1 lilianliu199836@gmail.com Qingyang Liu Nov, 2016
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Growing CO_2 emissions in China:

driving forces & impacts of the transportation sector

1. Introduction

Since China opened its gate to foreign business in 1978, its soaring economic growth has brought billions of Chinese out of poverty. But as a net-exporter back in the 1980s, China's economy was heavily dependent on manufacturing and primary industries powered by towering dirty coal-fired plants, while most of its processed merchandise is exported directly. It is true that China's economy was highly accelerated by those exported materials and products, but its carbon footprints have also grown apace with its prosperity and aroused significant environmental pressures. The most unpreceded one might be the global climate change, which is mainly driven by the rising accumulation of greenhouse gasses (GHG) such as CO_2.

Considering that China has been the largest carbon emitting country in the world, efforts to fight climate changes must accelerate across this region if global efforts are to succeed. It is clear that China cannot afford to obtained economic growth at the expense of its environment. In order to address the present problems and look for solutions, much research has been done on this country's energy use and CO_2 emission patterns.

1.1 China's growing CO_2 emissions

Back in 2004, China has a high carbon global emission growth, but a relatively low share of the global emission (Raupach et al, 2007). In Dhakal (2009)'s research of 37 Chinese major cities, rising economic growth boosts CO_2 emissions while the growing energy intensity dampens CO_2 emissions. Many studies addressing China's recent transition of energy mode have also been done. Zhang (2010) talks about China's multiple policies on promoting its use of clean energy and ecosystem-based adaptation. He found that China's participation in clean development mechanism projects, development of nuclear power, and other clean power strategies help to fulfill its climate obligations. Shi & Zhang (2011) analyze dominant factors influenced China's 1980-2007 carbon emission changes and conclude that energy use efficiency is of great importance in the process of downsizing carbon emissions.

1.2 China's CO_2 growth sectors

While a large number of studies have been done on China's general CO_2 decomposition and energy intensity patterns, many specific sectors determining CO_2 emissions have also been studied. Wu et al (2005) focus on the industry sector's attribution to the decline of energy-related CO_2 emissions from 1985 to 1999 due to the industrial restructuring. Nowadays, China has shown its persistent efforts on reducing energy intensity with respect to industry-related sectors (Wu, 2005); China has also achieved a significant reduction in energy consumption and carbon emission by developing third industries (Shi & Zhang, 2011). Apart from problems of the industry and fossil fuels use, the rising urban population reveals another problem: the increasing share of transportation in the whole pie of carbon emissions. Timilsina and Shrestha (2009) examine the transportation factor in the decomposition of CO_2 emissions of several Asian countries from 1980 to 2005. They identify three main factors contributing to the transport sector of emission growth: population growth, economic growth per capita, and changes in transportation energy intensity. Yang et al (2015) look at regional differences of CO_2 emissions in China from 2000 to 2012 based on a transportation carbon-emission model. Liu et al (2015) explore China's road, waterway, aviation, and railway as four main sources of transportation carbon emissions.

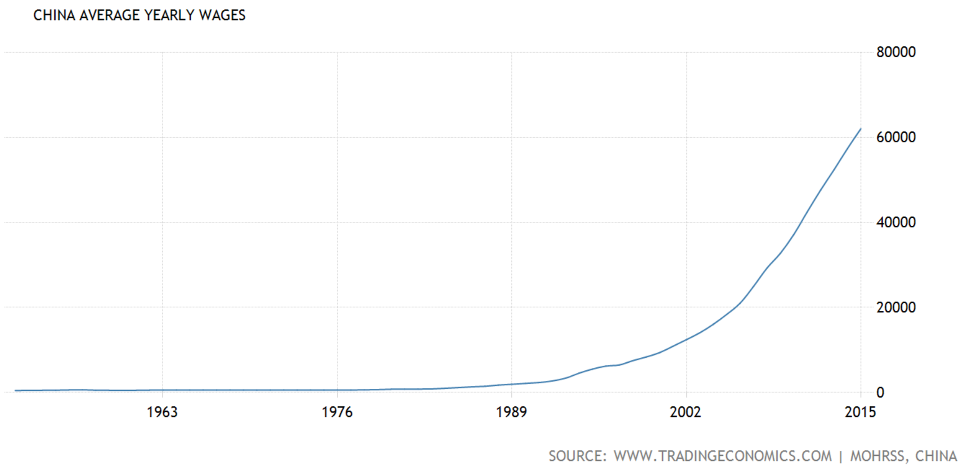
Much research above has successfully focused on China's CO_2 emissions from the transportation sector and revealed specific indicators; however, less attention has been paid to the CO_2 emission evaluation within an integrated accessing structure: not only focus on driving forces but impacts and responses. In order to fill this gap, in my current study, I adopt the framework of DSPIR, which distinguishes driving forces, pressures, states, impacts, and responses in an assessment of the environment (Kristensen, 2004). I will discuss a few questions below: what are the main driving forces of the growing CO_2 emissions related to the transportation sector in urban China; how is the current state and trend responding to pressures generated from those driving forces; what are the impacts and responses addressing those pressures?

2. Major driving forces

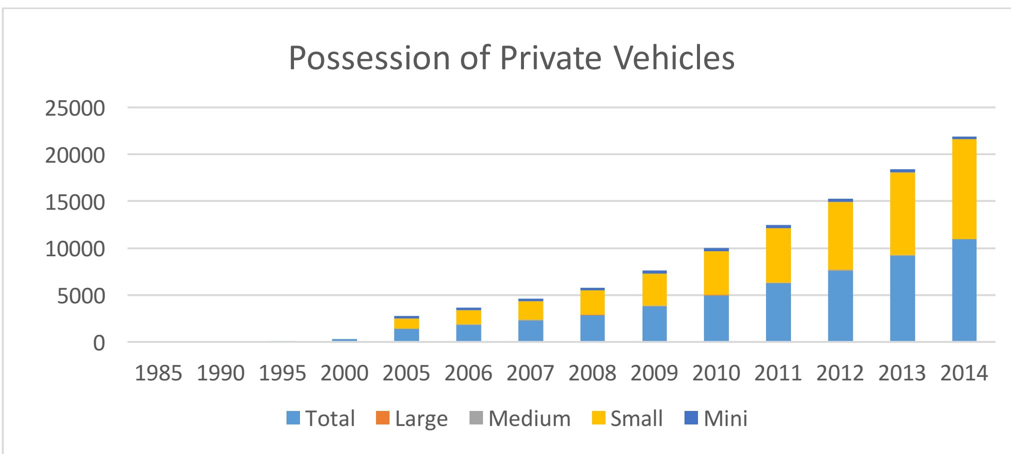
As early as 2007, China has become the world's largest emitter of energy-related CO_2. China's unprecedented economic growth drives up people's living qualities, but also creates significant energy consumption and CO_2 emissions. The increasing transportation share of carbon emissions requires further examination of major driving forces.

2.1 Urban population growth

Last time I checked online, China has a population of 138.4 million based on the latest United Nations estimates (*wordometers.info*). This number of population is equivalent to 18.72% of the total world population and ranks No.1 worldwide. Although China has adopted plentiful policies to impede its population growth, its large population base still gives rise to numerous births



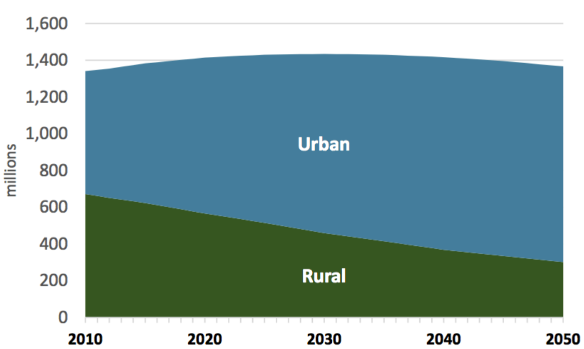
[Figure 1: China's average yearly wages trend 1952-2015, drawn from *tradingeconomics.com*]



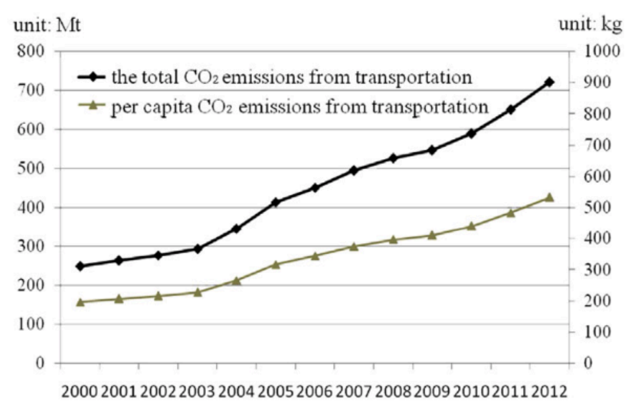
[Figure 2: possession of Private Vehicles from 1985-2014, data drawn from China Statistic Yearbook, 2015]

every day. This large number of population and people's increasing disposable incomes induce the massive purchase of private automobiles [Figure 1&2]. Even with the rapid construction of driveways, the increasing number of private cars outnumbers parking spaces, license plates, and eventually roads' carrying capacities. This significant increase in the number of private automobiles results in a direct generation of GHG through combustion engines.

China's rapid urbanization is also dramatic: in 2014, China's urban population has already reached 749 million, accounting for 55% of China's population and 10% of total world population (China Statistical Yearbook, 2015) [Figure 3]. However, different from my recognition of cities' sustainable benefits in comparison of suburban's extravagance use of energy, an interesting pattern is discovered by multiple scholars: China's rural carbon emissions per capita is much lower than the urban ones (Ohshita et al, 2015; Liu, 2015). This finding is further articulated in Yang et al (2015)'s study: every 1% increase in China's urban population density generates a remarkable 0.22% increase in per capita carbon emissions from transportation; a 1% per capita disposable income increase leads to a 0.43% increase in per capita CO_2 emissions from transportation [Figure 4]. It is true that China has astoundingly high densities in most cities: high densities determine the relatively low, compared in the world, share of each residents' carbon emissions; but rural Chinese's carbon emissions are even lower: their extremely low disposable incomes (approximately 1500 US dollar in 2014) and their farming lifestyles determine their limited commute needs and travel opportunities, which result in a low transport contributing sector. China's high-density cities prompt high frequencies and long distances of trips, which in turn affect the amount of energy consumed and carbon produced.



[Figure 3: China's Urban and Rural population trends (2010-2015), graph drawn from Ohshita et al, 2015]

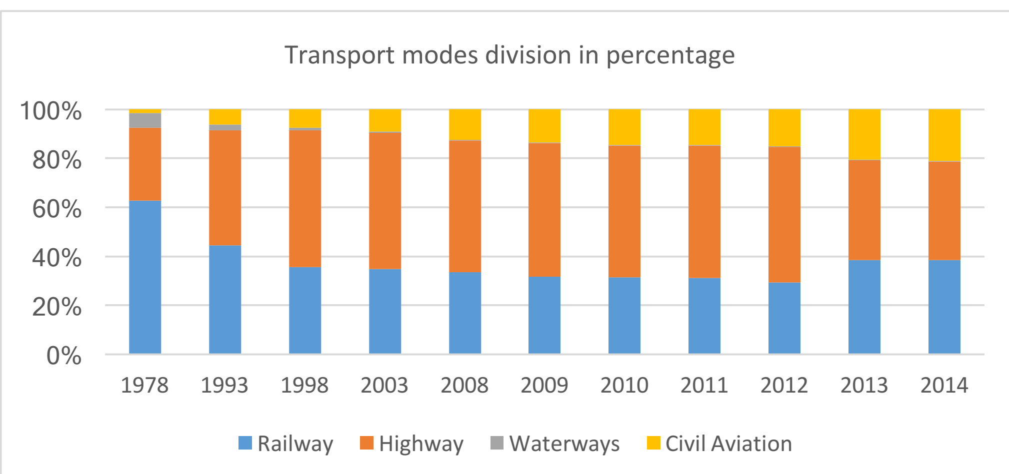


[Figure 4: the growth of CO_2 emission of transportation from 2000-2012, graph drawn from Yang et al, 2015]

Besides different choices of transportation in urban and rural China, public services also contribute to this difference: Qu et al (2015) find that urban Chinese have higher per capita expenditure on indirect services such road constructions. Therefore, considering those different ecological footprints of urban and rural China, rapid urbanization of China leads to net rising carbon emissions.

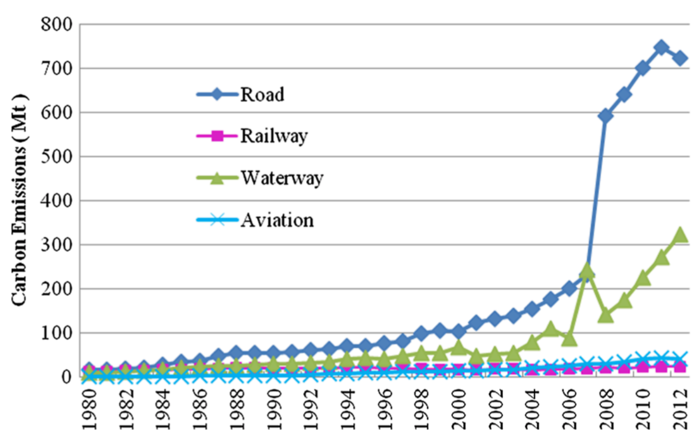
2.2 Changes in the transportation mode

As I mentioned above, China's prosperity and urbanization in the last twenty years boosted its rapid growth in private vehicles possessions. This consumption of automobiles results in an unprecedented change in the choices of trip modes: people who chose energy efficient public transportations such as subways and buses are now able and willing to drive to work. A case study in Brazil reveals that using buses for daily commute would save 8 times more carbon emissions than using private automobiles (Ribeiro & Balassiano, 1997). As we can see from the Figure 5, China has an increasing share of trips on road from 1978 to 2012 while the percentage decreases after 2012. On the contrary, the share of railway kept decreasing until 2012. Those



[Figure 5: Transport modes division in percentage, 1978-2014, data drawn from China Statistic Yearbook, 2015] complementary changes might not be a coincidence: the general completion of China's nationwide High-speed Rail (HSR) in 2012 extended and upgraded the original low-speed railway systems, changing the pervious exhausting and time-consuming trips to more pleasant ones. Those changes in cognitive distance, comfort, and opportunity cost in respect of time highly alter people's choices of transportation (Gardner & Abraham 2007): thirty minutes on the HSR seems more attractive than 3 hours on the highway. This decreasing share of highway and rising share of energy efficient railway after 2012 is a cheerful achievement in China's mission to mitigate carbon emissions: highway transport takes up to 70% in all CO_2 emissions (Liu et al, 2015) [Figure 6]. As for civic aviation, the unfaltering increasing share leads to a significant increase in carbon emission of 9.15 Mt from 2008 to 2010, owing to the fast enlarging aviation business scale benefited from the Olympics, Expo, and multiple other momentous transportation missions (Liu et al, 2015). Emergencies such as Wenchuan and Yushu earthquakes also put the aviation transportation in an indispensable place.

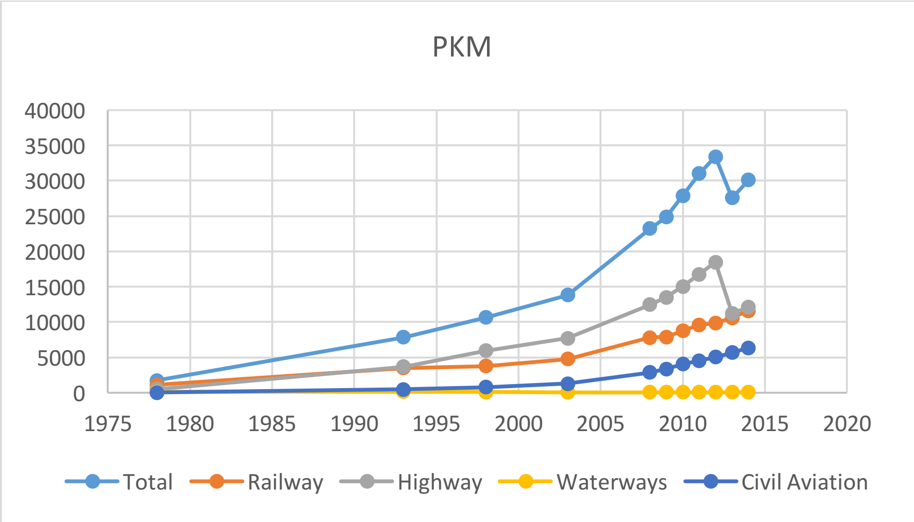
There is also a rising number of innovative modes of transportation related to shared mobility in China nowadays. These shared mobility services include car sharing, personal vehicle, bike-



[Figure 6: CO_2 emissions in China's four transport subsectors, 1980-2012, graph drawn from Liu et al, 2015] sharing, and many other on-demand ride services (Shaheen & Chan, 2015). According to Shaheen & Chan's study, it is ostensive to see the reduction of vehicle usage, ownership, and vehicle kilometers (VKT) traveled based on those services. As for China's shared mobility services, after the foundation of China's Didi taxi corporation in 2012, which provides fast and convenient taxi and private cars calling service, Uber also entered the Chinese market in 2013. The bruising price battle between those two companies to take up the Chinese market brought up heavy discounts for Chinese riders and incentive awards for Uber and Didi drivers in the last 3 years. Those benefits in prices for both drivers and riders strongly altered their transportation habits and encouraged the use of idle vehicles: people who drove to work might be attracted by decent prices of Uber and Didi, reduce auto ownership and usage, and mitigate carbon emissions. Another carsharing operator, car2go, entered China last year, also has been gaining traction in the country. Car2go's substantive efforts on reducing carbon emissions are proven by a three-year study on five northern American cities by Martin & Shaheen (2016): car2go results in fewer on-road private vehicles, fewer VKT, and less carbon intensive travel behaviors. On the other hand, research also shows that such ride-sourcing services compete with public transportation and exacerbate congestion (Flegenheimer & Fitzsimmons, 2015). Overall, the complexity and lack of research on carsourcing services in the Chinese market lead to an uncertain effect of carbon emissions sourced back to those services. I am glad to see the transformation of today's Chinese transport market and wishing it goes to a more sustainable end.

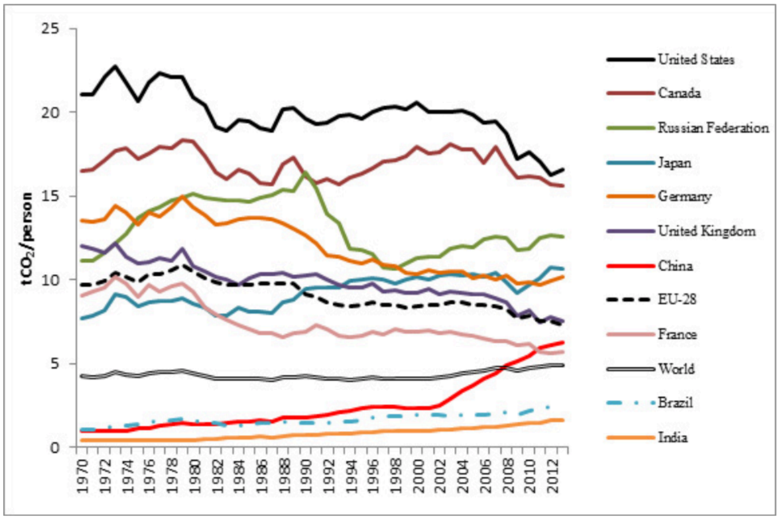
2.3 Changes in traveling length

Given the existing state of combustion engine technology and the dominance of automobiles in most urban areas, passenger-kilometer (PKM) traveled is a key indicator for the amount of energy used and GHG emitted by the transportation sector (Schafer & Victor 1999). According



[Figure 7: China's yearly PKM, 1978-2014, data drawn from China Statistical Yearbook, 2015]

to China Statistical Yearbook (2015), China has a generally increasing PKM from 1978 [Figure 7]. This increasing trend might result from both people's increasing daily commute and vacation traveling distances. As needs and prices for housing in Chinese cities keep rising, urban expansion is inevitable and has already shown some negative impacts: Zhao (2010) notes that the rapid sprawl and development on Beijing's urban fringe promote the need of long-distance commute and car usage. Meanwhile, apart from the original goal of meeting the rising needs for road capacity in terms of new viaducts and highways constructions, these constructions ultimately encourage more cars on the road, which ends up in a vicious circle (Jevon's paradox). On the other hand, the great growth of Chinese's consumption level lifts both the domestic and outbound tourism. Although domestic trips are not easily documented, outbound ones are more easily traced: in fall 2015, travel agencies organized 13.8 million Chinese visitors to foreign countries, increasing 29% in comparison with that of 2014 (China Outbound Tourism, 2015). China's present favorable policies, such as the Regulations for Paid Annual Leave for Employees, the increasing number of both statutory holidays and offers of visa-free accesses,



[Figure 8: CO_2 emissions per capita of major emitters, 1970-2012, drawn from Liu, 2015]

and the rising value of Yuan all incentivize the outbound market all contribute to the prosperous travel market. Considering the rapid growth in the outbound tourists, there might be a similar pattern with the inbound market, which leads to more transport. China's soaring length traveled per capita added from both commute and travel proffers increasing carbon to the world.

3. Current State and Trend

As the current largest GHG emitting nation, China has made commitments to decrease its total carbon emissions and adopted a series of policies. But China is less arresting in terms of carbon emission per capita-- 6.26t CO_2 per person-- a level reaching that of the EU average, and also one lower than the level of the US (17t CO_2 per person) (Liu, 2015). Look at Figure 8, most major developed countries have reached its peaking point of CO_2 emission per capita and have declined ever since. This difference between China's rising carbon emission and developed countries' dropping ones can be mostly attributed to trade. As a net importer for processing-based industry (GEO5, 2012, p20), China has shipped most of its processed products worldwide, leaving endless pollution and GHG to its own environment. China's substantial CO_2 emissions reflect the progressively global nature of its environmental crisis; the reduced carbon emissions of developed countries are relocated to China: from 2007 to 2012, 8%-12% of carbon emissions in China were attributable to exports to the US (Xu et al, 2009). Besides trade, China's rapid urbanization, increasing vehicle possession rates and kilometers traveled per person alongside with its bourgeoning affluent middle-class have contributed to a notable amount of carbon increase. Although the operation of energy intensive HSR has offset much CO_2 emissions of carbon intensive roadway-transportations, and new share-mobility services might temper carbon emissions, the overall rising transport-need of China results in an increasing carbon emission trend. In this case, without adaptive interference, China's current GDP indicate a long way to go before it reaches the turning point shown on the Kuznets Curve.

4. Impacts and Responses

While air pollutants such as harmful micro-particulates and aerosol might be regionally restricted to some extent, CO_2 emissions are non-toxic but long-lasting and influential in the global atmosphere. The increasing concentration of GHG such as CO_2 and methane is highly likely to invoke tipping points—irreversible changes such as global temperature increase, glacier melting, disease propagation, etc., in human timescales (GEO5, 2012, p37). Considering the fact that China's pace of development combined with the scale of the country has made it the world's biggest emitter, how China chooses to act is likely to determine the success or failure of any future plan to limit climate change.

In a traditional thinking of mitigating transportation carbon emissions, the Chinese government has started to improve traffic management, promote fuel qualities, new technology, and alternative energy sources, etc. I see numerous examples in various ways. Many cities have slapped limits on granting car plates to gasoline and natural gas fueled cars, meanwhile, electric vehicles are awarded free car plates: this act could encourage the purchase of electric vehicles, which have low carbon emissions. China's energy-efficiency labeling program has also offset 1.4 billion tonnes of carbon emissions from 2005– 2010 (Zhan et al, 2011).

However, despite those efforts mentioned above that Chinese government has done to regulate China's CO_2 emissions, accompanied by rapid economic development, the vehicles ownership (has increased annually 23.7% for two decades) and using frequencies will unavoidably increase in the future, which will further enhance carbon emissions. Furthermore, according to Banister (2011), new technologies may provide high mobilities with low carbon emissions, but this solution is misplaced: innovative technologies might facilitate more travel. Therefore, in this case, it is more urgent to improve urban public transportation systems to facilitate a paradigm shift from road-travel to non-motorized transportation and public transportation: encouraging low-carbon urban planning is a favorable choice. Guangzhou's integrated transit system, Beijing's massive promotion of renting bicycles, and Shanghai's driving restriction of one day per week all have shown efforts on mitigating the upswing of transport carbon emission in terms of low-carbon planning.

Maybe China would still be a country with large-scale carbon-tinged manufacturing until its labour costs rise. But all other efforts to temper its carbon emissions should not be overlooked. If we are all aware that human welfare depends on our ecosystem services whether they are improved or deteriorated, initiating the action of measuring the aggregate value of ecosystem services might push us towards a sustainable goal (Costanza et al, 1998). This means our presently externalized environmental costs should be internalized into overall costs of companies; companies' instinct to pursue minimized costs and maximized profits would contribute to less environmental detriment: we might avoid the tragedy of the commons and temper the currently soaring carbon emissions. In this case, the Chinese government should be resolute and powerful to initiate the pricing of ecosystem services.

5. Conclusion

In this study, I identify several major driving forces in the transportation sector of atmosphere CO_2 emissions in China, as well as the country's current environmental state influenced by excessive carbon emission pressures. I further look at the current and possible responses of the Chinese government in respect of its actively manifested environmental commitment. I find that China's rapid total and urban population growth, people's changing modes of transportation, and the rising PKM drive its transport carbon emission growth. Specifically, both the alternating choices of transportation and the growing PKM derive from the prosperity of China's economy and affluence of Chinese citizens. Since all data in this study is extracted from various resources and scholars, different measurement methods and dates may lead to inconsistent results. Therefore, future research should be done in a more rigorous and integrally assessed manner to address China's current carbon emission problem in the transportation sector.

References:

Banister, D. (2011). Cities, mobility and climate change. *Journal of Transport Geography*, 19(6), 1538e1546.

China Average Yearly Wages | 1952-2016 | Data | Chart | Calendar | Forecast. (n.d.). Retrieved November 05, 2016, from http://www.tradingeconomics.com/china/wages

China Outbound Tourism in 2015. (n.d.). Retrieved October 31, 2016, from https://www.travelchinaguide.com/tourism/2015statistics/outbound.htm

China Population (LIVE). (n.d.). Retrieved November 05, 2016, from http://www.worldometers.info/world-population/china-population/

China Statistical Yearbook-2015. (n.d.). Retrieved November 05, 2016, from http://www.stats.gov.cn/tjsj/ndsj/2015/indexeh.htm

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., ... & Raskin, R. G. (1998). The value of ecosystem services: putting the issues in perspective. *Ecological economics*, *25*(1), 67-72.

Dhakal, S. (2009). Urban energy use and carbon emissions from cities in China and policy implications. *Energy Policy* 37(11), 4208–4219.

Flegenheimer, M., & Fitzsimmons, E. (2015, July 16). City Hall and Uber Clash in Struggle Over New York Streets. City Hall and Uber Clash in Struggle Over New York Streets. Retrieved from http://www.nytimes.com/2015/07/17/nyregion/city-hall-and-uber-clash-in-struggle-over-new-york-streets.html

Gardner, B., and C. Abraham. 2007. "What Drives Car use? A Grounded Theory Analysis of Commuters' reasons for Driving." *Transportation Research Part F-Traffic Psychology and*

Behaviour 10 (3): 187–200.

Global environment outlook GEO 5: Environment for the future we want. (2012). Nairobi, Kenya: United Nations Environment Program.

Liu, Z. (2015). China's Carbon Emissions Report 2015 (Rep.).

Liu, Z., Li, L., & Zhang, Y. (2015). Investigating the CO2 emission differences among China's transport sectors and their influencing factors. Natural Hazards, 77(2), 1323-1343. doi:10.1007/s11069-015-1657-2

Kristensen, P. (2004, September 27). *The DPSIR Framework*, Paper presented at the 27-29 September 2004 workshop on a comprehensive / detailed assessment of the vulnerability of water resources to environmental change in Africa using river basin approach. UNEP Headquarters, Nairobi, Kenya.

Martin, E., & Shaheen, S. (2016). Impacts of car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An analysis of one-way carsharing across An Analysis of Five North American Cities (Rep.).

Ohshita, S., Price, L., Zhou, N., Khanna, N., Fridley, D., & Liu, X. (2015). The role of Chinese cities in greenhouse gas emissions reduction.

Qu, J., Maraseni, T., Liu, L., Zhang, Z., & Yusaf, T. (2015). A comparison of household carbon emission patterns of urban and rural China over the 17 year period (1995–2011). *Energies*, *8*(9), 10537-10557.

Raupach, M.R., Marland, G., Ciais, P., Le Quéré, C., Canadell, J.G., Klepper, G. and Field, C.B. (2007). Global and regional drivers of accelerating CO_2 emissions. *Proceedings of the National Academy of Sciences of the United States of America* 104(24), 10288–10293.

Ribeiro, S. K., & Balassiano, R. (1997). CO_2 emissions from passenger transport in Rio de Janeiro. *Transport Policy*, 4(2), 135e139.

Schafer, A., and D. G. Victor. 1999. "Global Passenger Travel: Implications for Carbon Dioxide Emissions." *Energy* 24 (8): 657–679.

Shaheen, S., & Chan, N. (2015). Shared Mobility: A Sustainability and Technologies Workshop (pp. 1-30, Rep.).

Shi, L., & Zhang, H. (2011). Factor Analysis of CO2 Emission Changes in China. *Energy Procedia*, 5, 79-84. doi:10.1016/j.egypro.2011.03.015

Timilsina, G. and Shrestha, A. (2009). Transport sector CO_2 emissions growth in Asia: underlying factors and policy options. *Energy Policy* 37(11), 4523–4539

Wu, L., Kaneko, S., Matsuoka, S., 2005. Driving forces behind the stagnancy of China's energy-related CO_2 emissions from 1996 to 1999: the relative importance of structural change, intensity change and scale change. *Energy Policy* 33 (3), 319–335.

Xu, M., Allenby, B. and Chen, W. (2009). Energy and air emissions embodied in China − US trade: eastbound assessment using adjusted bilateral trade data. *Environmental Science and Technology* 43(9), 3378–3384

Yang, W., Li, T., & Cao, X. (2015). Examining the impacts of socio-economic factors, urban form and transportation development on CO2 emissions from transportation in China: A panel data analysis of China's provinces. *Habitat International*, 49, 212-220. doi:10.1016/j.habitatint.2015.05.030

Zhan, L., Ju, M. and Liu, J. (2011). Improvement of China energy label system to promote sustainable energy consumption. *Energy Procedia* 5, 2308–2315.

Zhang, Z.X. (2010). *China in the Transition to a Low Carbon Economy.* East-West Centre Working Papers. Economics Series 109