



# Green process innovation and differentiated pricing strategies with environmental concerns of South–North markets



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## ABSTRACT

This paper investigates the green process innovation and differentiated dynamic pricing strategies for a Southern firm under a two-market framework where a North country imposes a carbon tariff and a South country announces an emission cap. Results from the dynamic optimization problem show that carbon tariff decreases innovation, domestic price, the firm's profit and the Southern social welfare but increases foreign price. A less strict binding emission cap enhances innovation, the firm's revenue and the Northern social welfare but cuts domestic price. The domestic price can be higher, lower or intersect with its counterpart in the North under different situations.

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## 1. Introduction

The environmental concern has brought firms opportunities and challenges worldwide. As consumers are getting increasingly green-sensitive, governments also place multiple enforcements and policies to abate pollution. One major issue refers to carbon emission mitigation which has aroused specific attention by countries and international organizations. The transboundary nature of carbon emission especially calls for collaborations between regions, governments and countries. In this paper, we investigate a monopolist producing in a developing country but distributing products to both the local market and a foreign developed country. The firm is confronted with two environmental policies: one refers to a carbon tariff charged by the developed country to fight carbon leakage, the other names a domestic emission cap (constraint) which restrains total carbon emission during producing process. In response to the two imposed policies, the firm determines its green process innovation and two differentiated pricing strategies so as to maximize profit.

While in most industrialized countries emission abatement has been top of the government agenda, it has not been given fully priority in several developing countries due to other urgent economic issues (Masoudi and Zaccour, 2013). Stringent environment policies in developed countries usually introduce additional cost for manufacturers, hence firms sometimes would rather relocate to developing countries to avoid heavy taxation, strict audit and extraordinary punishment. Such phenomenon is generally termed as Pollution Haven Hypothesis (PHH) and has attracted many research attention (Levinson and Taylor, 2008; Eyland and Zaccour, 2014; Zhang, 2010).

One alternative policy employed by developed countries points to carbon tariff (equivalently termed as Border Tax Adjustments, BTAs), indicating that exported products from developing countries like China are subject to be taxed by

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the target countries such as the US and the EU members. For instance, the US Clean Energy and Security Act gave permission to the US government to impose carbon tariff on imports in 2009, which gives a sign of the tax policy being officially enforced in the near future (Wang et al., 2015). In practice, a constant carbon tariff rate is often applied when the embodied carbon of exported products from the developing country to the developed country is taxed. Such constant per-unit carbon tariffs are captured in several researches, e.g., Eyland and Zaccour (2014) and Wang et al. (2015).

Apart from the developed countries, developing countries especially China, have begun to take the responsibility and announced several pollution abatement commitments as well. China has promised to reduce CO<sub>2</sub> emissions per unit of GDP by 40–50% by 2020 from 2005 level, by achieving such goal multiple policy measures are proposed, e.g., domestic carbon tax, export carbon tax and so on (Zhao et al., 2014; Li et al., 2012). All these carbon emission mitigation schemes aim at carbon emission mitigation, and act directly to legislate firms' obligation and to impact their producing strategies. In this paper, we propose an emission constraint to the firm, a commonly seen regulation imposed by the government to reduce emission (Absi et al., 2013; Chen et al., 2013; Helmrich et al., 2015). For instance, the Chinese government has established a specific department of pollution emission control in the ministry of environmental protection, whose duties include setting total emission caps and monitoring the policy's application. Under the emission constraint, a firm locating in a developing country faces a total emission constraint, carbon emission being by-product of the manufacturing process.

With top-down policies enforced by governments contributing to external factors for companies to go green, pressures of growing green demand also exert bottom-up driving forces to firms (Huang et al., 2016). Among multiple emission-reducing measures, green innovation is regarded as a survival need for firms to keep competitiveness (Medeiros et al., 2014). As one of the key measures of green innovation, process innovation is proved to significantly reduce pollution during the manufacturing process and largely improves the product's green process performance (Lee et al., 2015; Gavronski et al., 2011). Hence firms worldwide emphasize process innovation, in response to both government requirement and consumers green demand. One thing to notice is that technology ages with time, which means that current innovation outcome will experience depreciation as competition heated and will decay with time (Lambertini and Mantovani, 2009; Chenavaz, 2012). This leads to a decay rate in our model, describing the innovation outcome depreciation.

With the two government policies taken into consideration, focus of this paper is to investigate in a dynamic setting the optimal green process innovation and two differentiated pricing strategies of a monopolist who manufactures in a developing country (South) but sells products both locally and internationally to a developed country (North). Optimal strategies are obtained by solving the corresponding optimization problem on basis of Pontryagin's Maximal Principle, and impacts of parameters on key outcomes are investigated. Results indicate that carbon tariff discourages innovation, cuts the price in the South but lifts up the Northern price. Higher tax rate leads to less total products, a majority of which are sold locally. Meanwhile, the firm experiences profit loss and the social welfare in the South hinders. There exists a carbon tariff rate in the North at which the Northern social welfare peaks. On another front, a less strict binding emission cap set by the Southern government encourages innovation, and allows the firm to charge lower in the South. The firm's total profit increases with the cap and the Northern social welfare enlarges. There exists an emission cap which maximizes the Southern social welfare. What's more, the domestic price can be lower, higher or intersect with its foreign counterpart under different market parameters in the North. In addition, we provide suggestions to a South firm which only sells products domestically on whether or not to open a new foreign market.

Outline of this paper is as follows. Literature review is provided in Section 2. Section 3 formulates the model and gives optimal strategies under two cases. In Section 4, sensitivity analysis with regard to several key parameters are presented. A further discussion of whether or not to open up a foreign market is given in Section 5. Conclusions and future work directions in Section 6 close this paper.

## 2. Literature review

Researches related to our work can be partitioned into three streams: one discusses the background of carbon emission abatement policies, one delves into green innovation which aims to improve the green performance of a product so as to cut emission, and the last one refers to dynamic pricing.

The implement of carbon tariff (or BTA) is called for to alleviate carbon leakage as stated in introduction. Some papers discuss the problem from the standpoint of the developed country. For example, Böhringer et al. (2011) talk about whether imposing a carbon tariff extends the OECD (Organization for Economic Co-operation and Development) countries climate policy via a computable general equilibrium model of global trade and energy use. Results verify the claim of extending the climate policy, but the implement of carbon tariff hardly improves the unilateral climate policy to a globe context. Several researches look at the problem from the perspective of either the developing country or the firm. Wang et al. (2015) assume a two-stage game between two firms, each producing partially substituted products respectively in two countries. With the developed country imposing carbon tariff, the research results indicate that carbon tariff is able to reduce total emission but also negatively impacts global social welfare. Dong et al. (2015) compare an ECT (Export Carbon Tax) policy imposed by China, a major carbon emitter country, with scenarios under a BTA enforcement. The results indicate that ECT brings less efficiency in reducing carbon emission either locally or globally. Liang et al. (2016) investigate the impacts of a domestic carbon tax on macro-economy, sectoral profits and total carbon emission. Results show that carbon tax reduces exports and profit, while a tax cut is called for to ease such negative effects.

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