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Abstract

Since the early 1990s, the air pollution level in the Jakarta Metropolitan Area (JMA) has arguably been one of the highest among mega cities in developing countries. This paper utilises the self-reporting data on illnesses available in the 2004 National Socio-Economic Household Survey (*Survei Sosial Ekonomi Nasional*, or SUSENAS) to test the hypothesis that air pollution impacts human health, particularly among children, in JMA. Test results confirm that air pollution, represented by the PM10 level in a sub-district, does significantly correlate with the level of human health problems, represented by the number of restricted activity days (RAD) in the previous month. The results also show that a given level of PM10 concentration is more hazardous for children.

Keywords: Air pollution, environmental economics, health economics and exposure response model

JEL: Q53, Q51, I18

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1 Introduction

Since the early 1990s, the air pollution level in the Jakarta Metropolitan Area (JMA covering areas of Jakarta, Bogor, Depok, Tangerang and Bekasi) has arguably been one of the highest in the developing countries. Both the annual average of total suspended particles (TSP) and nitrogen oxides (NO_2) in JMA are above the international standards set by the World Health Organization (WHO) (Health Effect Institute, 2004; Resosudarmo & Napitupulu, 2004). In addition, particulate matter with an aerodynamic diameter of less than 10 micrometer (PM10) concentration in JMA has been among the highest in the world (The World Bank, 2006) and in Asia (Figure 1). It has also been argued that these air pollutants impact negatively on society in the form of illnesses such as respiratory problems, eye irritation and cardiovascular diseases. Resosudarmo and Napitupulu (2004) estimated that the total health cost associated with pollutants in Jakarta in 1998 was approximately 180 million USD or approximately one percent of Jakarta's GDP, or approximately as much as the total revenue of the Jakarta government for that year. Applying a hedonic pricing model to housing rental prices, Yusuf and Resosudarmo (2009) predicted that the value of air pollution per household in Jakarta ranges from US$28 to US$85 per $\mu g/m^3$.

<<Figure 1>>

Major pollutants in JMA are carbon monoxide (CO), nitrogen oxides (NO_x), sulphur oxides (SO_x), volatile organic compounds (VOC) or hydrocarbons (HC) and PM10 as a fraction of TSP (IMAP, 2002). In the primary stage of emission, CO, NO_x, SO_x and VOC are gaseous substances. In the secondary stage, NO_x and SO_x can form secondary PM10. PM10 presents in the form of liquid and solid substances: liquid substances such as nitric acid (HNO_3) and sulphuric acid (H_2SO_4) in the presence of water, and solid substances such as ammonium nitrate (NH_4NO_3) and ammonium sulphate (NH_4HSO_4) in the presence of ammonia. Considering the wide variation in chemical content of PM10 as well as its possible impacts on health, in this paper, both primary and secondary PM10 were selected as the main indicators of air pollution in JMA. Besides variation in the chemical content, the physical characteristics of PM10 make it more dangerous compared to the other aforementioned pollutants. According to Gamble and Lewis (1996), 80 per cent of PM10 stays in the respiratory system if inhaled. PM10 is known to cause respiratory diseases, especially in children with asthma (Sirikijpanichkul et al., 2006).

This paper focuses on the quantification of PM10 impacts on child health using the number of restricted activity days (RAD) as the unit of analysis. Children are the focus of this paper since, particularly in developing countries, they are the group most vulnerable to health related air quality problems due to their relatively high exposure to the low quality of air and their under-developed immune system (WRI, 1999; Bernard et al., 2001; Haryanto, 2007). The types of illnesses considered are lower and upper respiratory illnesses. In this research, the causal relationship between PM10 and respiratory illnesses was estimated using dose-response functions or exposure response[4] models (ERM) (Ostro, 1994; Resosudarmo & Napitupulu, 2004).

Hospital and health center data on health impacts caused by air pollutant in most developing countries are not an accurate representation of the actual number of people affected, since many prefer to visit private doctors or to buy pharmacy medicines (Frankenberg et al., 2005). Other reasons to avoid using such data are that collecting patient data from all hospitals and health centers in big cities in developing countries is time consuming and also would not comply with the scientific research ethical directive regarding data released from hospital and other public facilities to the researcher as the third party. As a result, this paper utilises the self-reporting data on illnesses available in the 2004 National Socio-Economic Household Survey (*Survei Sosial Ekonomi Nasional*, or SUSENAS) to develop an ERM estimating the impact of air pollution on human health, particularly among children, in JMA. The indicator used to represent air pollution is PM10 while its impact on human health is represented by the number of restricted activity days (RAD) in the past month caused by lower and upper respiratory tract infections. SUSENAS is a large-scale, nationally representative, repeated cross-section survey conducted since the 1960s.[5]

In this paper, current literature on the public health impacts and risk assessment of air pollution is reviewed in Sections 2 and 3, respectively. Section 4 provides modeling results and Section 5 concludes the paper.

2 Air pollution impacts on human health

Literature on the impacts of air pollution on human health, in general, believes that the most damaging pollutant to human health is PM10 (Gamble and Lewis, 1996; Le-Bihan et al., 2002). PM in the form of TSP, PM10, PM2.5, NO_x and SO_x is related to upper respiratory

[4] Exposure-response is the effect of certain chemical on an individual depending on the amount of exposure received (Botkin & Keller, 2005, p.310) or 'the frequency of the health outcome and the level of exposure' or 'the relative increase in adverse health for a given increment in air pollution' (Kunzli et al., 2000, p.796).
[5] See Surbakti (1995) for a history of the development of the *Susenas*.

tract symptoms such as cough, bronchitis and chest infection especially in young children (Bernard et al., 2001). These pollutants are also closely linked to lower respiratory tract system conditions (Bernard et al., 2001) such as asthma (Koren & Utell, 1997). With higher PM concentrations in urban areas, asthma becomes more common, especially in children (Koren & Utell, 1997).

Hospital admissions for asthma attack show a positive relationship with PM from two days to a week's lag time (Pope III et al., 1995). Asthma causes the loss of approximately three million working days and 90 million RAD annually in big cities in the USA (Pope III et al., 1995). Asthma attacks are also considered to cause death, although a study by Koren and Utell (1997), using the total number of deaths and the average PM10 concentration per year could not establish the relationship between these factors. For instance, in the US, asthma deaths increased from 1979 to 1989 while PM10 and SO_x average concentrations decreased (Koren & Utell, 1997).

Deposition of PM in lungs can cause lung inflammation and cytokine release affecting heart activity and can further cause cardiac arrest (Bernard et al., 2001). Due to its ability to deposit in the lungs, PM10 is also a threat to the elderly and children. It has been associated with hospital admission and emergency room visits for chronic obstructive pulmonary disease[6] (COPD), pneumonia and cardiovascular disease such as ischemic heart disease[7] (IHD) (Brumback et al., 2000; Samet et al., 2000; Schwartz, 1995). A study conducted in the USA concluded that the effect of TSP — including PM10 and PM2.5 — on adult mortality is large and positive (Chay et al., 2003). Researchers agree that the smaller the particles, the more dangerous they are (Dockery et al., 1995; Marrack, 1995; Pope III et al., 1996) since the chance of them being deeply inhaled is greater. McCubbin and Delucci (1996) argue that PM contributes the most to health costs. Therefore, they conclude that stronger regulation of particulates will reduce mortality and morbidity.

On modeling the relationship between air pollutants and human health or ERM, literature concludes that pollutant concentration can be used in single pollutant models, however, an aggregation of several single air pollutant models can overestimate the overall health outcomes and cause double counting in economic analysis (Kneese, 1984; Kunzli et al., 2000). All the same, the use of a single indicator alone may underestimate the value of health impacts, it may disregard effects of other pollutants which are independent of the

[6] Partly blocked lung. Most people with COPD have both emphysema and chronic bronchitis. Symptoms include shortness of breath, coughing and a build-up of phlegm (Lung Foundation, 2009).
[7] Coronary artery disease causes reduced blood supply to the hearth muscle. Symptoms include chest pain and decrease exercise tolerance (Goldstein et al., 2006; RxMed, 2009).

selected pollutant (Kunzli et al., 2000). To estimate the correct value of ambient air improvement, researchers have developed different pollutant combination to value the total impacts of air pollutants on human health. Some use a surrogate pollutant to estimate some or all of the effects of all the other pollutants (BTRE, 2005; EPA, 2002). For instance, Kunzli et al. (2000) use PM10 only because they argue that PM10 is a reliable indicator of several sources of outdoor air pollution. Other researchers agree with the Kunzli et al. (2000) approach, for several reasons:

1. Hong et al. (1999) and Eyre et al. (1997) use PM10 as the surrogate pollutant for SO_2, CO and NO_2 since PM10 is correlated significantly with SO_2, CO and NO_2 and not with O_3 and because acid pollutants such as SO_2 and NO_2 contribute to the formation of PM10.
2. Pope III et al. (1995), Danielis and Chiabai (1998) and Eyre et al. (1997) use PM10 as a surrogate because PM10 is a respirable air pollutant and is an important contributing factor to respiratory disease[8] and has a strong relationship to mortality.
3. PM10 is a complex pollutant since it is a 'heterogeneous mix of solid or liquid compounds' such as organic aerosols, primary and secondary pollutants, and metal. Hall et al. (1992) use this property so that PM10 is a surrogate measure for one of its components or for other pollutants.

The above studies agree that PM10 or PM2.5 is the best estimator for calculating the health effects of air pollution (Peters & Dockery, 2006). The first reason for this is its close relationship with mortality and morbidity. The second reason is that secondary PM10 also consists of transition compounds of SO_x and NO_x in the form of ammonium sulphate and ammonium nitrate. This paper, hence, will use PM10 as the measure of air pollution to estimate the human health impacts of air pollution in JMA.

3 Method: risk assessment for public health

ERM estimation is one of the processes used in Risk Assessment for Public Health (Kessel, 2006). The complete process of this risk assessment includes first, determining the average annual concentration of each pollutant over a period of time; second, calculating the health impact and estimating the relationship between the pollutants and the health impact. This is carried out through the following sub-steps: (1) identification of health hazards by calculating the number of deaths, hospital admissions, or other health outcomes during a certain period of time (Samet et al., 1994); (2) estimation of the ERM; and (3) estimation of the population's

[8] Increased respiratory symptoms, decreased lung function, increased hospitalisations and other health care visits for respiratory and cardiovascular disease, increased cardiopulmonary disease mortality (Pope III et al., 1995, 472).

profile of exposure to the health hazard. The last step of this risk assessment is aggregating health risk in the form of a monetary unit (Kessel, 2006; Samet et al., 1994).

As this paper intends to develop an ERM, it only applies the second step with its sub-steps, using cross sectional data analysis of the aforementioned risk assessment process. Cross sectional analysis uses pollutant level data from different areas and relates them to the morbidity levels within the corresponding area (Hall et al., 1992). The general model of an ERM is a multivariate model as follows (Frankerberg et al., 2005);

$$h_i = a_o + a_1.p_i + a_2.Z_i + a_3.X_i + e_i \qquad (1)$$

where: h_i is whether or not an individual was impacted by the air quality. Appropriate models for Equation 1 are probit or multinomial models. p_i is an index measuring the level of air pollution exposure. $\boldsymbol{X_i}$ is a matrix of various individual and village socio-economic characteristics (Frankenberg et al., 2005). $\boldsymbol{Z_i}$ is a matrix containing levels or proxies of indoor air pollution or other pollutants. $\boldsymbol{Z_i}$ is meant to resolve the issue of omitting variable bias that commonly occurs in ERM models. Meanwhile e_i is white random errors. The main hypothesis is that α_1 is equal to zero.

In addition, a population profile analysis was added to determine the most affected and sensitive groups in a population. Sensitive groups such as infants and elderly people might react differently from other groups to the same exposure. To gain a complete estimation an ERM must consider the total dose received by certain groups in the entire population (Sexton & Ryan, 1988, cited in Hall et al., 1992). The population profile is based on: individual physical and health conditions; individual habits and activities; socio-demographic and socio-economic characteristics as well as housing including sources of indoor air pollution and community or neighbourhood conditions.

4 Data construction

PM10 is identified as the surrogate pollutant to represent all main pollutants in JMA. Average annual concentration of PM10 is estimated using a PM10 Dispersion Model (PMDM). This model is developed by combining two available dispersion models: the Simplified Mobile Emission Model (SIMEM) (Tomo & Syahril, 2002) and the Simple Interactive Model for Better Air Quality (SIM-AIR) (the World Bank, 2002). Figure 2 shows the ambient level of PM10 in 2004 resulting from the PMDM utilised in this paper.

<<Figure 2>>

All possible health hazards caused by PM10 are identified and listed. According to Sirikijpanichkul et al. (2006), human responses to PM10 pollution are: mortality, morbidity, chronic and acute bronchitis, hospital admissions, lower and upper respiratory illnesses, chest pain, respiratory symptoms, minor and major RAD, and asthma affecting children and elderly people especially with respiratory and/or cardiovascular diseases. These possible responses are matched with the list of illnesses in the 2004 SUSENAS. Here, respondents were asked to state the types of illnesses they had suffered in the month before the survey was conducted. They were then asked to state their number of absences from work, school or from not carrying out their daily social activities because of their illnesses. Illnesses listed in the 2004 SUSENAS were: fever, cough, cold, asthma, diarrhoea, headache and toothache. Cough, cold and asthma were selected to represent lower and upper respiratory illnesses possibly caused by PM10 pollution (Haryanto, 2007, Pers. Comm., 4 August; Peters & Dockery, 2006; Sirikijpanichkul et al., 2006). It is important to note that this information is self-reported, and so should be interpreted with caution since survey respondents might have different perceptions of their state of illness. They might have reported different levels of illness using a uniform unit: number of days of absence or restricted activity days (RAD).

The 2004 SUSENAS also contains data on the population profile. Proxies for the population profile are grouped into: individual physical and health condition; individual activities and habits; socio-demographic and socioeconomic characteristics; indoor pollution; as well as house and community conditions. Proxies for each group are as follows:

1. individual physical and health status: parents' and siblings' health status a month before the survey was conducted;
2. individual activities and habits: smoking habit, number of cigarettes per day, number of years of routine smoking, members of the family who smoke indoors, family smoking habit;
3. socio-demographic and socioeconomic characteristics: expenditure, expenditure per capita, head of household's education, occupation and income and average working hours per week; and
4. house condition, indoor pollution and community conditions which include:
    a. proxies for house condition: ceiling, age, wall, floor, density, function, land/house area ratio;
    b. proxies for indoor pollutants: sprays, disinfectants, bleach, batteries, paint, insecticides; and

c. proxies for community conditions: location, disaster area, access to street, street width, street cover materials, community average expenditure, average distance to community facilities such as primary schools, community health centres and sub-district offices.

The list of final variables extracted from the 2004 SUSENAS dataset are presented in Table 1 and the list of variables used in the model with their descriptive statistics are presented in Table 2.

<<Table 1>>
<<Table 2>>

5 Estimation strategy

To determine the appropriate functional form for the ERM, the distribution of the dependent variable — number of RAD in the past month — in the 2004 SUSENAS is investigated. This variable has a non-normal distribution (Figure 3). Attempts are made to identify possible transformation so as to normalise the distribution. However, none of the transformation results shows a normal distribution (Figure 4), so that implementing an Ordinary Least Square (OLS) technique would cause serious bias (Long & Freese, 2007). Other models such as a model for count data need to be identified and applied.

<<Figure 3>>
<<Figure 4>>

Observation of Figure 3 shows that the dependent variable has a similar pattern to the Poisson distribution. This paper then seeks the appropriateness of implementing a Poisson Regression Model (PRM) for the ERM model in this paper. Following Long and Freese (2006), the analysis begins by comparing the observed distribution with a Poisson distribution that has the same mean. Long and Freese (2006) suggest analysing the data using PRM without independent variables, then comparing the model prediction with the observed data proportion using post estimation command. It is important to consider that the generalised additive PRM provides the possibility of including non-linear dependence of the dependent variable (Schwartz et al., 2001). In many studies, count variables are treated the same as continuous variables by applying a linear regression model. The use of the linear regression model can cause 'bias, inefficient and inconsistent estimate' (Long, 1997). In a case where the amount of zero observation exceeds the allowable number, a zero inflated model for PRM is applied. On the other hand, when there are no zeros, a truncated version needs to be applied (Long, 1997).

The result from data analysis using PRM without independent variables (solid line in Figure 5) indicates that the observed proportion shows that respondents tended to choose 'convenient numbers' for RAD such as one week, two weeks, three weeks and one month represented by seven, fourteen, twenty one and thirty days, respectively. Three days has the highest probability: a possible explanation for this condition is that doctors usually recommend staying home for a maximum of three days in a letter addressed to the employer or school administrator. The prediction result using PRM (dash line in Figure 5), shows a smoother graph reducing extreme probability at three, seven, fourteen, twenty one and thirty days of RAD. It can be seen that PRM is relatively appropriate to be utilised with the data set available for this paper.

<<Figure 5>>

The minimum number of RAD is one day and the maximum is thirty days, therefore an estimation using Zero Truncated Poisson Regression Model (ZTP) is also utilised.

In estimating the ERM, this paper will, first, utilise the overall sample in the 2004 SUSENAS to observe the health impact of air pollutants on the overall population of JMA. After that a focus on the impact of air pollutants on child health is conducted. Children are defined as family members aged of fourteen or under. A comparison with the impact on non-head of household adults and the elderly group is conducted. Adults are those aged between fourteen and sixty. Elderly is defined as sixty and older. The main reason for removing the household head from the adult group is that they typically spend most of their day at a work place and/or travelling outside their sub-districts; meaning they are most likely exposed to a different level of air pollutant to their children. On the other hand, non-head of household adults and the elderly are most likely exposed to the same air pollutants as their children.

6 Results of all samples

Table 3 presents the results of estimating ERM in JMA for the overall population using PRM and ZTP models. This table shows that the estimation results using ZTP are better than those using the usual PRM, since ZTP produces lower Bayesian Information Criterion (BIC) and higher Pseudo-R^2. Further analysis is done using a Zero Truncated Negative Binomial (ZTNB) Model to observe overdispersion. The likelihood ratio test shows that Alpha is not significantly different from zero (p-value > 0.05). The result indicates that the estimation results using ZTP is appropriate since when the overdispersion parameter is zero then the estimation result using ZTNB is equivalent to ZTP.

<<Table 3>>

From Table 3, it can be seen that the average PM10 concentration in a sub-district is a significant determinant for the number of RAD. It hence can be said that the number of RAD in the general population is caused by the level of air pollution. The positive sign indicated that respondents living in sub-districts with higher average PM10 concentration tend to have a higher number of RAD.

Among demographics and socioeconomics variables, age, age squared, gender, expenditure per capita and head of household education were significant. It is important to note that the age variable is negative and the age squared variable is positive but very small, indicating the function is relatively linear and downwards sloping. The interpretation of this relation between age and the number of RAD is that young people or children tend to have a higher RAD than adults do.

Among smoking habit variables, the number of years of routine smoking and indoor smoking are both significant with positive signs, indicating that the number of years of routine smoking and indoor smoking contribute to the number of RAD. The number of family members who smoke turns out to be insignificant.

The third group of variables is the house and community condition. Significant variables are wall and floor types, size of building per parcel ratio, insecticide usage, street width in front of the house and average distance to community centres. Significant and positive wall and floor types indicates that respondents living in houses with bamboo walls and dirt floors tend to have more RAD. A significant and negative size of building per parcel ratio indicates that respondents living in houses with smaller front or back yards have a higher number of RAD. A probable explanation for this condition is that a small front or back yard prevents good circulation of air, trapping impurities inside the house. The use of bleach and insecticide are assumed to add to the indoor pollution problem. However, the results show both variables to have negative signs. Bleach and insecticide usage reduce the number of RAD. The reason for this might be because reasonable bleach usage can reduce microorganisms as the main cause of infection, and insecticide reduces the number of parasites, making respondents' houses cleaner and healthier to live in.

Respondents living in wider streets tend to have a lower number of RAD since wider streets usually have better street cover than narrower ones and are complemented with good sewers and drainage systems, making the environment cleaner. The location of houses relative to community centres (average distance to community centres) is also significant and positive, indicating that respondents living further from community centres have a higher number of RAD. This condition indicates that the longer it takes for the respondents to reach their daily destination, the higher the number of RAD.

7 Results for groups

Modeling results for the number of RAD among children, adults (non-head of household) and the elderly are set out in Table 4. Observing the relationships between PM10 concentration in a sub-district and the number of RAD in the previous month among the three age groups, it can be seen that they all have a positive relationship with almost the same coefficient size. The difference is that this relationship is highly significant (with a 1 percent significance level) among children, weakly significant among adults (with only a 10 percent significance level), and not significant among the elderley; i.e. the impact of PM10 concentration in a sub-district on children's health in that sub-district is much more consistent compared to that for other age groups.

<<Table 4>>

For children, other significant variables are age, gender, head of household income, head of household education, and average distance from home to community centres. Again, among children, with the same level of exposure to pollution, the younger the child, the higher the number of previous month RAD.

For adult family members, other significant variables are individual smoking habits, head of household income, head of household education, wall type, street width in front of the house, and average distance from home to community centres. For elderly family members, other significant variables are individual smoking habits, gender, age, head of household education, wall type, and average distance to the community centre and types of work. For this group of respondents, older males who smoke and who come from a family where the head of the household has lower education tended to have more RAD compared to other members of the group.

A rather puzzling result is the impact of household income on the number of RAD. Among children, a higher family income means a lower number of RAD; i.e. something that is expected. Among adult family members, however, a higher family income means a higher number of RAD. And, among the elderly, family income is not a significant determinant of the number of RAD. Further study in this subject depends on good explanations for this result.

8 Conclusion

Impacts of PM10 pollution in JMA on health are investigated in this paper. The main contribution of this paper is that it uses individual self-reporting data on health problems in the population of interest. There are problems associated with self-reporting information. Survey respondents might have different perceptions of their state of illness. They might report different levels of illness using a uniform unit. Nevertheless, this paper proposes that, for developing regions such as Jakarta, information derived from self-reporting is more useful in dealing with health problems than estimations derived from using ERM programs designed for developed countries.

The ERM in this paper is estimated using a PRM and ZTP since the distribution of the dependent variable, i.e. number of RAD during last month, was similar to the Poisson distribution. The results from the analyses show that once a person falls ill, PM10 concentration becomes one of the causal variables in increasing or reducing the number of RAD. The relationship between PM10 in a sub-district and the number of previous month RAD, in general, is positive and significant. The results also show that the younger the person, the higher the number of previous month RAD; i.e. the impact of a given level of PM10 concentration is more fatal for younger persons.

To better identify the vulnerable groups, the data set is split into three groups: adult family members, children and elderly family members. The results show that children are the group most vulnerable to PM10 pollution. PM10 concentration is a highly significant causal variable in children falling ill as a result of fever, cold, cough and asthma.

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Table 1: Variables extracted from Susenas 2004 data sets

Variables		Type	Notes on variables' value
Illnesses			
	Number of RAD in the past month	count	number of RAD
Physical and health			
Health	Tbc	binary	Tbc = 1
	Siblings' hlt	binary	Ill sibling = 1
	Parents' hlt	binary	Ill parents = 1
Activity and habit			
Smoking	Habit	binary	Smoking = 1
	No cigarettes	continuous	Number of cigarettes per day
	Years	continuous	Number of years of routine smoking
	Indoor	binary	Indoor = 1
	Family habits	count	At least 1 family member smokes = 1, more than 1 family member smokes= 2
Demographic	Gender	binary	Male = 1
	Age	continuous	Respondents' age
	Married	binary	Married = 1
	No family	continuous	Number of family members
	No children	continuous	Number of children
Socioeconomic	Expenditure	continuous	Family expenditure
	Ex capita	continuous	Expenditure per capita
	Education	continuous	Head of household education
	Income	continuous	Head of household income
Work	Occupation	continuous	Head of household education
	Days	continuous	Head of household working days/week
	Hours	continuous	Head of household working hours/day
	Hours/week	continuous	Head of household working hours/week
House and community condition			
House	Condition	binary	Poor = 1
	Ceiling	binary	Asbestos = 1
	Age	binary	Old = 1
	Wall	binary	Bamboo = 1
	Floor	binary	Dirt = 1
	Density	continuous	Number of family member per m2
	Function	binary	Mixed use = 1
	Parcel ratio	continuous	Building per parcel ratio
Indoor pollution	Spray	binary	Spray = 1
	Disinfectant	binary	Disinfectant = 1
	Bleach	binary	Bleach = 1
	Battery	binary	Battery = 1
	Paint	binary	Paint = 1
	Insecticide	binary	Insecticide = 1
Community	Location	binary	Old housing area = 1
	Disaster	binary	Disaster area = 1
	Street	binary	Close to street = 1
	Street width	continuous	Street width
	Street cover	binary	Dirt = 1
	Average exp	continuous	Average sub-district expenditure
	Distance	continuous	Distance to sub-district facilities

Table 2: Descriptive statistics for variables used in Poisson Regression Model (PRM) and Zero Truncated Poisson Model (ZTP)

Variable	Mean	Std. Dev.	Min	Max
Number RAD in past month	4.41	4.22	1.00	30.00
Number of years of routine smoking	1.14	5.28	0.00	66.00
Indoor smoking	0.54	0.50	0.00	1.00
Smoking habit in household	0.78	0.61	0.00	2.00
Gender, 1=male	0.50	0.50	0.00	1.00
Age	27.07	17.40	0.00	99.00
Age squared	1035.55	1165.73	0.00	9801.00
Expenditure per capita (log)	12.65	0.63	10.37	16.59
Head of household education	3.40	1.71	0.00	9.00
Wall type, 1=bamboo	0.08	0.27	0.00	1.00
Floor type, 1=dirt	0.06	0.23	0.00	1.00
Building per parcel ratio	0.78	0.27	0.01	5.33
Bleach	0.64	0.48	0.00	1.00
Insecticide	0.55	0.50	0.00	1.00
Street width	2.50	1.52	0.00	9.00
Average community distance to central JM	2.18	3.02	0.00	38.75
Average PM10 concentration in a sub-district	30.98	50.97	0.01	408.54

Table 3: Estimation results for the number of RAD in past month caused by fever, cold, cough and asthma using Poisson Regression Model (PRM) and Zero Truncated Poisson Regression Model (ZTP)

Variable	ZTP		PRM	
Air Pollution				
Average PM10 concentration	0.001	**	0.000	*
	(2.015)		(1.917)	
Demographics and socioeconomics				
Age	-0.003	*	-0.003	**
	(-1.795)		(-1.992)	
Age squared	0.000	***	0.000	***
	(6.905)		(6.997)	
Gender, 1=male	-0.059	***	-0.055	***
	(-2.897)		(-2.813)	
Number of family member	-0.012	**	-0.011	**
	(-2.006)		(-1.975)	
Head of household income (million Rp)	0.000		0.000	
	(0.018)		(0.007)	
Head of household education	-0.032	***	-0.030	***
	(-4.591)		(-4.458)	
Smoking habit				
Number of years of routine smoking	0.004	***	0.004	***
	(2.827)		(2.844)	
Indoor smoking	0.069	***	0.065	***
	(2.728)		(2.637)	
Smoking habit in household	0.003		0.002	
	(0.129)		(0.121)	
House and community				
Wall type, 1=bamboo	0.171	***	0.164	***
	(5.463)		(5.343)	
Floor type, 1=dirt	0.085	**	0.083	**
	(2.216)		(2.214)	
Building per parcel ratio	-0.117	***	-0.110	***
	(-3.113)		(-3.021)	
Bleach	-0.033		-0.032	
	(-1.489)		(-1.477)	
Insecticide	-0.125	***	-0.117	***
	(-5.862)		(-5.678)	
Street width	-0.035	***	-0.033	***
	(-4.634)		(-4.450)	
Average distance from home to community centre	0.010	**	0.009	**
	(2.232)		(2.162)	
Constant	1.716	***	1.718	***
	(31.857)		(32.851)	
N	2434		2434	
Log likelihood	-6716.608		-6759.639	
chi2	624.519	***	594.828	***
Pseudo R2	0.044		0.042	
aic	13469.216		13555.279	
bic	13573.567		13659.630	
Ln Alpha for ZTNB	-0.754			

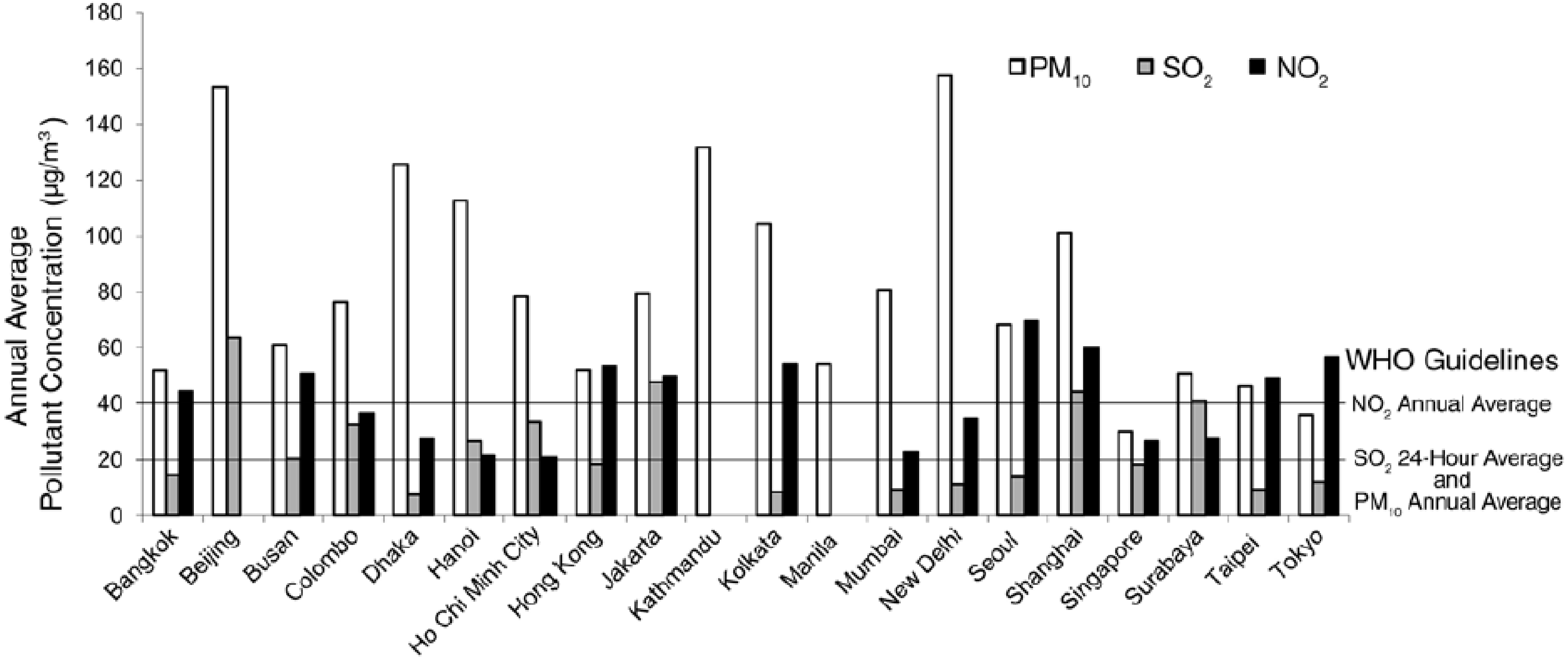
Notes: ***, **, * significant at 1%, 5% and 10% respectively. Numbers in the brackets are z-statistics. Expenditure per capita was transformed into its log form.

Table 4: Estimation results for number of RAD in past month caused by fever, cold, cough and asthma using Zero Truncated Poisson Regression Model (ZTP)

Variable	Adult	Elder	Children
Air Pollution			
Average PM10 concentration	0.001 *	0.001	0.001 ***
	(1.672)	(0.478)	(2.835)
Demographics and socioeconomics			
Age	0.009	0.010 **	-0.013 ***
	(4.966)	(2.021)	(-3.219)
Gender, 1=male	-0.041	0.230 ***	-0.055 *
	(-0.762)	(3.029)	(-1.728)
Head of household income	0.219 ***	0.069	-0.098 *
	(3.393)	(0.366)	(-1.684)
Head of household education	-0.052 ***	-0.069 **	-0.076 ***
	(-4.032)	(-2.774)	(-6.776)
Health condition and habit			
Individual smoking habit	0.087 *	0.306 ***	
	(2.129)	(4.106)	
House and community			
Wall type, 1=bamboo	0.276 ***	0.402 ***	
	(5.050)	(4.340)	
Street width	-0.039 ***		
	(-2.805)		
Average distance from home to community centre	0.044 ***	0.027 **	0.017 **
	(5.130)	(2.116)	(2.586)
Occupation			
Worker	-0.174	-0.231 **	
	(-3.749)	(-2.340)	
Student	0.018		
	(0.221)		
Constant	1.297 ***	0.978 **	1.655 ***
	(13.900)	(2.504)	(32.742)
N	674	118	1076
Log likelihood	-1885.881	-475.915	-2574.144
chi2	180.706	87.126	76.183
Pseudo R2	0.046	0.084	0.015
aic	3797.761	977.831	5162.287
bic	3856.433	1013.850	5197.154

Notes: ***, **, * significant at 1%, 5% and 10% respectively. Numbers in the brackets are z-statistics. Expenditure per capita was transformed into its log form.

Figure 1: Five years (2000–2004) average PM10, SO2 and NO2 concentration in selected Asian cities



Source: Health Effect Institute, 2010

Figure 2: Concentration of PM10 in every subdistrict in JMA

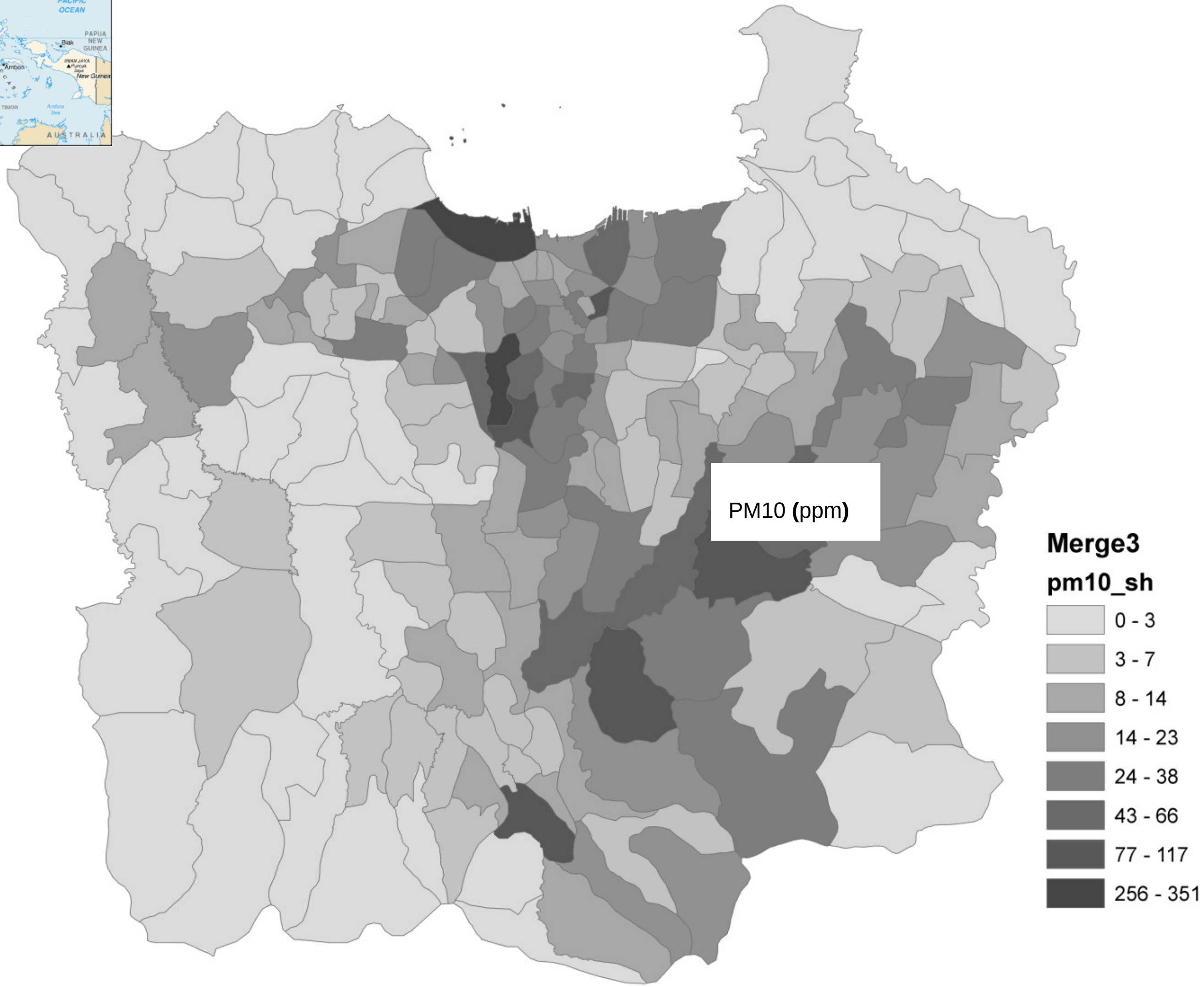


Figure 3: Density function of Number of restricted activity days

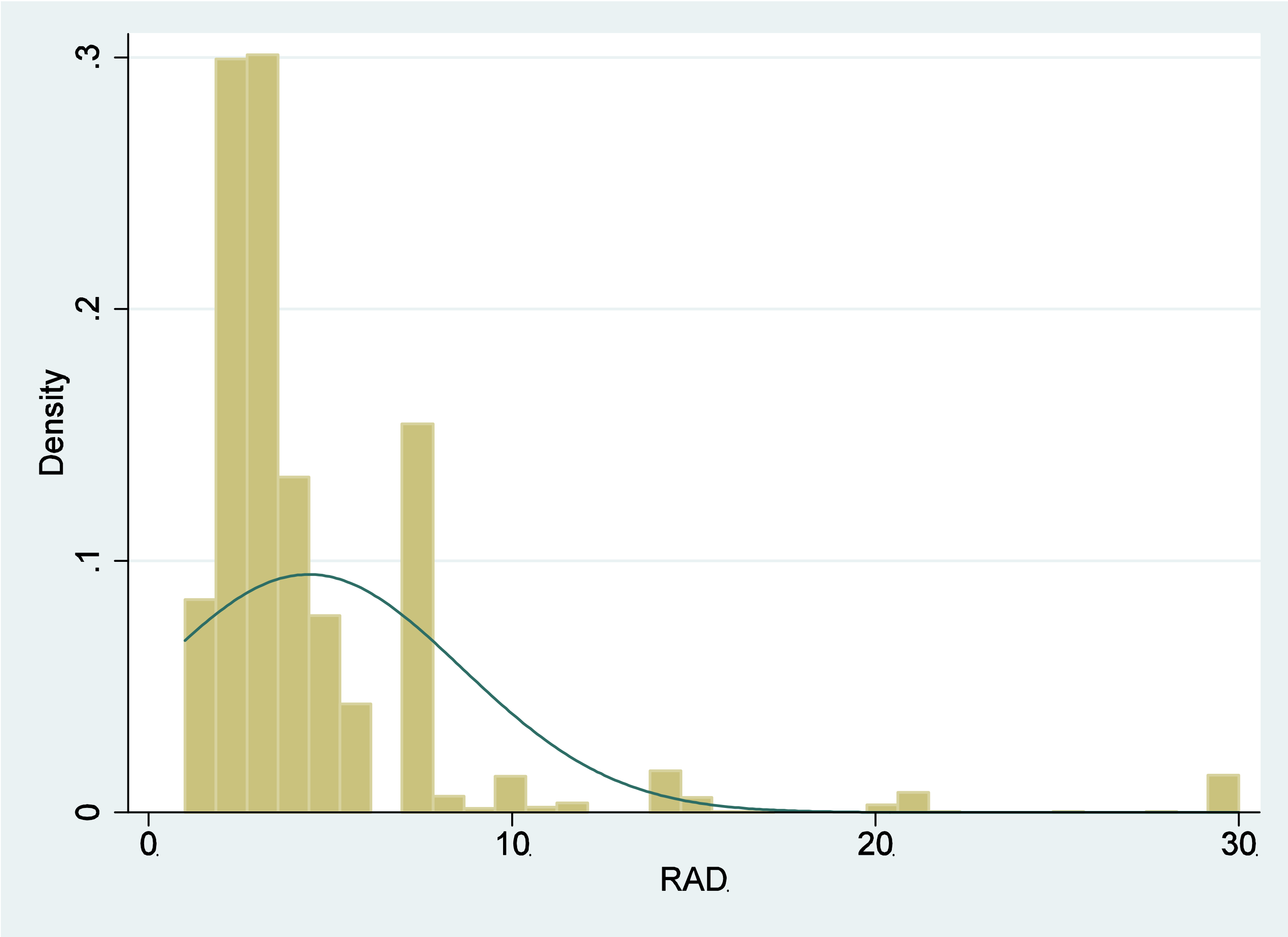


Figure 4 Transformations of the dependent variable: Number of restricted activity days

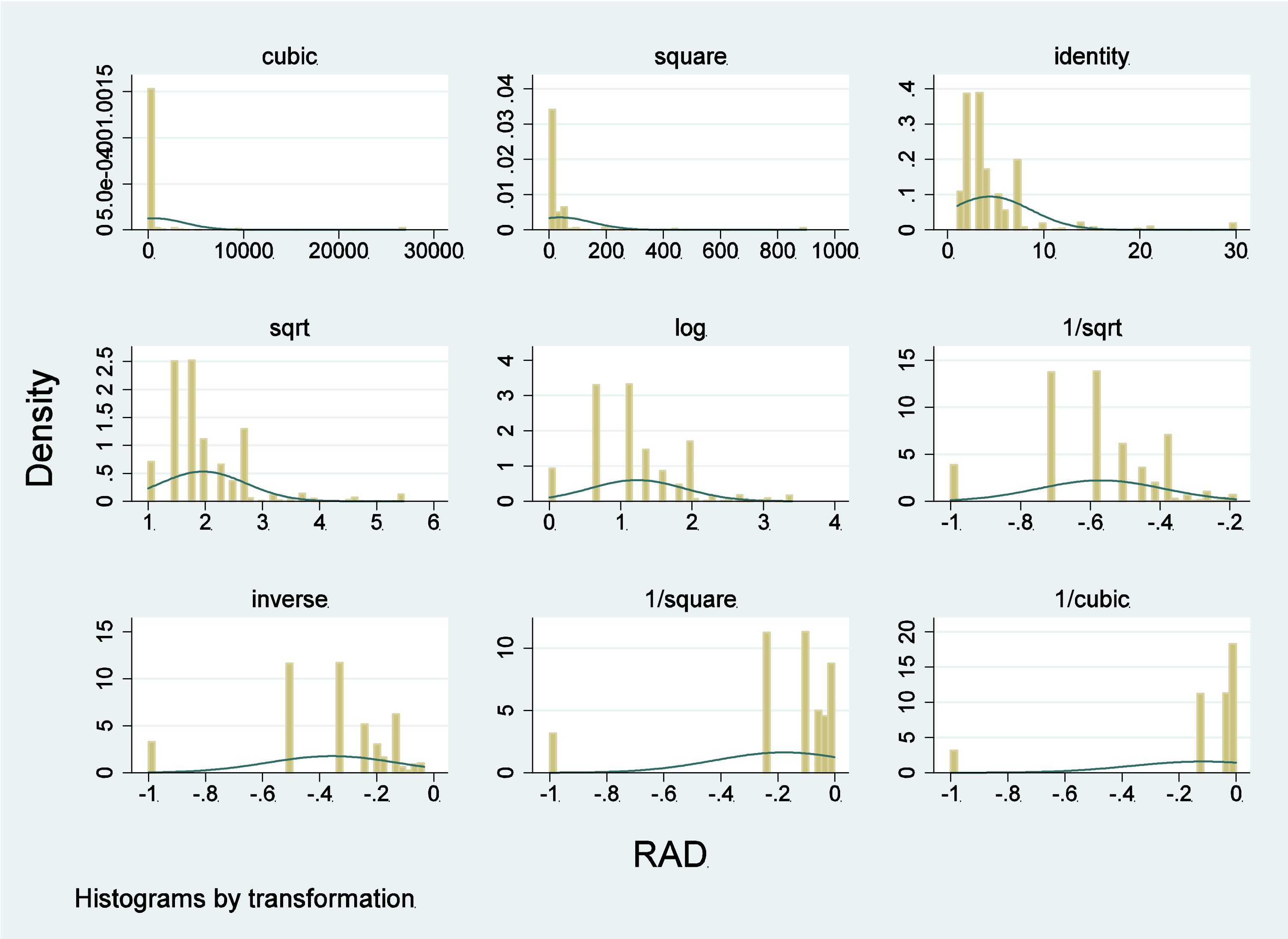
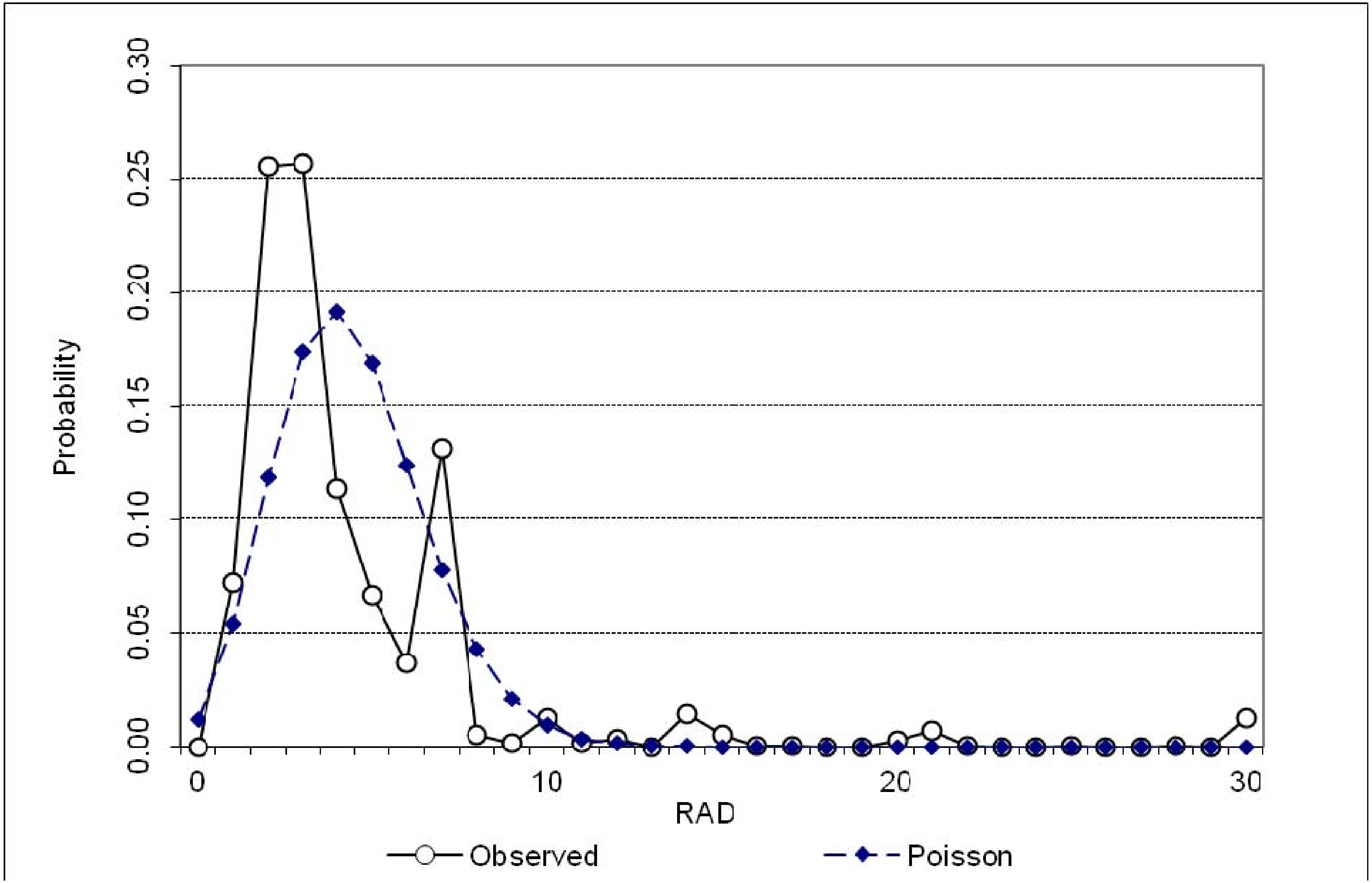


Figure 5: Comparison between real data and Poisson prediction



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