Environmental Effects of Carbon Taxes: A Review and Case Study

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Received: January 17, 2017 Accepted: March 6, 2017 Online Published: March 15, 2017

doi:10.5430/wjss.v4n2p7 URL: https://doi.org/10.5430/wjss.v4n2p7

Abstract

A carbon tax imposes additional costs on emission-intensive fuels so as to reduce emissions. The primary aim of this paper is to investigate the environmental effects of carbon taxes. First, this paper reviews existing studies which evaluated the effects of carbon taxes on carbon dioxide (CO_2) emissions for different countries. The review shows that carbon taxation is an effective instrument to reduce CO_2 emissions. Then, Transportation and Environment Strategy Impact Simulator (TRESIS) is used to assess the impacts of a carbon tax on car use and CO_2 emissions in the Sydney metropolitan area, and results shows that it would reduce CO_2 emissions by 3.7 percent and reduce car kilometres driven by 3.5 percent in 2017. Its potential economic impact in terms of revenue generated is also presented in this paper.

Keywords: carbon tax, carbon dioxide emissions, car use, market-based instrument

1. Introduction

Road transport, in particular passenger cars, is a major producer of carbon dioxide (CO_2), which is a primary source of greenhouse gases emitted through human activities (or *enhanced* greenhouse effect). For example, in the United States, CO_2 accounted for 84 percent of enhanced greenhouse gases emitted in 2010, where transport contributed to 31 percent of CO_2 emissions, the second largest source after electricity (i.e., 40 percent) (Environmental Protection Agency 2012). The enhanced greenhouse effect is a significant contributor to climate change and global warming.

Various policies have been implemented to reduce CO_2 emissions from road vehicles, mainly though technological improvements or environmental taxation. The Corporate Average Fuel Economy (CAFE) is an example of the former approach. In the United States, All new registered cars and light trucks must perform beyond the standards, for example, the average standard for new passenger fuel economy is 33.3 miles per gallon in 2012, a substantial improvement compared to the 1980 CAFE standard (i.e., 20 miles per gallon). The system works such that if a manufacturer fails to meet the CAFE standards, a penalty is applied. Another major category of policy is environmental taxes, which impose additional costs on emission-intensive fuels so as to reduce the consumption of these fuels and hence reduce emissions. If a charge is on the emission quality of carbon dioxide, it is often referred to as a carbon tax (based on the quality of carbon emitted) or a carbon dioxide tax (based on the quality of CO_2 emitted). In this study, both carbon taxes and carbon dioxide taxes are referred to as carbon taxes. If a tax is imposed on the quantity of energy consumed, it is called an energy tax or a fuel tax. Compared to an energy tax, an advantage of a carbon tax is its direct link to carbon content.

The aim of this paper is to investigate the environmental effects of carbon taxes. First, it presents a review on existing studies that evaluated the effectiveness of carbon taxes in terms of CO_2 emission abatement for different countries. Then, this paper uses Transportation and Environment Strategy Impact Simulator as the evaluation framework to assess the impacts of a carbon tax on car use and CO_2 emissions in the Sydney metropolitan area.

2. Carbon Taxation: A Market-Based Environmental Instrument

A carbon tax is levied on the carbon content of fuels (e.g., petrol and diesel). Carbon taxes are implemented to reduce CO_2 emitted into the atmosphere, through their pricing effects on fuel consumption and energy selection, which are normally set as the marginal cost of CO_2 abatement across all fuels with carbon components (Zhang and Baranzini 2004). By adding a carbon tax, the price of fuel or energy with higher emissions will increase, and consequently its demand (as well as CO_2 emissions) may be driven to a lower level by the market. Some important issues related to carbon taxation have been extensively discussed in the literature (see e.g., Pearson 1995, Barker and Köhler 1998, and Padilla and Roca 2004 for equality and distributional effects; see e.g., Goulder 1995, Prasad 2008, and Callan *et al.* for revenue distribution). With regard to the equality issue, a common finding is that carbon taxes tend to be regressive. However, different revenue distribution strategies have been used or suggested such as carbon mitigation programs (e.g., Quebec), income tax reductions (e.g., the UK) or government revenue (e.g., Sweden and Norway).

Cost-effectiveness is a critical concern when governments consider environment instruments. Koopman (1995) developed a partial equilibrium simulation model within which to examine the efforts of different policy instruments in decreasing greenhouse gas emissions from road transport in Europe, which also considered the effects on welfare changes. Koopman found that the carbon tax is the most cost-effective tool to reduce Europe passenger transport emissions among those examined policies (e.g., annual car ownership taxes). Baranzini *et al.* (2000) found that a carbon tax may save 20-40 percent of the total cost for the same reduction in CO_2 emissions, relative to a fuel tax.

The carbon tax was first introduced by Finland in January 1990. Other countries also implemented carbon taxes such as Sweden, Norway, the Netherlands, Denmark, Italy and the UK. Recently, some Canadian provinces introduced carbon taxes (e.g., Quebec in 2007 and British Columbia in 2008), as well as a few areas in the United States (e.g., Boulder in Colorado in 2007 and Bay Area Air Quality Management District in California in 2008), although there are no national charging schemes in these two countries. In the literature, the effects of carbon taxes on CO_2 emissions have been evaluated for different countries (see e.g., Larsen and Nesbakken 1997 for Norway; Tiezzi 2005 for Italy). The rest of this section provides a review on the environmental effects of carbon taxes.

2.1 Carbon Taxation in Sweden

Sweden started its carbon taxation in 1991, along with a sulphur tax and a nitrogen oxide charge (Ekins and Speck 1999). The initial charging rate was 250 Swedish Krona (SEK) or US$30 per tonne of CO_2 emitted, which was levied on all fossil fuels (transport, heating, and power generation), which increased to 930 SEK (US$150) in 2007. The focus of this charging scheme is to meet the “double-dividend”: environmental taxation and public finance (Brännlund and Nordström, 2004). According to Ekins and Speck (1999), some industries were partially exempt from the carbon charging regime. For example, manufacturing and horticulture industries only needed to pay 25 percent of the general carbon charging rate. OECD (2004) further updated that 65 percent of refunds are given for energy sources used as non-fuel inputs to manufacturing industries.

Swedish Environmental Protection Agency (SEPA) announced that national emissions in 2005 were 6.8 percent lower than in 1990 (SEPA 2007). The decreasing trend has been maintained, as SEPA (2012) reported to a 7 percent CO_2 reduction in 2010 relative to in 1990. While during the same period, national CO_2 emissions increased by 44 percent in Australia (Department of Climate Change and Energy Efficiency (2012), 26 percent for Spain, 20 percent for Portugal (European Environment Agency (EEA) 2012), where carbon taxes have not been implemented. This comparison to some extents illustrates the effectiveness of carbon taxation. That is, Sweden’s carbon tax contributed to the reduction of CO_2 emissions in Sweden as part of its environmental policy (Baranzini *et al.* 2000). Johansson (2000) also found a 15 percent reduction in emissions from 1990 to 1996 because of the carbon tax.

SEPA (2012) found that, between 1990 and 2010, CO_2 emissions from passenger cars were also reduced, and further explained that environmental policies such as the taxes on carbon and fossil fuels, tax exemption for transport renewable fuels and tax relief for green cars, together with rising petrol and diesel prices, have stimulated the switching to more fuel-efficient cars, an increased number of fuel-flexible cars and renewable fuels. However, during the same period, the emissions from heavy duty vehicles and light duty vehicles increased, mainly due to surging freight activities.

2.2 Carbon Taxation in Italy

Italy started its carbon taxation in 1999 to support its commitment to the Kyoto protocol. Motor fuels including petrol (leaded and unleaded), diesel and LPG are covered in this scheme, as well as heavy fuel oils, diesel for heating purpose, natural gas for heating purpose etc. Between 1990 and 2000, national greenhouse gas emissions in Italy increased from increased from 435 to 462 million tonnes of CO_2. After the implementation of carbon taxation, emissions dropped to 426 million tonnes of CO_2 in 2010 (EEA 2012). Given Italy’s carbon tax was implemented in 1999, this indicates the role of carbon taxation in reducing emissions. Tiezzi (2005) also concluded the carbon tax is a cost-effective method to reduce CO_2 emissions from the Italy's transport sector, particularly from cars.

2.3 Carbon Taxation in Norway

Norway launched its carbon taxation in 1991 as one of its key climate policy instruments. A significant feature of the Norwegian carbon charging system is extensive exemptions (Ekins and Speck 1999). Around 36 percent of national CO_2 emissions were exempted from the carbon taxation in Norway (Bruvoll and Larsen, 2004). Bruvoll and Larsen also evaluated the environmental impact of the Norwegian carbon taxa, and results showed that this charging regime was not effective in terms of CO_2 reduction. Given a 12 percent decrease in average emissions per unit GDP between 1990 and 1999, the carbon tax implemented since 1991 only contributed two percent of this reduction. Over the same period, total CO_2 emissions in Norway increased by 12 percent. For the road transport sector, its emissions increased by 21 percent from 1990 to 2003 (Norwegian Pollution Control Authority 2005). Bruvoll and Larsen concluded that extensive tax exemptions and price-inelastic demand are the primary factors to the unsuccessful carbon tax in Norway.

2.4 Evidences from Other Countries

Finland introduced the carbon tax in 1990, based on the carbon content of fossil fuels. Prime Minister's Office (2000) that Finland's carbon tax contributed to a seven percent reduction in emissions. Since 1997, the carbon tax has been imposed only on transport fuels and heating fuels. This exemption to some extents explains increasing CO_2 emissions in Finland from 57 to 64 million tonnes (12.3 percent) between 2000 and 2010 (EEA 2012). In the EU-15 Member States with carbon taxes (i.e., Denmark, Finland, Italy, the Netherlands, Sweden and the United Kingdom), CO_2 emissions decreased from 1990 to 2010 with the exception of Finland and the Netherlands. However, in the other nine States without carbon taxes, five (Austria, Greece, Ireland, Portugal, and Spain) produced more CO_2 emissions in 2010 than in 1990, in which Spain showed the biggest percentage increase (26 percent) mainly due to emission increases from road transport, electricity and heat production, and manufacturing; while Belgium, France, Germany and Luxembourg decreased their CO_2 emissions, in which Germany had the largest reduction (223 million tonnes or 21.4 percent) mainly attributed to increasing efficiency in power and heating plants, and despite that France reduced its total emissions, CO_2 emissions from road transport increased substantially (EEA 2012).

In addition to those studies which evaluated the effects of carbon taxes based on market monitoring evidence, some studies also estimated the potential outcomes of hypothetical or proposed carbon taxes for different countries. For example, Böhringer *et al.* (2003) estimated a 25 percent of reduction in Germany's carbon emissions under a proposed charge of US$65 (in 1995 dollar) per tonne of CO_2 by 2005 compared to its 1990 emission level, using a general equilibrium model. Kasahara *et al.* (2007) applied the MIT Emissions Prediction and Policy Analysis (EPPA) model developed by Paltsev *et al.* (2005), and found that Japan needs to implement a carbon tax of US$45.3 (in 2010 dollar) in order to achieve the Kyoto target. Gerlagh *et al.* (2004) used a general equilibrium model within which to investigate the effect of carbon taxes on global carbon dioxide emissions, and the result shows that CO_2 emissions throughout the entire 21st century could be maintained at the 2000 levels under a tax of US$13.6 per tonne of CO_2.

3. Effects on Car Usage and CO_2 Emissions: A Case Study

In this study, TRESIS is employed to predict the potential effects of this carbon tax on car usage and emissions. TRESIS (Transportation and Environment Strategy Impact Simulator) is a strategic prioritising tool to evaluate the impact of potential policy instruments on urban travel behaviour and the environment. TRESIS examines strategic level policy scenarios for the Sydney metropolitan area by a number of performance indicators (see Hensher 2008). The estimated effects for the Sydney metropolitan area are summarised in Table 1.

This carbon tax (i.e., Au$23.0 per tonne of CO_2 in 2012-13, Au$24.15 per tonne in 2014-15, and Au$25.40 per tonne in 2015-16) would reduce car CO_2 emissions by 3.7 percent in 2017 (with vs. without the carbon tax). The reduction in CO_2 emissions is mainly contributed by less usage of cars with a 3.5 percent reduction in vehicle kilometres and a 1.4 percent reduction in the number of car trips. As expected, this carbon tax would stimulate the switch from cars to public transport (e.g., 12.6 percent increase for train patronage and 9.2 percent increase for bus patronage). Such a carbon tax would deliver a 1.5 percent increase in micro cars and 1.0 percent increase in small cars, and decrease other types of cars by 0.1 percent – 1.0 percent. In Australia, the size of a car is correlated with its fuel consumption. For example, the average fuel consumption per 100 kilometres for a micro (or subcompact) petrol car is 7.1 litres, 8.9 litres for a small (or compact) car, 10.6 litres for a medium-size car.(Note 1) Given this, the switch to smaller-sized cars would also lead to lower fuel consumption, and as a consequence reduce emissions. In 2017, the revenue generated by applying this carbon tax to Sydney's car sector would be around 8 million Australian dollars (or 6 million US dollars). This carbon tax would lead to public transport patronage growth, including 12.6% for train, 9.2% for bus and 4.5% for light rail.

Table 1. Estimated Effects of the Carbon Tax on Car Use and CO2 Emissions in 2017

Indicators	Percentage Change
Total annual CO_2 Emissions for cars	-3.7%
Total annual kilometres driven	-3.5%
*Patronage by mode**	
Trips by car	-1.4%
Trips by train	12.6%
Trips by bus	9.2%
Trips by light rail	4.5%
Changes in car types	
Micro	1.5%
Small	1.0%
Other classes	-0.1% to -1.0%

*: These percentages are calculated based on changes in patronage (with and without the policy).

4 Conclusions

This paper reviewed the effects of carbon taxation on CO_2 emissions, in which both market monitoring evidence and prediction are included. The key finding is that carbon pricing is an effective instrument to reduce CO_2 emissions, although there are a few exceptions (e.g., Norway mainly due to extensive tax exemptions and price-inelastic demand). This paper also estimated the likely effects of a carbon tax on car usage and emissions in Sydney, and results showed that it would reduce CO_2 emissions by 3.7 percent and reduce car kilometres driven by 3.5 percent in 2017. This carbon tax would encourage more use of public transport, which is manageable under existing and planned expansion of public transport capacity. Meanwhile, it would stimulate the switch from less fuel-efficient cars to more fuel-efficient cars.

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Note

Note 1. These fuel consumption figures are obtained from an ongoing study – Regional TRESIS for the State of New South Wales, Australia.