Does emission permit allocation affect CO₂ cost pass-through? A theoretical analysis

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1. Introduction

Carbon emissions trading has evolved as a major policy instrument for realizing cost-effective emission reductions in the post-Kyoto period of climate change. Many countries/regions have gradually launched their emission trading systems (ETS) since 2005, such as the European Union (EU, comprising 31 countries), New Zealand, Australia, Korea and China (seven provinces and cities). In addition, countries such as Canada, Ukraine, Brazil and Russia are developing or to be developing their ETS. One fundamental question in an ETS is how CO₂ emission permits should be allocated among the participants in a carbon market (Zhou et al., 2013). Several commonly used CO₂ emission permit allocation methods are grandfathering, benchmarking and auctioning (Zetterberg et al., 2012). In line with economic theory, ETS determines a rise in marginal cost equal to the CO₂ opportunity cost regardless of whether CO₂ emission permits are allocated free of charge or not (Chernyavs’ka and Gulli, 2008).

In order to avoid putting domestic carbon intensive industries at a disadvantage relative to competitors in non- or less carbon constrained countries, policy makers consider free allocation of CO₂ emission permits as an appropriate measure (Alexeeva-Talebi, 2011; Zetterberg et al., 2012). For example, during the first two phases (2005–2007 and 2008–2012) of EU ETS, CO₂ emission permits were freely allocated to the participating firms mainly by grandfathering. However, previous studies show that carbon intensive firms (e.g. those in the power, cement, newsprint, steel, aluminum, petroleum, and aviation sectors) covered in the first two phases of EU ETS passed through their CO₂ cost to product prices, resulting in windfall profits (Sijm et al., 2006; Smale et al., 2006; Ponsard and Walker, 2008; Zachmann and Hirschhausen, 2008; Alexeeva-Talebi, 2011; Nelson et al., 2012; Jouvet and Solier, 2013; Castagneto-Gissey, 2014; Mokinski and Wölfing, 2014; Meleo et al., 2016). Sijm et al. (2006) found that 60–100% of the carbon price was passed through to electricity prices in Germany and the Netherlands. Alexeeva-Talebi (2011) showed the full pass-through potential of carbon cost in European petroleum markets. Nelson et al. (2012) conducted a literature review of pass-through rate in Australian wholesale electricity markets, which indicated that the average pass-through rate was 93.45%.
CO₂ cost pass-through can be defined as the impact of carbon price on product price due to the implementation of an ETS, which can be measured by CO₂ cost pass-through rate (Wild et al., 2015). A higher rate of CO₂ cost pass-through indicates that consumers bear most of the carbon cost, which tends to affect low income groups disproportionately but may reduce product consumption and thus CO₂ emissions. On the contrary, a lower rate shows that the CO₂ cost would be mainly undertaken by manufacturers, subsequently encouraging the investment of carbon efficient technologies but possibly putting domestic carbon intensive industries at a disadvantage (Nelson et al., 2012; Nazifi, 2016). In either case, quantifying the CO₂ cost pass-through provides valuable information for policy makers to avoid the windfall profits and market distortion in a carbon market.

Many studies have been devoted to study the influential factors of CO₂ cost pass-through rates. Sijm et al. (2006) found that the pass-through rate was dependent on the carbon intensity of the marginal production unit, market structure, and other technology factors. Chen et al. (2008) showed that the CO₂ cost pass-through rate in power industry of northwest Europe was affected by market competitiveness, merit order changes, and elasticity of demand and supply. Chernyavs’ka and Gulfi (2008) showed that the CO₂ cost pass-through rate in Italian electricity market was dependent on several structural factors such as market structure, capacity availability, power plant mix and power demand level. Kim et al. (2010) showed that CO₂ pass-through rate varied with the dispatch potential of generators and the availability of competing cleaner forms of generation. Sijm et al. (2012) conducted a theoretical analysis of the impact of power market structure on the CO₂ cost pass-through rate.

Earlier studies have shown that the magnitude of CO₂ cost pass-through rate may be influenced by a wide range of factors. Several scholars, e.g. Burtraw et al. (2002), Demailly and Quirion (2006), Hahn and Stavins (2011) and Zhang et al. (2015), pointed out that emission permit allocation is likely to affect the CO₂ cost pass-through since the product prices of firms covered in an ETS vary under different permit allocation methods. But to what extent emission permit allocation will affect the CO₂ cost pass-through? It is the purpose of this paper to develop a Nash-Cournot equilibrium model to theoretically quantify the impact of CO₂ emission permit allocation method on the CO₂ cost pass-through rate. The proposed model is general enough to be applicable to oligopolistic market (such as cement, newspaper, steel, aluminum and aviation industry) (Smale et al., 2006), monopolistic market (electric power industry) (Kim and Lim, 2014), and duopolistic market (petroleum industry) (Wang and Wang, 2015). Although the degree of CO₂ cost pass-through may vary from one situation to another, we show that there are some rules of thumb that give a reasonable approximation of the pass-through rate. The main contribution of this paper lies in two-fold. First, we show that the CO₂ cost pass-through rate is indeed affected by emission permit allocation. Second, previous studies discuss how to choose emission permit allocation method by evaluating the impact of permit allocation on producer’s profit and emission reductions, while this paper yields insights for policy makers to choose allocation method from the perspective of consumers.

The rest of this paper is organized as follows. In Section 2, after introducing CO₂ cost pass-through rate and major CO₂ emission permit allocation methods, we present the Nash-Cournot equilibrium model in ETS. Section 3 summarizes the main results and findings. Section 4 concludes this study with some policy implications.

2. Models
2.1. CO₂ cost pass-through

In literature, there are mainly three definitions of CO₂ cost pass-through rates with reference to electricity market. The most popular one is the proportion of CO₂ emission permit price (expressed in $/tons of CO₂) that is passed through to electricity price (expressed in $/MWh) (Zachmann and Hirschhausen, 2008; Nelson et al., 2012; Mokinski and Wölffing, 2014; Wild et al., 2015). The second defines the CO₂ cost pass-through rate as the ratio of change in the price of electricity (expressed in $/MWh) to the change in marginal cost of the marginal unit (expressed in $/MWh) due to the introduction of ETS (Chernyavs’ka and Gulfi, 2008; Sijm et al., 2012). The third refers to the change in the electricity price (expressed in $/MWh) divided by the CO₂ emission cost of the marginal production unit (the product of CO₂ emission permit price and CO₂ emissions per unit of product, expressed in $/MWh) (Lise et al., 2010; Sijm et al., 2012; Nazifi, 2016).

Let PTR be the CO₂ cost pass-through rate. DP denotes the change of product price after the implementation of ETS. P refers to the CO₂ emission permit price in carbon market. dMC is the change of marginal cost of the marginal unit after implementing ETS, which can be regarded as net cost change. dCC signifies the CO₂ emission cost of the marginal production unit, i.e. the product of CO₂ emission permit price and CO₂ emissions per unit of product, which can be seen as gross cost change. The gross cost change dCC is the change in marginal cost change by keeping production output fixed. However, a gross cost change dCC induces an output change and thus marginal cost change, which must be considered to obtain the net cost change dMC (Ten Kate and Niels, 2005). The three kinds of CO₂ cost pass-through rates are defined as

\[
PTR_1 = \frac{dp}{Pc}
\]  
\[
PTR_2 = \frac{dp}{dMC}
\]  
\[
PTR_3 = \frac{dp}{dCC}
\]  

Fig. 1 shows the net cost change and gross cost change under full competition with varying and constant marginal costs and linear demand.¹ With the varying marginal cost and linear demand, PTR₂ is greater than PTR₁ because dMC is always lower than dCC. If the marginal cost of the marginal unit is constant, dMC would be equal to dCC so that PTR₂ is equal to PTR₁. In particular, it can be observed from Fig. 1 that the price change resulting from a gross cost change is equal to the induced net cost change. Thus, with the varying marginal cost and linear demand, the cost pass-through rate under full competition remains 100% provided that the second definition is used.

2.2. CO₂ emission permit allocation methods

The methods for CO₂ emission permit allocation may be broadly grouped into indicator approach, optimization approach, game theoretic approach and hybrid approach (Zhao and Wang, 2016). In the existing ETS, three popular allocation methods are grandfathering, benchmarking and auctioning.

Grandfathering is regarded as the most widely used method for CO₂ emission permit allocation, probably due to its simplicity, wide acceptability and potential for reducing carbon leakage (Schmidt and Heitzig, 2014). Grandfathering refers to the free allocation of emission permits in proportion to the historical emissions of a firm, which indicates that the amount of emission permits assigned to the firm is independent of its current behavior (Demailly and Quirion, 2006). Let \( \bar{f} \) be the amount of free CO₂ emission permits allocated to firm \( i \), \( d \) denotes the CO₂ emission allocation coefficient or reduction rate, \( e_0 \) is the amount of historical CO₂ emissions for the base year. The CO₂ emission allocation coefficient \( f \) and the base year are determined by regulators, which means that both \( f \) and \( e_0 \) are exogenous. The initial CO₂ emission permits of firm \( i \) by grandfathering are equal to the product of the CO₂ emission allocation

¹ In Fig. 1, \( S_0 \) is the supply (i.e. marginal cost) curve excluding CO₂ cost, \( S \) includes CO₂ cost, \( D \) is the demand curve, \( Q_L \) is the equilibrium output before ETS, and \( Q^* \) is the equilibrium output after ETS.
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