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Towards greater socio-economic equality in allocation of wastewater discharge permits in China based on the weighted Gini coefficient

Qiang Yuan[a], Neil McIntyre[b], Yipeng Wu[a], Yichao Liu[a], Yi Liu[a,*]

[a] School of Environment, Tsinghua University, 1 Qinghuayuan, Haidian District, Beijing 100084, China
[b] Centre for Water in the Minerals Industry, Sustainable Minerals Institute, The University of Queensland, St Lucia, Queensland 4072, Australia

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ABSTRACT

Although there are many methods based on efficiency and equality in allocating discharge permits, developing both reasonable and feasible discharge permit allocation methods remains a challenge. This study proposes an allocation method that aims to achieve equitable allocations with respect to population, land area, environmental receiving capacity, and Gross Domestic Product, which are incorporated into a multi-index Gini coefficient. Previous methodological advances are enhanced by assigning weights to each index using the Analytic Hierarchy Process; and by introducing a new Inequality Factor to quantify the residual inequality. These methods are applied to a case study of chemical oxygen demand discharge permit allocation among 13 cities in Jiangsu Province, China. The allocations obtained by optimizing this method reduce the current level of inequality and are considered more feasible for achieving pollution reduction targets than the equal ratio or average amount benchmark methods. In the case study, the Inequality Factor was used to identify the cities that are the greatest beneficiaries and losers under the allocation scheme. A potential option for improving equality is to relax the constraints imposed on the allocation reductions; however little sensitivity to this was found implying that the limits are not barriers to equality. A sensitivity analysis was conducted to exam the uncertainty in the weights, showing significance for individual cities, but low significance for province-level equality. It is concluded that the integrated use of the Weighted Gini coefficient and Inequality Factor can offer new insights into regional and the city-level equality of discharge permit allocations.

1. Introduction

Cumulative impacts of wastewater discharges are often managed through a system of discharge permits, whereby the sum of the permits in a given management unit is less than or equal to the acceptable total pollution load for that unit. Because constraints on wastewater discharges may affect productivity and/or costs of wastewater treatment, discharge permits are generally regarded as economic goods, and competition for permit allocations is expected (Sun et al., 2010). Allocating the permits in a way that maximizes overall socio-economic benefits while minimizing inequality between management units is the general aim of discharge permitting policy (Han et al., 2016; Liu and Lin, 2017; Nikoo et al., 2012; Vaillancourt and Waaub, 2006) and hence is the concern of the responsible environmental management authorities. However, which socio-economic metrics to use, and how to balance multiple alternative metrics in a transparent, and constructive manner, remains a challenge globally. This is especially the case where major reductions in discharges are envisaged and hence there may be acute socio-economic impacts and disparity. In this respect, the industrial regions of China make an excellent case study (Zhang et al., 2012).

The Chinese government has applied the approach of total pollutant load control since 1996 for Chemical Oxygen Demand (COD) and Ammonia Nitrogen (NH3-N) from industrial and domestic sources (Wu, 1999). According to the policy, water pollutant discharge permits are usually allocated based on the current pollutant load of each administrative region of the watershed (Wang et al., 2016) and are reallocated every five years following the governments Five-year Plan for National Economic and Social Development (Sun et al., 2010).

This is implemented in the four steps shown in Fig. 1. In the first step, the national environmental protection ministry determines the total water pollutant discharge permits for each province. Next, the province-level environmental protection bureau (EPB) allocates discharge permits to each city-level environmental protection bureau, and each city-level EPB allocates county-level permits. In the last step, an allocation is made to each registered point source. Thus the four steps can be categorized into two types of allocation: from region to region and from region to point sources. This may be followed by trading of

* Corresponding author.
E-mail address: yi.Liu@tsinghua.edu.cn (Y. Liu).

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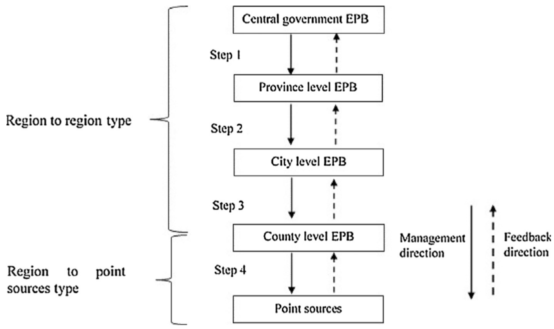

Fig. 1. Discharge permit allocation steps in China.

allocations between permit-holders.

Meanwhile, the Chinese central government applies a uniform proportional reduction in discharge permits for all main rivers and water basins (Sun et al., 2010). In other words, every five years, the permitted total pollutant discharge should reduce by a target percentage. However, a uniform reduction does not consider many of the socio-economic differences between sub-regions (Miao et al., 2016), such as wealth, dependence on particular natural resources and industry mix. To address this, the Chinese central government is attempting to strengthen the discharge permit system, including constructing improved allocation methods for the region to region allocation type.

Globally, there are two general mechanisms for initial allocation of waste discharge permits: auction and grandfathering (Cramton and Kerr, 2002; Goulder, 1995; Requate, 2005).

The auction mechanism aims to create economic efficiency based on the market (Edwards and Hutton, 2001; Liao et al., 2015). It has been used in the European Union Emissions Trading System and the Regional Greenhouse Gas Initiative and Western Climate Initiative schemes in the USA. However, the auction mechanism has faced implementation challenges because of potential additional transaction costs of permits (Hanley et al., 1997), in some cases leading to its rejection by stakeholders (MacKenzie et al., 2008). Unsurprisingly, stakeholders prefer to obtain permits freely rather than paying for them under the auction mechanism (Norregaard and Reppelin-Hill, 2000).

Grandfathering is when governments allocate waste discharge permits for free, with the allocation typically based on historical emissions or production output, or some proxy of these. Some scholars have discussed how to make the methods of grandfathering more efficient so that the allocation brings greater benefit and/or lower cost (Cho et al., 2004; Liang et al., 2015; Mostafavi and Afshar, 2011; Rahman et al., 2009). For example, minimizing wastewater treatment costs has been suggested (Murty et al., 2006; Mostafavi and Afshar, 2011) and 19 types of allocation method have been recommended by the US Environmental Protection Agency, many of which are based on the efficiency (productivity per unit discharge) principle. However, methods based on efficiency do not take equality (i.e. the principle that each stakeholder has an equal right to use environmental resources) into account, and there have been numerous discussions about alternative equality-focused approaches. These include aiming for equality in terms of reduction proportions (Brill et al., 1976; Takyi and Lence, 1996), and in terms of allocations per unit of multiple relevant indicators, such as population (Deng et al., 2010). To balance equality with efficiency, some scholars have proposed that a series of indicators are considered, each of a reasonable weight, in which the allocation is directly proportional to the integrated indicator value (Bohm and Larsen, 1994). However, that may face challenges in their practical feasibility (Chen et al., 2012).

In recent years, many scholars have focused on the Gini coefficient, which aims to measure the inequality in use of environmental resources (Cullis and Koppen, 2007; Druckman and Jackson, 2008; Jacobson et al., 2005; Zhong et al., 2008), including allocation of waste discharge permits (Chen et al., 2012; Sun et al., 2010; Wang et al., 2011; Zhang et al., 2012). The Gini coefficient, a ratio between 0 and 1, was originally proposed by the Italian economist Gini in 1912 to measure the inequality of income according to the Lorenz curve (Bosi and Seegmuller, 2006; Lambert, 1985), which is a graphical representation of the distribution of income or of wealth. Fig. 2 shows an example Lorenz curve, in which the inequality is measured over the population and in terms of income, although the indices on both the x-axis and y-axis may be defined differently. The Gini coefficient is the ratio of the area A to the area (A + B) (Biancotti, 2006; Kleiber and Kotz, 2002; Moyes, 2007; Xu, 2004). The higher value the Gini coefficient has, the less equality there is. 1 implies absolute inequality while 0 implies absolute equality, while surpassing 0.4 has been regarded as warning of impending inequality risk (Xiao et al., 2009).

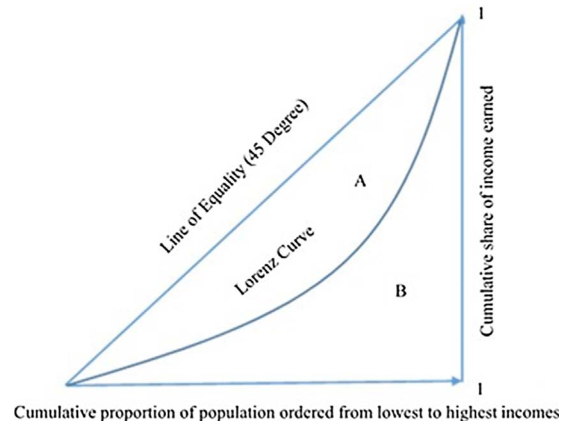

Fig. 2. Calculation of Gini coefficient using the Lorenz curve.

Following the application of the Gini coefficient to a range of other environmental management problems (e.g., Druckman and Jackson, 2008; Jacobson et al., 2005; White, 2007), Sun et al. (2013) introduced it to the problem of discharge permit allocation. A selected index, which may represent the population, land area, local economy and environmental receiving capacity (ordered from low to high allocation per unit index) are on the x-axis and the share of allocated discharge permits on the y-axis. Using Tianjin, China, as an example, Sun et al. (2013) calculated the Gini coefficient for each of four indices, and used the sum of the four Gini coefficients as a basis for optimizing the discharge permit allocations for the next round of allocations. Based on that work, Zhang et al. (2012) and Wang et al. (2016) applied the environmental Gini coefficient considering socio-economic and environmental factors, and reduced the inequality of region to region discharge permit allocations.

These applications show that the Gini coefficient method can offer new insight into the level of equality achievable in the allocation of discharge permits; and that multiple indices of equality may be relevant, in which case a multi-index Gini coefficient may be used (Sun et al., 2010; Wang et al., 2009). However, the multi-index view introduces two further challenges: 1) as different levels of importance may be attached to different indices, there is a need to consider how to attach weights to the indices; and 2) as the multi-index Gini coefficient will generally still be greater than 0 after optimization, there is a need to also quantify the source of the remaining inequality (Qin et al., 2013).

This paper investigates the applicability of an equality-based approach using the Gini coefficient to region-to-region discharge permit allocation. Using an Analytic Hierarchy Process (AHP), Gini coefficients representing different indices of equality are given weights to reflect their relative importance. A new indicator called the Inequality Factor (IF) is proposed and used to explore and report the sources of inequality in the allocation. A case study of allocating COD discharge permits to the 13 cities in Jiangsu Province, China is used.