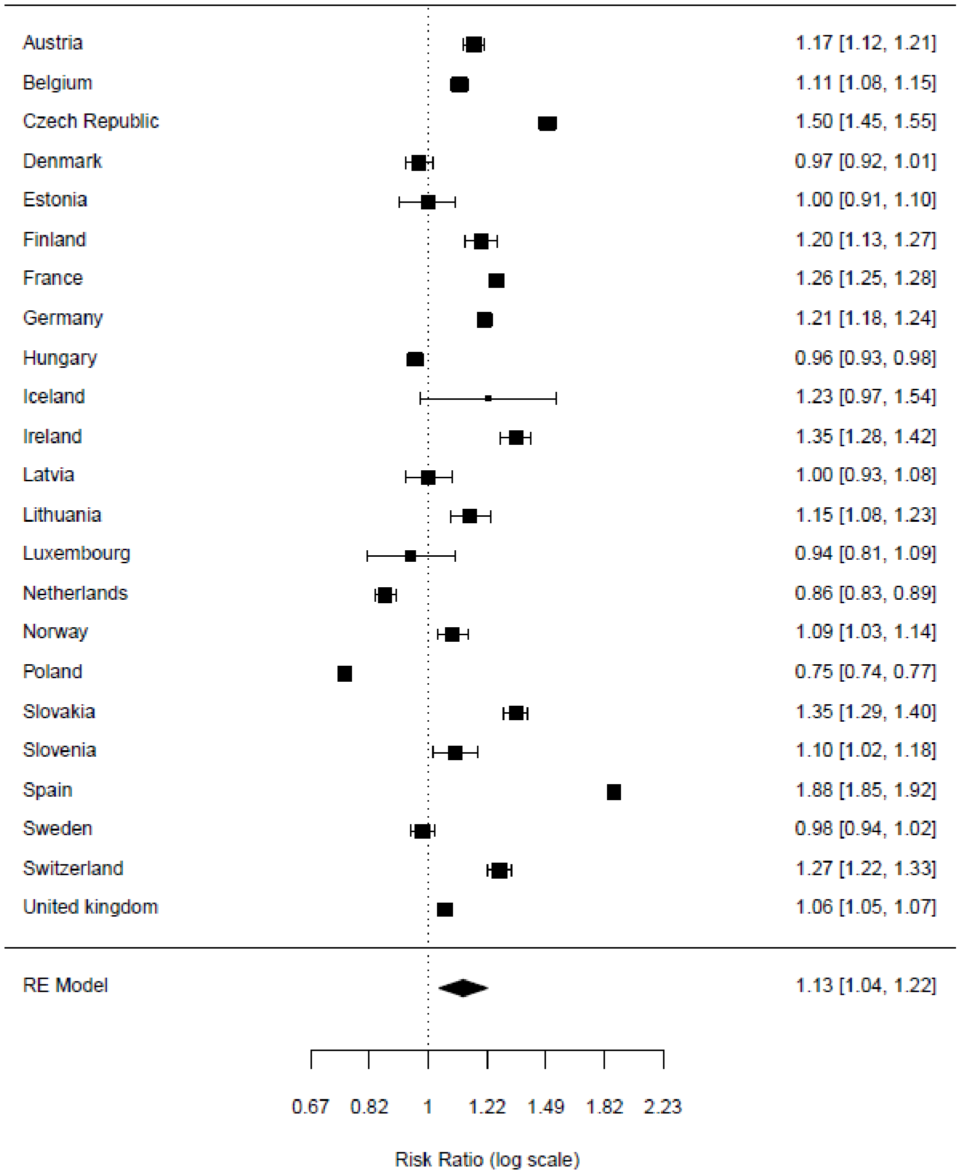
Note: This forest plot (Figure 2.5) shows the risk ratios in log for each countries (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of E-PRTR on the number of LBW for European countries (N = 26: information disclosure program).

Figure 2.6: Effect of E-PRTR on the number of LBW, considering levels of internet accessibility greater than 70 %



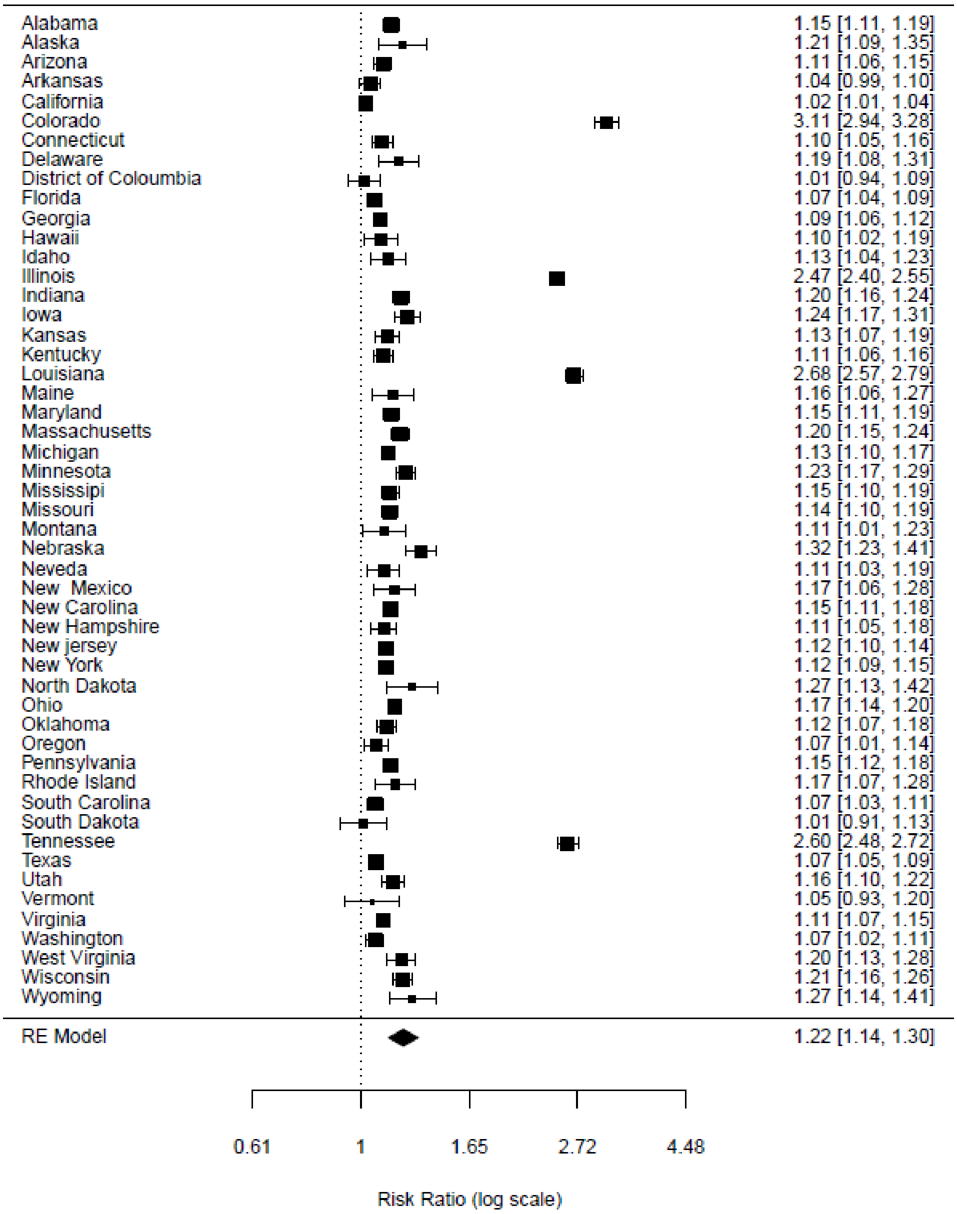
Note: This forest plot (Figure 2.6) shows the risk ratios in log for each countries (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of E-PRTR on the number of LBW for European countries (N = 26: information disclosure program).

Figure 2.7: Effect of E-PRTR on the number of LBW, considering levels of internet accessibility greater than 80 %



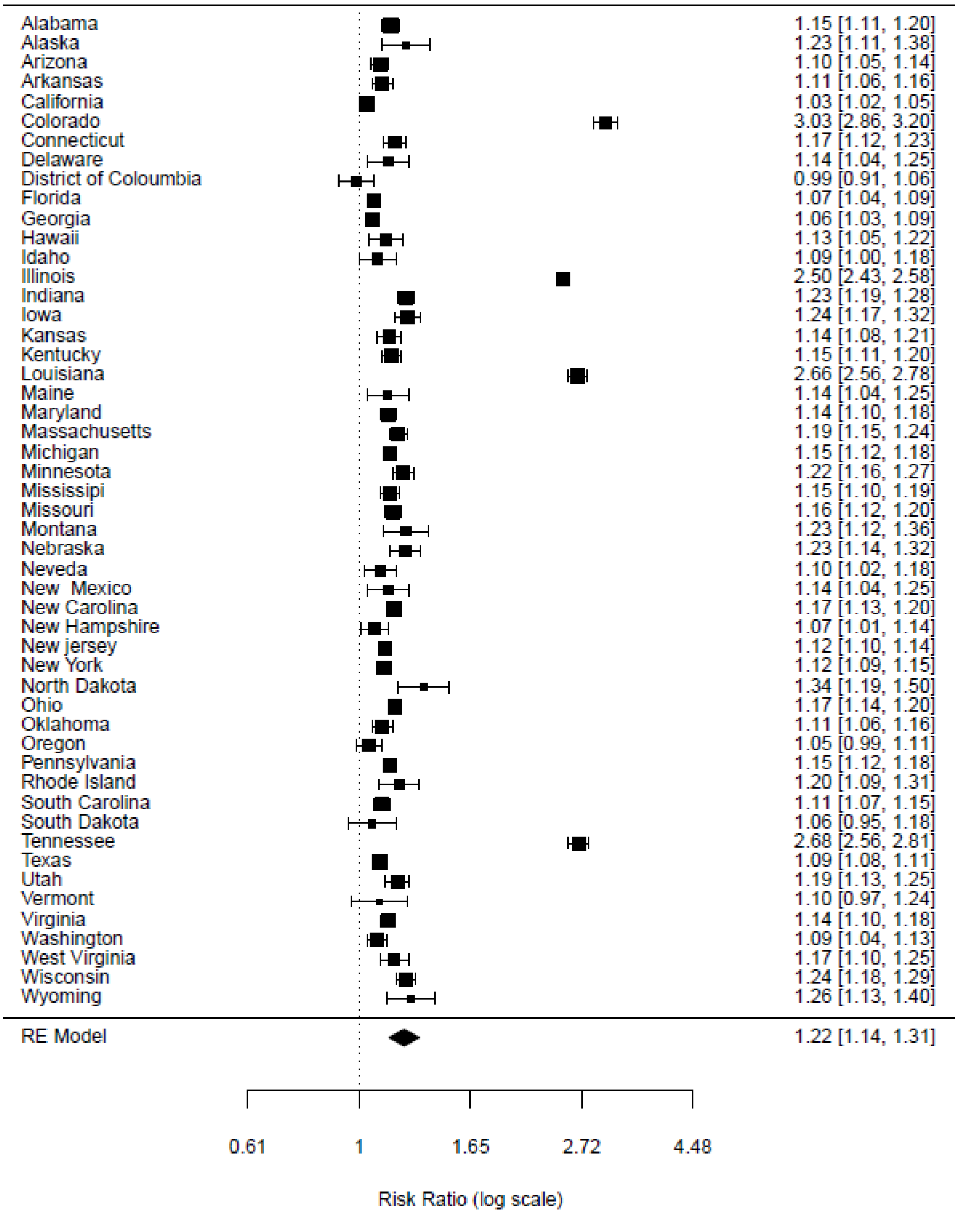
Note: This forest plot (Figure 2.7) shows the risk ratios in log for each countries (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates the effect size of E-PRTR on the number of LBW for European countries (N = 26: information disclosure program).

Figure 3.1: Effect of TRI on the number of LBW, considering levels of internet accessibility greater than 20 %



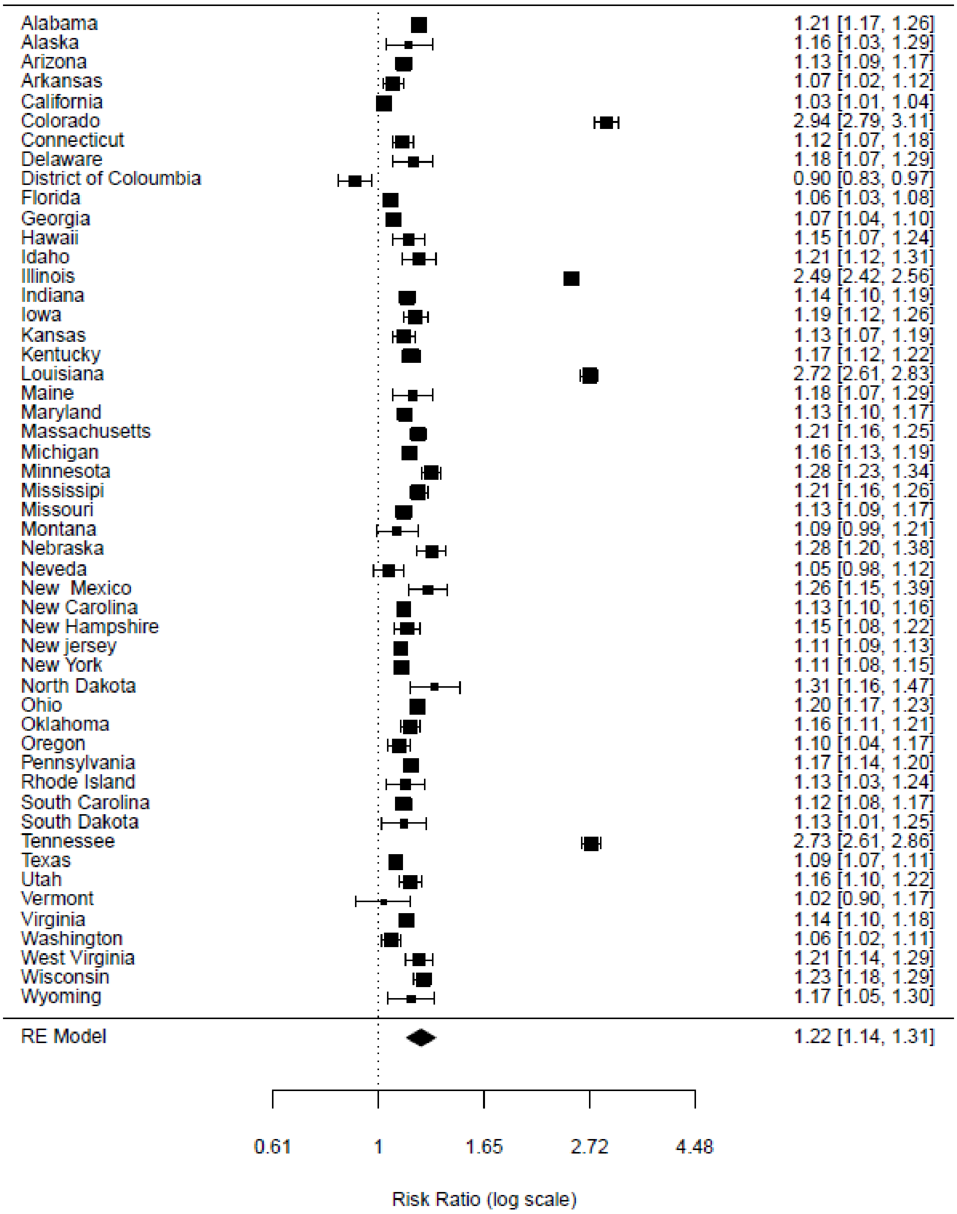
Note: This forest plot (Figure 3.1) shows the risk ratios in log for each United States (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates TRI effect size on the number of LBW for the United States (N = 51 States).

Figure 3.2: Effect of TRI on the number of LBW, considering levels of internet accessibility greater than 30 %



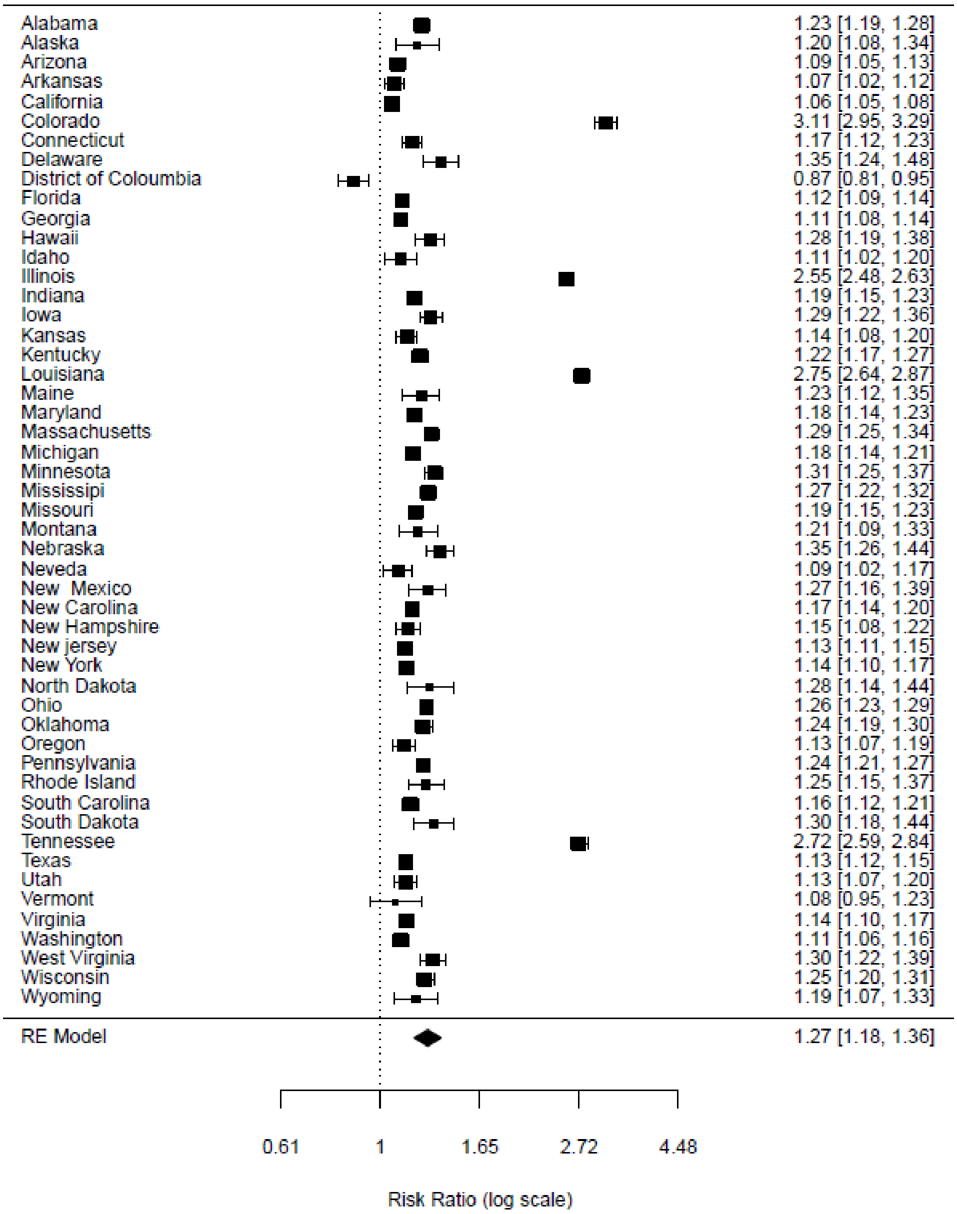
Note: This forest plot (Figure 3.2) shows the risk ratios in log for each United States (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates TRI effect size on the number of LBW for the United States (N = 51 States).

Figure 3.3: Effect of TRI on the number of LBW, considering levels of internet accessibility greater than 40 %



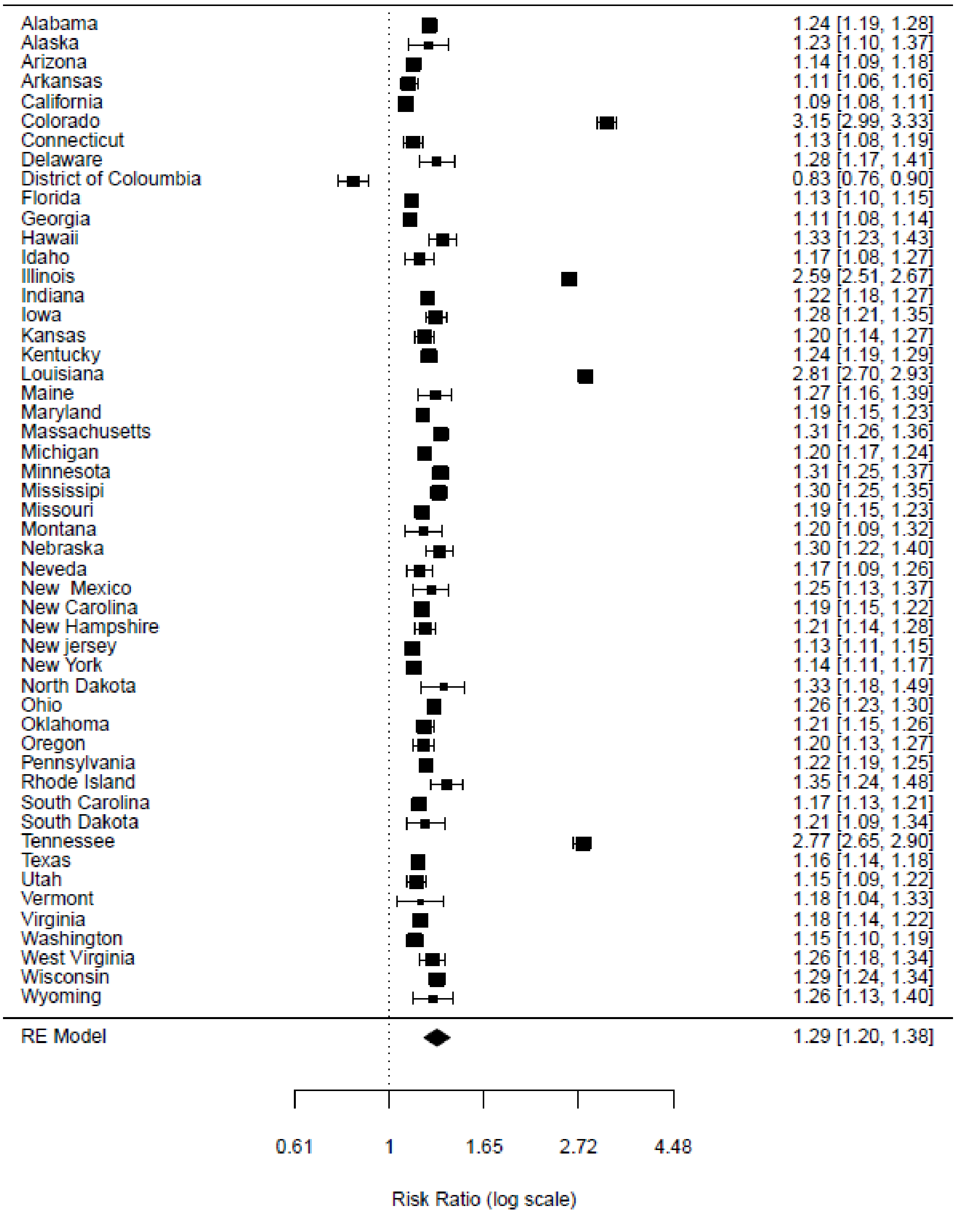
Note: This forest plot (Figure 3.3) shows the risk ratios in log for each United States (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates TRI effect size on the number of LBW for the United States (N = 51 States).

Figure 3.4: Effect of TRI on the number of LBW, considering levels of internet accessibility greater than 50 %



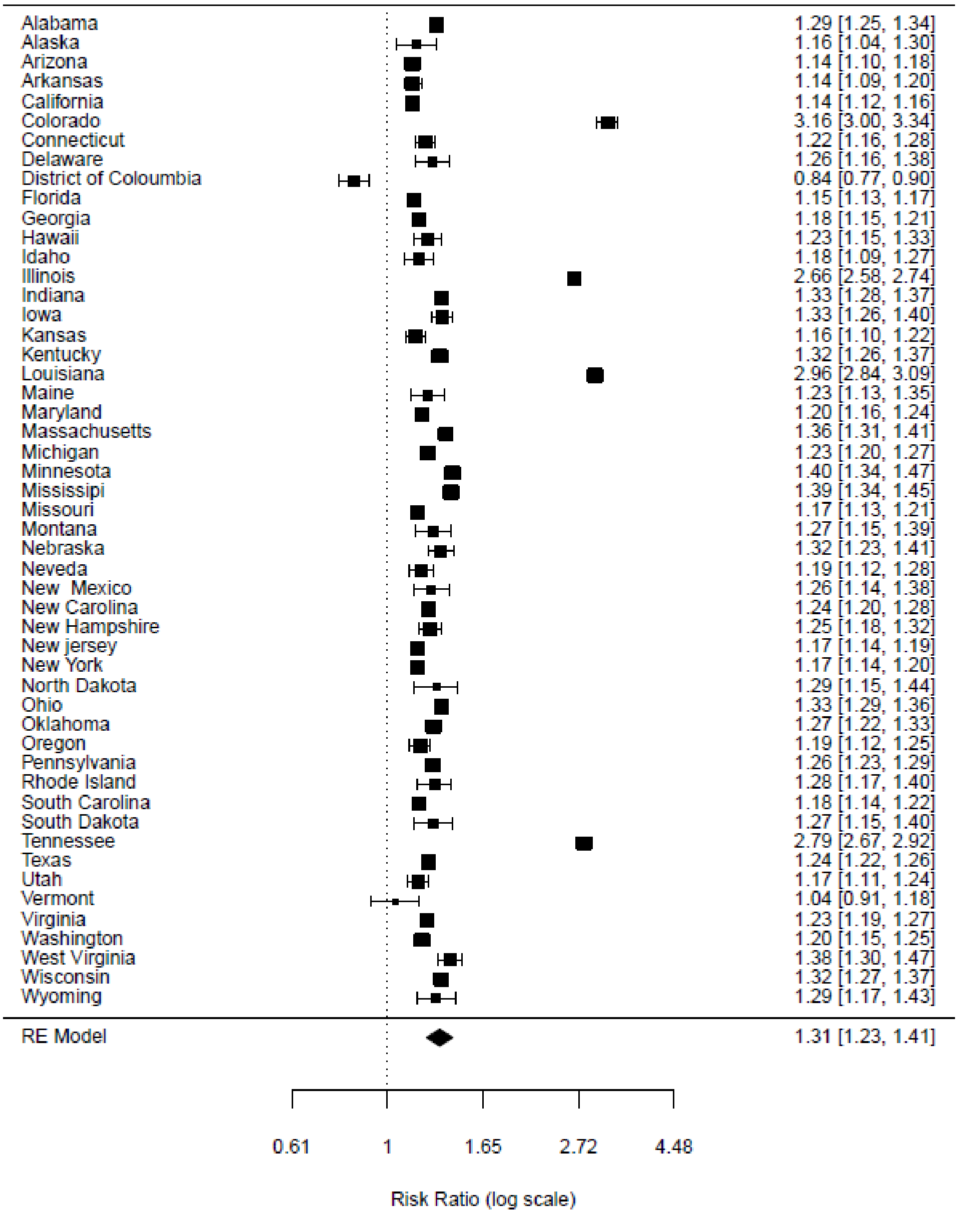
Note: This forest plot (Figure 3.4) shows the risk ratios in log for each United States (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates TRI effect size on the number of LBW for the United States (N = 51 States).

Figure 3.5: Effect of TRI on the number of LBW, considering levels of internet accessibility greater than 60 %



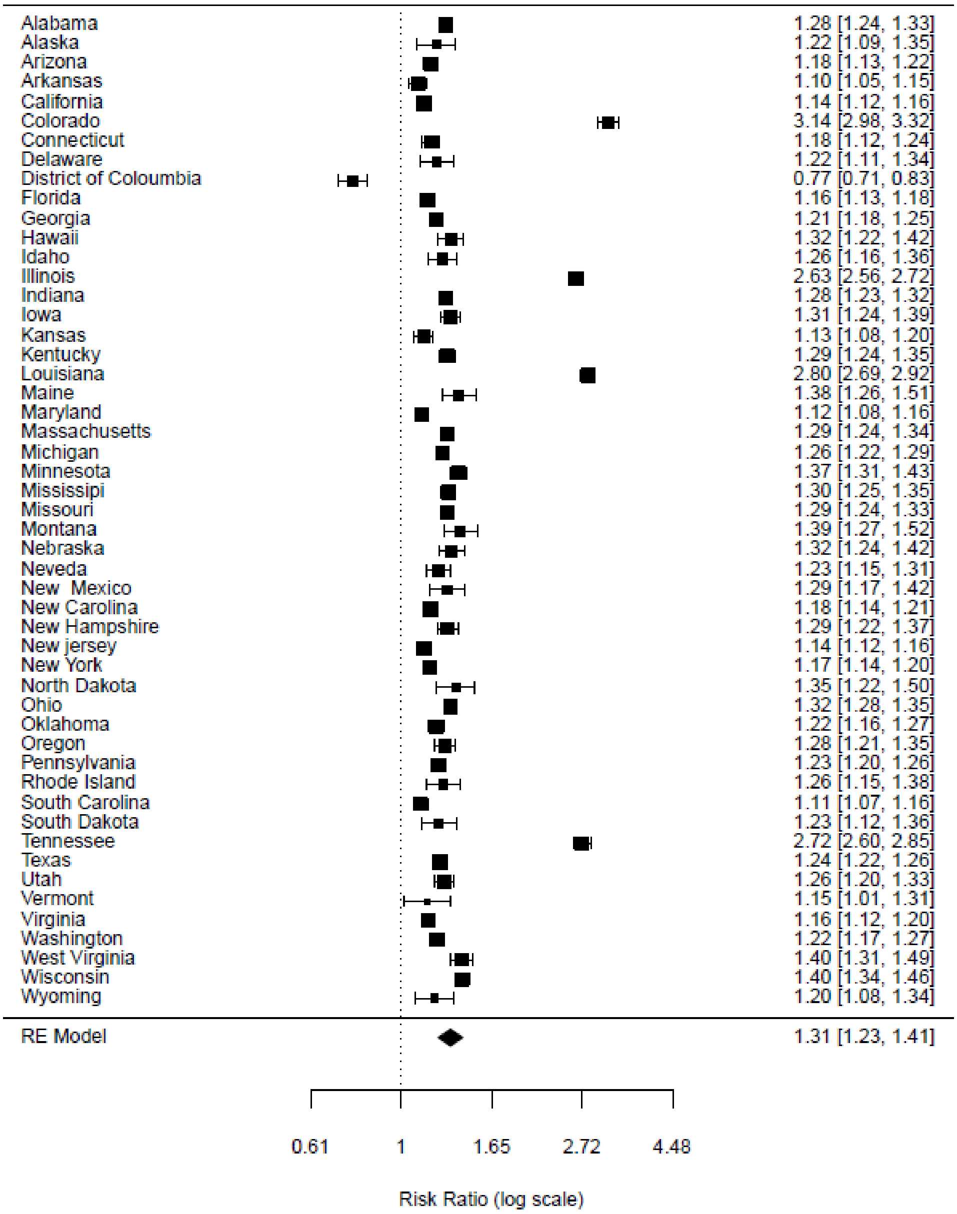
Note: This forest plot (Figure 3.5) shows the risk ratios in log for each United States (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates TRI effect size on the number of LBW for the United States (N = 51 States).

Figure 3.6: Effect of TRI on the number of LBW, considering levels of internet accessibility greater than 70 %



Note: This forest plot (Figure 3.6) shows the risk ratios in log for each United States (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates TRI effect size on the number of LBW for the United States (N = 51 States).

Figure 3.7: Effect of TRI on the number of LBW, considering levels of internet accessibility greater than 80 %



Note: This forest plot (Figure 3.7) shows the risk ratios in log for each United States (point estimate as square, two standard errors as lines). The lozenge at the bottom indicates TRI effect size on the number of LBW for the United States (N = 51 States).