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Development of natural gas vehicles in China: An assessment of enabling factors and barriers

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HIGHLIGHTS

- We assess the effectiveness of NGV policies in China.
- Relatively low natural gas price promotes NGV development.
- Coordinated development of refueling stations and NGVs is important.
- Policies that encourage private NGV development should be adopted.
- Middle-income and medium-sized cities are more suitable for developing NGVs.

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ABSTRACT

Replacing conventional gasoline or diesel vehicles with natural gas vehicles (NGVs) is necessary if China hopes to significantly reduce its greenhouse gas emissions in the short term. Based on city-level data, this paper analyzes the enabling factors and barriers to China's NGV development. We find that a shortage in natural gas supply and a relatively high price ratio of natural gas compared to gasoline are the main factors impeding China's NGV development. Imbalanced development between natural gas refueling stations and NGVs also hinder the popularity of these lower-carbon vehicles. While various policies have been implemented in recent years to promote NGVs in China, only those encouraging adoption of NGVs by the private sector appear effective. To promote further NGV development in China, the following strategies are proposed: (1) improve natural gas delivery infrastructure across the country; (2) reasonably reduce the relative price of natural gas compared to gasoline; (3) give priority to middle-income and medium-sized cities and towns, since siting natural gas refueling stations is easier in these areas; and (4) promote the use of NGVs in the private sector.

1. Introduction

As the world's fastest growing economy, China's fossil fuel consumption and greenhouse gas (GHG) emissions are growing rapidly. China surpassed the United States (US) and became the largest fossil fuel consumer in 2013 (BP, 2014a). The previous year (2012), China had already become responsible for the most carbon dioxide (CO_2) emissions of any country, accounting 26.4% of the world's total – almost equivalent to the US's and the European Union's emissions combined (Olivier et al., 2013). As one of the leading emerging economies that has an obligation to alleviate climate change, China has set the goals of reducing carbon dioxide emissions per unit of GDP by 40–45% by 2020 compared to 2005 levels and reaching peak carbon dioxide emissions by 2030,[1] and been focusing its efforts on controlling fossil fuel consumption and curbing carbon emissions.

Decomposition analysis identifies the transportation sector as the most important driving force for China's rising oil consumption between 2000 and 2009. Over this period, oil consumption increased by 71%, from 224 million tons to 384 million tons. Among the 160 million tons increase, nearly half – 76 million tons

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[1] The first mission mentioned here is promised by China at the Copenhagen in 2010, and the second is at Asia-Pacific Economic Cooperation (APEC) meetings in 2014 (UNFCCC, 2010; IFENG, 2014).

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– can be attributed to the transportation sector (Ma et al., 2012). Therefore, effective limits on the transportation sector's oil consumption are of crucial importance if China hopes to cut its overall oil consumption and emissions.

The rapid growth of oil consumption in the Chinese transportation sector may be attributed to several factors. First, China witnessed a sharp increase in the number of civil vehicles,[2] which increased nearly seven-fold, from 16 million to 109 million vehicles between 2000 and 2012 (NBS, 2013). During the same time period, the Chinese population became a more mobile one: In 2012, the total distance travelled by all passengers on a highway was 1.8 trillion kilometers (km) and the average distance of goods carriage reached 187 km, 1.7 times and 2.1 times higher, respectively, than the distances that people and goods traveled in 2000 (NBS, 2013). As the country becomes wealthier and more urbanized, more people will own their own vehicle – a trend difficult to reverse in the foreseeable future.

How can China curb its GHG emissions while maintaining the trend towards increased mobility in its transportation sector? Empirical and theoretical studies confirm that developing alternative fuel vehicles (AFVs), especially natural gas vehicles (NGVs), will be necessary to achieving these two seemingly opposing goals in the short term (Ou et al., 2010; Yao et al., 2011; Ma et al., 2013). There are two main types of AFVs that are commercially available: electric vehicles (EVs) and NGVs. Both have the potential to reduce and eventually eliminate the use of oil in the transportation sector. They are, therefore, known as “clean energy vehicles” or “low-carbon vehicles”. Compared to NGVs, EVs have more government support because China has set the goal of promoting electricity production from renewable energy, and EVs are considered the ideal technology for renewable energy utilization. However the emissions of AFVs heavily depend on their power source. In Europe and the US, EVs are recognized as “clean vehicles”, since electricity in these countries has diversified away from coal in many areas. For example, 55% of the US's electricity is generated from power plants running with natural gas, nuclear, hydropower, or renewable energy (World Bank, 2014). Life-cycle carbon emissions from a typical EV in the US are only 60% of that from a vehicle fueled by oil (Doucette and McCulloch, 2011). In contrast, 70% of China's electricity is still produced from coal-fired power plants (CEPYEC, 2013), a trend that energy companies estimate will continue for the next 20 years (BP, 2014b). Without carbon capture or carbon intensity control measures, life-cycle carbon emissions from EVs powered by coal-based electricity are almost the same as that from conventional gasoline vehicles (Zhou et al., 2013).

Although in the long run switching to EVs is a promising option in terms of energy savings and GHG mitigation, even widespread adoption of EVs would have a limited effect on China's GHG emission control in the short term. In contrast, NGVs provide a timely pathway to helping China achieve its carbon emission reduction goals. Substituting conventional gasoline vehicles with NGVs is technologically feasible, since the two categories of vehicles can be produced with almost the same technologies and a conventional vehicle can be easily converted to an NGV by simply refitting the car with a cylinder that works with both gasoline and natural gas (Yang et al., 1997). In addition, NGVs have been proven to reduce the emission of GHG, nitrogen oxides (NO_X), volatile organic compounds (VOC), and toxics,[3] emitting approximately 75%, 85%, 18%, and 40%, respectively, of the emissions of conventional gasoline vehicles (CEC, 2007). Moreover, if diesel vehicles, with the emission characters specified by the Europe IV standard, were substituted with NGVs, NO_X and particulate matter (PM) emissions could be reduced by 50% (Ryan and Caulfield, 2010). In addition to environmental benefits, such substitution would also bring economic advancement. The acquisition cost of a private NGV in China is only RMB 6000 to RMB 10,000 higher than that of an equivalent gasoline car – and the cost of converting a gasoline car into an NGV is only RMB 5000 to RMB 8000, around 10% of the car price. Assuming fuel cost savings of RMB 0.3 per km and an average driving mileage of 50 km per day (both conservative estimates), this additional cost would be fully compensated within one to two years. For commercial vehicles,[4] the cost of an NGV is RMB 20,000 to RMB 70,000 more than the cost of an equivalent conventional vehicle, but the extra upfront cost would be fully compensated within one year if the vehicle runs, on average, 200 km per day (fuel savings for commercial NGVs are approximately RMB 0.8/km) (Li, 2012).

Based on these advantages, NGVs have been widely promoted all over the world. From 2003 to 2012, global NGV ownership was growing at an annual rate of 21.6%, with more than 16 million NGVs on the road by the end of 2012 (IANGV, 2013). Furthermore, the adoption of NGVs has gradually extended from public transportation to private cars, taxis, heavy-duty trucks, garbage trucks, and other vehicles with special uses (Yeh, 2007). NGVs have come to pervade most sub-sectors in transportation, and have the potential to replace conventional gasoline and diesel vehicles altogether.

However, compared to the rapid development of NGVs worldwide, the adoption of these low-carbon vehicles in China has lagged behind. Although China ranks fifth worldwide for NGV ownership, with 1.57 million NGVs on the road by 2012 (up from just 6000 in 2000), overall market penetration remains low: just 1.13% of all civil vehicles are NGVs, ranking China 21st among the 79 countries with NGVs. In addition, our analysis indicates that the phenomenon of NGV underdevelopment in China is regional rather than national. Based on data for NGV adoption in China's major cities in 2012, we find that some provinces, such as Xinjiang, Shandong, and Sichuan, have advanced NGV development, with 56% of China's NGVs located in these three provinces. Xinjiang, in particular, is home to the largest number of NGV owners, boasting a market penetration of 21.2% and putting the province on par with the most highly developed NGV markets, such as Iran and Bangladesh (IANGV, 2013). However, in most other provinces, NGV market penetration is less than 1%. Lower penetration is on the one hand a symbol of underdevelopment, but it also indicates significant potential for growth.

Why is the NGV market underdeveloped in the majority of China? This question is far from answered. Existing studies have confirmed that NGVs are a technologically feasible and environment-friendly option for greening China's transportation sector (Yang et al., 1997; Ou et al., 2010; Yao et al., 2011; Ma et al., 2013). For instance, with data collected from the field, Yang et al. (1997) found that developing the NGV market in Beijing is a cost-effective strategy in terms of pollution control and GHG mitigation. This conclusion was strengthened with a life-cycle analysis conducted by Ou et al. (2010). They showed that an NGV uses 14% less fossil energy and emits 28% less GHGs than a counterpart diesel vehicle. Existing studies also document extensive government support to promote NGV development, including the policy tools for setting up basic infrastructure, building public awareness, and compensating first-mover users who incur extra upfront costs. For example, supported by the State Planning Commission at that time,

[2] By civil vehicles, we mean vehicles operated by non-military and non-official agents, including both private vehicles and vehicles running for public transportation.

[3] Toxics consist of Benzene, 1-3 butadiene, and particulate matter by their weights.

[4] Commercial vehicles include light trucks, heavy trucks, and large- and medium-sized passenger cars. These vehicles are mainly fueled by diesel.