



Effectiveness and equity implications of carbon policies in the United States construction industry

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ABSTRACT

With an increasing American public desire to regulate carbon emissions from stationary and mobile sources, and with more states adopting renewable energy standards and green building codes as an effort toward green environment initiatives, there is an imperative need to evaluate the effectiveness and equity implications of using different mechanisms to reduce carbon emissions in the construction and facility management industry. After all, building construction and operation contributes more than one-third of the carbon emissions in the United States (US). However, the impact of emerging carbon regulatory policies on the construction industry is still unclear. This paper presents a carbon regulation based duopoly model to evaluate the effectiveness and equity of various carbon policies including emission standards, carbon tax, and emissions trading. An empirical analysis of the US housing industry is conducted to illustrate the impacts on the industrial production, emission reduction target, market structure, technology selection, and carbon cost allocation etc. The results encompass emission reduction contributions from large and small firms, the extent of carbon cost burden pass-through to consumers, changes in house price, industry output, and market share. Especially, the analysis shows the market-based mechanisms outperform the emission standards in terms of effectively achieving emission targets while maintaining a stable industrial production. To meet the 17% emission reduction target, a carbon price of \$22.3 per metric ton is expected for construction firms. About 54% of carbon cost will be passed through to the end consumers at this carbon price.

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1. Introduction

1.1. Climate change

Over the last century, the average global surface temperature has increased by 0.74 ± 0.18 °C (1.33 ± 0.32 F). This growing temperature, primarily due to increasing concentrations of Greenhouse Gases (GHG) from human activities, has caused severe global climate change, sea level rise, massive flooding, landscape changes, and infectious diseases spread, etc. [1]. Failing to address climate change can also inflict considerable economic damages. According to the Stern Review on the Economics of Climate Change [2], global Gross Domestic Product (GDP) will reduce by roughly 5% annually for inaction on climate change. Under the most severe scenario, the loss could amount up to 20% of the world's economic

output. By contrast, the cost of reducing GHG emissions (mainly CO₂) and adapting to climate change could be limited to only 1% of global GDP annually.

World leaders have been collaborating closely to combat climate change and to reduce carbon emissions over the last two decades. The development led to the first global agreement in 1997, the Kyoto Protocol. The Kyoto Protocol set legally binding targets for 37 industrialized countries and the European community to reduce GHG emissions by 2012 [3]. More recently, over 110 countries signed on to the nonbinding Copenhagen Accord at the United Nations Climate Change Conference in 2009 [4]. The Copenhagen Accord emphasizes urgent climate change initiatives in accordance with the principles of common but differentiated responsibilities and respective capabilities, recognizes that the increase in global temperature should be less than 2 °C, and commits to take actions to meet this objective consistent with science and on the basis of equity and finance plans.

Furthermore, both developed and developing countries have made strong commitments to reduce carbon emissions in a long term [4,5]. The Obama Administration is committed to reduce

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carbon emissions by 17% below 2005 levels by 2020, 83% below by 2050 [6]. European Union countries unconditionally commit to adequately reduce their emissions by at least 20% below 1990 levels, and to conditionally reduce them by 30% below 1990 levels by 2020 if other developed countries and more advanced developing nations commit to comparable emission reductions. China pledges to reduce emissions per unit of economic output by 40–45% relative to 2005 levels. India is obligated to reduce its emission intensity by 20–25% by 2020. And Brazil aims to reduce emissions by 38–42% from business-as-usual levels by 2020. It is obvious that carbon intensive industries including power generation, petrochemical, transportation, and construction must be strictly regulated to successfully achieve these emission reduction targets.

1.2. Construction carbon emissions

The construction industry had the third highest carbon emissions among the US industrial sectors. The US Environmental Protection Agency (EPA) [7] reported that 131 million metric ton carbon dioxide equivalent (MMTCO₂e) were produced by construction site activities in 2002. Among those emissions, 76% of emissions result from fossil fuel combustion for on- and off-road construction equipment, and 24% come from purchased electricity. Moreover, the embodied emissions from construction material processing and transportation account for a great amount [8,9]. For example, cement production emitted almost 77 MMTCO₂e annually [10]. The construction process consumes 16% of total iron and steel production annually [11], which contributes more than 20 MMTCO₂e in 2002 [12]. Taking all embodied emissions from other sectors into consideration, the emissions from the construction industry are estimated at 470 MMTCO₂e or approximately 6.8% of the US total emissions according to the Green Design Institute at Carnegie Mellon University [13]. Additionally, construction emissions sources would cover facility operation and maintenance when the life cycle project emission is to be determined [14]. Based on the estimates from the US Department of Energy, building operations were responsible for approximately 38% of total US carbon emissions in 2002 [15]. This number remains close for both developed and developing countries even when different emission estimation methods are used [16–19].

The US federal and state governments have already taken actions. The US EPA endorsed the goal of reducing 46 MMTCO₂e GHG emissions in the building sector (compared to the 2002 level) by 2012 [20]. On October 5, 2009, the Executive Order 13514 was signed by President Obama that requires all federal agencies to lead by example in building clean energy economy and reduce carbon emissions [21]. At the state level, by passing Assembly Bill 32, the state of California calls for 26 MMTCO₂e of emission reductions from the green building sector, which represents 15% of California's 2020 GHG emission reduction target of 169 MMTCO₂e [22]. With an increasing public desire to regulate carbon emissions, and with more agencies adopting building and energy standards in their efforts toward green environment initiatives, there are imperative needs for the construction industry to understand emerging carbon policies and evaluate the impact of various policy options.

2. Carbon regulation and policy

Various regulations and policy approaches exist to mitigate carbon emissions. These policies, in addition to addressing the global environment and public health, must be able to correct the market failure caused by the negative environmental externality. The externality arises when the cost of carbon emissions from construction activities is not factored in the market price, although,

carbon emissions cause significant social and economic impacts. The following sections describe three major carbon policies, namely emission standards, carbon tax, and emissions trading, followed by an empirical analysis of their impacts on the construction industry.

2.1. Emission standards

Emission standards regulate acceptable amount of pollutant discharge. In most cases, the regulations also define verified emission mitigation technologies for achieving compliance [23], and environmentally hazardous activities [24]. In the building construction industry, example emission standards include building code provisions, acquisition regulations, appliance standards, mandatory audit programs, and mandatory labeling and certification, etc. [25].

The emission standards are typically regulated by government agencies under the legislation or mandate. In April 2007, the US Supreme Court decided an environmental landmark case that stated that US Environmental Protection Agency (EPA) has the authority to regulate carbon dioxide emissions and other GHG emissions under the Clean Air Act (CAA) [26,27]. Under the latest EPA Permitting Guidance for GHG Emissions issued in November 2010, new capacity of large stationary emission sources, e.g. electric generators, refineries, and cement plants will be regulated to meet required emission target. Alternative control and measurement technologies must be implemented to protect air quality and reduce emissions [28]. This policy, although straightforward to implement and meet the emission reduction target, has been criticized for being excessively rigid, insensitive to geographical and technological differences, lack of flexibility, and complex of establishing regulatory frameworks [29,30].

2.2. Carbon tax

Carbon tax is an environmental tax levied on the carbon content of fossil fuels. Fossil fuels including oil, coal, and natural gas will produce carbon dioxide and other greenhouse gases to the atmosphere when they are burnt. A carbon tax imposes an additional cost to carbon-based energy sources and eventually encourages energy producers and the public to reduce carbon emissions by improving energy efficiency and switching to renewable energy sources. Carbon taxes have been adopted in Denmark, Germany, the United Kingdom, Sweden, several cities and counties in the US, and other areas and counties [31,32]. The carbon tax rates are generally set on the basis of economic conditions, energy resources, and supply and demand relations in the specific country. Under the current economic condition and market, carbon tax rates range from \$10 per ton of carbon dioxide (e.g. Canadian province of British Columbia) to \$150 per ton (e.g. Sweden). In the US, Boulder voters in Colorado approved the nation's first "carbon tax" in 2006 to charge a tax based on electricity consumption (utility bills). Since May 2008, the air pollution regulators in the San Francisco Bay area had started to impose an environmental fee on businesses that emit high level of carbon dioxide. It set the stage for 2500 companies and agencies to pay 4.5 cents for every metric ton of carbon dioxide they expel [33]. In May 2010, Montgomery County council in Maryland passed its carbon tax legislation that calls for payments of \$5 per ton of carbon dioxide emitted from any stationary sources that release more than one million tons of carbon dioxide annually [34].

Carbon taxes can be imposed on the upstream producers and even a product's end user. The flexibility of carbon taxes will effectively affect the public awareness and behavior concerning energy consumption. This advantage makes the carbon tax policy a preferred emission abatement solution for major energy-

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