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Interactive Comment

Interactive comment on "Characterization of road freight transportation and its impact on the national emission inventory in China" *by* X. F. Yang et al.

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Interactive comment on "Characterization of road freight transportation and its impact on the national emission inventory in China" by X. F. Yang et al.

We would like to thank Referee #2, Tami Bond, for her detailed comments on our manuscript. Our responses to her questions and comments can be seen below. Overview: This paper provides an expanded approach to calculating truck freight emissions throughout China. New information from surveys and GPS measurements is provided and combined with extensive review of the literature to improve the state of this portion of this emission inventory. Response: Thanks for your comment.

Specific comments: 1. The abstract needs to be tightened so that more of the interesting findings and novel approach of this study are highlighted. Not so much background is needed in the abstract. Response: Thanks to this comment. The abstract is tightened according to the suggestions and now reads as:

“Diesel trucks are major contributors of nitrogen oxides (NOx) and primary particulate matter smaller than 2.5 μm (PM2.5) in transportation sector. However, there are more obstacles on existing estimation of diesel truck emissions compared with that of cars. The obstacles include both inappropriate methodology and missing basic data in China. According to our research, a large number of trucks are conducting long-distance inter-city or inter province transportation. Thus, the method, used by most of existing inventories, based on local registration number is inappropriate. A road emission intensity-based (REIB) approach is introduced in this research instead of registration population based approach. To provide efficient data for the REIB approach, 1,060 questionnaire responses and approximately 1.7 million valid seconds of onboard GPS monitoring data were collected in China.

The estimated NOX and PM2.5 emissions from diesel freight trucks in China were 5.0 (4.8 – 7.2) million ton and 0.20 (0.17 – 0.22) million ton, respectively in 2011. The provinces based emission inventory is also established using REIB approach. It was found that the driving conditions on different types of road have significant impacts on the emission levels of freight trucks. The largest differences among the emission factors (in g/km) on different roads exceed 70% and 50% for NOX and PM2.5, respectively. A region with more inter-city freeways or national roads tends to have more NOX emissions, while urban streets play a more important role in primary PM2.5 emissions from freight trucks. Compared with inventory of Ministry of Environment, which allocate emissions according to local truck registration number and neglect inter-region long distance transport trips, the differences for NOx and PM2.5 are +28% and -57% differences respectively. And the REIB approach matches better with traffic statistic data on province level. Furthermore, the different driving conditions on the different roads types are no longer overlooked with this approach."

2. Page 15221 Line 8:"Compared with former studies..." Please provide some quantitative information about emissions have shifted. Response: Thanks for the suggestion. Information about quantitative difference between our result and MEP former inventory was added here in the abstract read as: "Compared with inventory of Ministry of Environment, which allocate emissions according to local truck registration number and neglect inter-region long distance transport trips, the differences for NOx and PM2.5 are +28% and -57% differences respectively. And the REIB approach matches better with traffic statistic data on province level."

3. Page 15226: calculation of representative emission rate for each bin. Was this calculation done in this study, or was it done by the other studies cited here? Such a calculation is a major undertaking. If it was done for this study, then much more information is needed to describe the results. If it was done in another study that should be made clear. Response: Thanks for this comment. As we quoted in the paper, the emission rates that were used in this research came from multiple former researches in China. We combined emission factors from research of Zhang et.al., Wang et.al., and relative relations of representative emission rates of each bins to calculate the representative emission rates in this research. As anonymous referee #1 suggested, we have figured the representative emission rates and added the figures in supplementary materials, Figure S1. In this case, researchers in the future will be able to use the emission rates for further studies. To clarify, we have modified our former description of how we calculated emission factors in Chapter 2.2. Former statement "One-second on-board measurement data from Liu et al., Wu et al. and the Vehicle Emission Control Center of China (VECC) was used to calculate a representative emission rate for each bin according to the IVE model (Liu et al., 2009;Zhang et al., 2013;Wang et al., 2012)." now read as: "Data from multiple researches was used to obtain the representative emission rates in this research since no study provides suffi-

cient data of emission rates for all types of trucks. Emission rates of each bin from Liu's study (Liu et al. 2009) were used to generate curves of emission versus bins, what we called bin-emission curves. Emission factors of different vehicle classes from Wang et al. (2012) and Zhang et al. (2013) were used to amend the bin-emission curves, moving the curves up or down without changing the relative relationship among bins. The outcome representative emission rates of each bin are shown in Supplementary Information, Figure S1." (Figure S1 shown as Fig. 1 here)

Figure S1. Emission Rates of Each Bin: a)LDT NOx Emission Rate; b)MDT NOx Emission Rate; c)HDT NOx Emission Rate; d)LDT PM2.5 Emission Rate; e)MDT PM2.5 Emission Rate; f)HDT PM2.5 Emission Rate.

4. Page 15228, Line 17. "However, this research founded an acceptable empirical summary for trucks at different ages." Authors have not given any information about statistical validity. So, one cannot say that it is acceptable. If there is no other information, and the surveys here are the only data available, authors should say so. Response: Thanks for the comment. The data here we use is the only data available. Here by 'acceptable' we meant the quantity of samples we used is acceptable compared with former researches. However, it's true that we can't say so without information about statistical validity. Therefore, Page 15228, Line 17 now reads as "However, the investigation result is the only data available now to understand the characteristics of trucks at different ages."

5. Section 3.1: Activity level A lot of valuable information is found from the surveys, and used in the emission inventory. However this information is not provided in the paper, and thus it is impossible for readers to take advantage of it, or to compare it with previous research. How much does mileage reduce as trucks age? Does this differ to different types of trucks? What is the survival probability for the different types of trucks in China? This information could be given in tables, even in supplementary information, but the basic information really needs to be provided. Figure 4 is a good example.

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Some of this information could be gleaned from figurer 3a and 3b. But the implied survival curves look odd. What is the reason for the large jump in 2009 vehicles compared with 2008? It implies that there was a huge purchase in 2009, or that vehicle retire within 3 years.

Response: Thanks for the referee's comments. First of all, information of kilometers travelled versus ages can be calculated according to the empirical equation shown in Figure 2. The quadratic fitting equation provides answers to the first question. Following the fitting equation, average vehicular kilometers travelled for trucks at each age could be calculated. As for the different types of trucks, we used mileage correction factors to reflect the differences between different trucks, which can be found in Table 2, Row 3. And survival probability for the different types of trucks in China is added in Supplementary Information, Figure S2. Relative revisions were also made in this paper so that it would be easier for the readers to find the data needed. The second paragraph in Chapter 3.1 now read as: "Moreover, mileage correction factors by vehicle type was introduced to identify the differences between each type of truck, as shown in Table 2. The correction factors were the ratio of the average kilometers travelled of a certain type of truck versus the entire truck fleet. From the value of correction factors we can see that as GVW grows, the average kilometers travelled increase.

Detailed information of survival rate was added section 2.3, after Eq.4. And survival curves of different types of trucks used in this research is now shown in Supplement Information, Figure S2 (Fig. 2 here). It now reads as: " is the survival rate of a k-year-old type j vehicle, The data came from a nationwide vehicle survival pattern research conducted by Hao el al. (2011). And the survival curves are shown in SI, Figure S2."

Figure S2. Survival Rates of Trucks in China The referee also mentioned that there was a huge jump in the population of 2009 versus 2008. The reason to this huge jump was that truck purchase, especially LDTs and HDTs, increased tremendously quickly in 2009, according to the data from National Statistical Bureau of China. The new truck population during 2002-11 is shown in Fig. 3 in this reply. In 2009, there was 0.98 million more new trucks came into the market compared with 2008, which was equivalent to 8.7% of the total truck stock in 2008. Considering that the survival rates for the first 3 years are very close to 100%, the existing stock of trucks that came into the market during 2009-2011 in the 2011 market were even higher. However, it is important for us to illustrate the reason to this jump so that the readers won't feel confused. Therefore, we added a few sentences to explain in Section 3.1. They read as: "Truck population in China experienced a tremendously growth during 2009-2011, according to the data from National Statistical Bureau of China. In 2009, there was 0.98 million more new trucks came into the market compared with 2008, which was equivalent to 8.7% of the total truck stock in 2008. And most of the 2009-2011 trucks survived in the 2011 market. Therefore, there was an obvious excess of trucks from 2009-2011 in the 2011 market compared with previous years."

Figure 1 New Vehicle Population in China, 2002-2911 6. Driving characteristics The GPS data were taken on 16 trucks in 15 provinces (according to table 1). This means that 1 truck per province was testes, and about 30 hours per truck. I don't think this number of GPS data could be considered sufficient to characterize all of China. It seems reasonable for this study, which is extensive in other ways, but it should be recommended that more GPS studies could be done. It seems likely that different truck sizes, cities, etc. could have different practices and perhaps the GPS data collected here do not fully capture these, especially idling time which is mentioned in the next section.

It is also not discussed whether the frequency of speed on different types of roads is the same for each province. I don't think it needs to be discussed here, but I encourage the authors to exploit the collected data in a later paper.

Response: Thanks to the referee's comments on the GPS data we collected. First of all, we have to admit that the number of trucks tested in this researcher is not sufficient to represent all of China. However, the data we collected is remarkable compared to former research. 16 trucks in 15 provinces were tested in this research, but it doesn't mean that we only have only one truck to represent each of the provinces. As mentioned in the article, a lot of trucks in China travel across provinces. The longest single trip we monitored travelled across 8 provinces. And for each truck, we monitor 2 weeks to present its full business cycle. The average 30 hours for each truck is the average time length for the 16 trucks with their engine on. These 30 hours were distributed in the monitored 2 weeks. Moreover, we are trying to get massive GPS data from several truck companies in China for greater representativeness. The problem is these kinds of commercial GPS only provide data per minute. The time resolution is not enough to further emissions study. Thus, we are still working on finding an approach to solve this as one of our future work. The referee's suggestion that we discuss the differences of running conditions on the same type of roads in different provinces is very helpful. We'd love to have this discussion in our later paper after we collect data massive enough to present the differences among provinces.

7. Section 3.4 effect of older truck mileage on inventory. This is an important point and it is nice to see it quantified. Emission comparison between this method (distribution by roads, compared with registration province). This is also an important point. Is it possible to compare quantitatively as was done with the truck mileage? How much would each province differ under the traditional versus this method?

Also, I recognize that this distribution is likely better. But it still contains significant uncertainty; I think it means that all roads are assumed to have equal congestion. It might be a better assumption, but it is still an assumption. Authors should state the limitations clearly.

Response: Thank you! We totally agree that it's very interesting to give quantitative comparisons between the traditional method and this new method. We added two kinds of comparison to clarify this. First, in this revision, we compared our provincial-level results with the MEP 2011 inventories. The MEP inventory was used as the official vehicle emission inventory in China. The comparison are shown in Figure 10 after revision. Second, we redo the VKT calculation for each province using traditional method. And the differences of provincial total VKT proportions are shown in Figure 11. In this way, the impact from other factors are avoided and only distributions are compared. Therefore we are capable to identify the differences caused by distribution quantitatively.

Since we made a lot of comparisons between our results and other researches, a new sector (Sector 3.5 Comparisons with Other Studies) was added to address all the comparisons. It includes former quantitative comparisons between emission results and the newly added comparisons between different distributions. The new chapter now read as:

“NOX emission from this research is 28% higher than the MEP’s estimation of 3,900,000 ton NOx emissions from trucks in 2011 (MEP, 2012b). And according to the MEP, the total PM2.5 emissions from the truck fleet were 460,000 ton in 2011 (MEP, 2012a), which is 130% higher than estimation in this research. The differences come from method, basic data and major assumptions.

Briefly, MEP estimated vehicle emission on the basis of local vehicle stock, activity level and emission factors. The truck classification is the same with our study, according to gross vehicle weight and the national emission standards. For each group, the emission equals the product of local registration number, kilometer travelled per vehicle and emission factor. Adding up emissions of each group is the total emission. The emission factor that MEP used is based on the national emission standard. Detailed information of emission standards in China is shown in SI, Table S2. However, no further input data related to vehicle kilometer travelled was provided in this inventory.

The difference on NOx emissions was mainly caused by emission factors used in these two studies. In our study, the emission factor of China 3 trucks was not improved compared with China 2 (Wu et al., 2012; Liu et al., 2009). Thus, compared with MEP inventory and other inventory based on low NOx emission rate, our NOx emission is much higher.

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Compared with MEP results, the PM2.5 emissions calculated in this research are significantly lower. A major reason for this lower result is that we included the decreasing trend of mileage traveled by trucks per year in this calculation. In China, overloading was common for commercial trucks. This accelerated the deterioration of trucks, which means older trucks had to run less due to deteriorated performance and more frequent repair and maintenance. The decrease of VKT was proved by our questionnaire investigation. If the mileages variation with age were omitted, the calculated PM2.5 emissions would increase 50%, exceeding 300,000 ton. However, the VKT variation is not such a large problem for NOx because the NOx emission factor did not improve from old trucks to new trucks.

The provincial level NOx and PM2.5 emissions from road freight transportation are shown in Figure 10 (a) and (b), respectively, ranking from the highest to the lowest. For both NOx and PM2.5, Shandong and Guangdong, where most of the freight transportation in China is conducted, take the leading positions in freight truck emissions. The NOx and PM2.5 emissions in these two provinces exceeded 600,000 ton and 25,000 ton, respectively. Provincial emissions from MEP inventory are also shown in Figure 10. The provincial differences between the outcome of REIB approach and MEP inventories are obvious. The greatest differences are 220% and -72% for NOx and PM2.5 respectively (REIB compared with MEP inventory). Not only the emission scales are different, discrepancies also exist in the rankings of provinces. The differences come from both different basic data and different methods. To avoid influence from input data, we re-calculated provincial VKT using our method and the traditional approach. Here traditional approach means calculating total VKT based on local registration data and average mileage travelled. The differences between the provincial proportions of VKT are shown in Figure 11. Taking Shanghai as an example, REIB method has 39.9% lower VKT compared with the traditional method. In the report published by MEP (2012a), the largest contributor of both NOx and PM2.5 in China during 2011 was Hebei province. However, Shandong contributed the most road freight emissions in 2011 according to this research. This difference was caused by the methodology on which the inventory was based. As discussed earlier, the registration number based approaches have a significant bias because trucks are not limited to the province where they are registered. Therefore, a province with the largest registration number of trucks might not have the most freight transportation. According to the China Statistics Bureau, Shandong has the greatest cargo volume and cargo turnover volume in the road transportation sector (Bureau, 2012). These data verified our assumption from a different perspective. Therefore, the former approach would be inaccurate without considering that the real range of truck activities might be different from the place where they are registered. There is an assumption of REIB approach that the same type of roads have equal congestion in different provinces. This is a limitation of our study and the limitation is mainly because the limited data amount. This limitation could be avoided if future GPS data could be sufficient to characterize driving conditions in each province, which means that the REIB approach is still suitable for future mass data analysis. Now, we can still trust the results because the differences within the same types of roads is much insignificant compared with that among different types."

Figure 10 and 11 are shown as Fig. 4 and Fig. 5 here.

Figure 10 Provincial Diesel Truck Emissions from This and MEP Inventories: a) NOx Emissions Ranks; b) PM2.5 Emissions Ranks. (*Ranking according to emission scales in this research).

Figure 11. Provincial VKT Proportions in REIB Approach and Traditional Approach.

And the referee also mentioned that we should state the limitations in the paper. REIB approach does have limitations because it assumes that all roads of the same type have the equal congestion. This is a limitation with current data amount. We can still trust the results because the differences within the same types of roads is much insignificant compared with that among different types. This limitation could be avoided if future GPS data is sufficient to characterize driving conditions on different roads in different provinces/cities. In the revision, we added discussion about the assumption

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of REIB approach and the limitations in the last paragraph of the new sector 3.5 so that the readers can get a full understanding of this method. The sentences read as: "There is an assumption of REIB approach that the same type of roads have equal congestion in different provinces. This is a limitation of our study and the limitation is mainly because the limited data amount. This limitation could be avoided if future GPS data could be sufficient to characterize driving conditions in each province, which means that the REIB approach is still suitable for future mass data analysis. Now, we can still trust the results because the differences within the same types of roads is much insignificant compared with that among different types."

8. Section 3.5 Uncertainty analysis: Table 3 gives the inputs but no support for why they were chosen! The uncertainties seem rather low. Please discuss which uncertainty were included, and which were not included.

Response: In this research, we refer to other former researches in China and use what they have used for uncertainty analysis. As we quoted in the paper, we used uncertainties from researches of Zhang et.al. (Historic and future trends of vehicle emissions in Beijing, 1998e2020: A policy assessment for the most stringent vehicle emission control program in China, 2014). For uncertainties in emission rates, we refer to the standard errors of the emission test that we used (Wang et al. 2012; Zhang et al, 2013). To clarify this, Page 15237 Line 9-11 now read as: "The statistical distributions of the annual kilometers travelled and stock are determined according to Zhang et al. (2013). And the uncertainty of mileage distribution was estimated according to our questionnaire results. For uncertainties of emission factors, we used the standard errors in the emission measurements to represent the uncertainties (Wang et al. 2012; Zhang et al, 2013). Considering that the activity level data are estimated based upon survey since it is not available through official channels, there is inevitable systematic bias in the estimation (Zheng et al., 2009)."

Editorial comments

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Response: All the editorial comments have been accepted.

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 15219, 2014.

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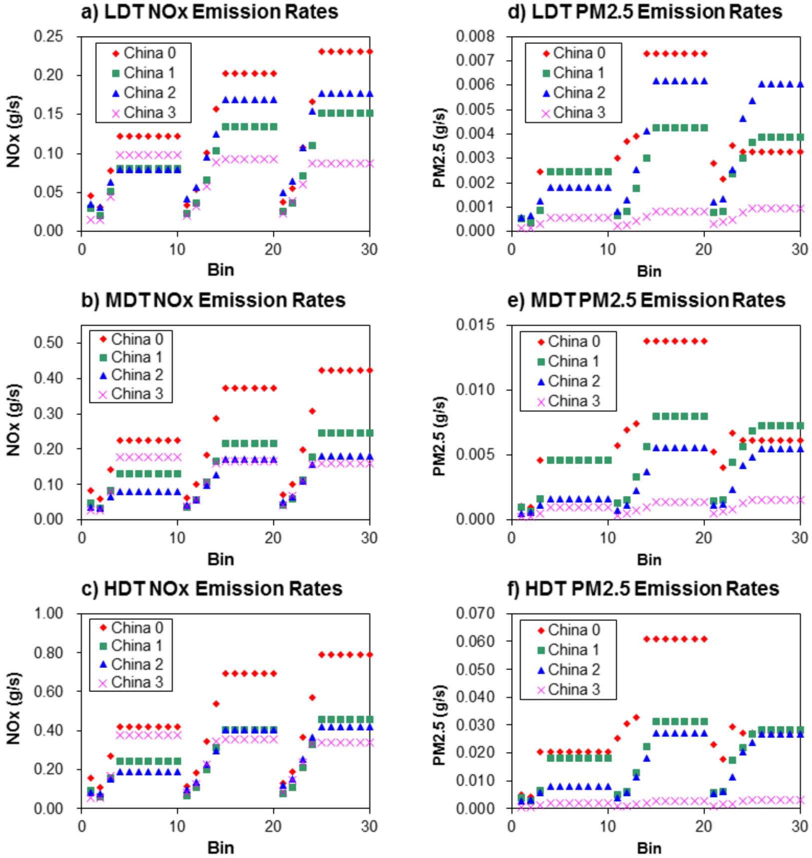

Fig. 1.

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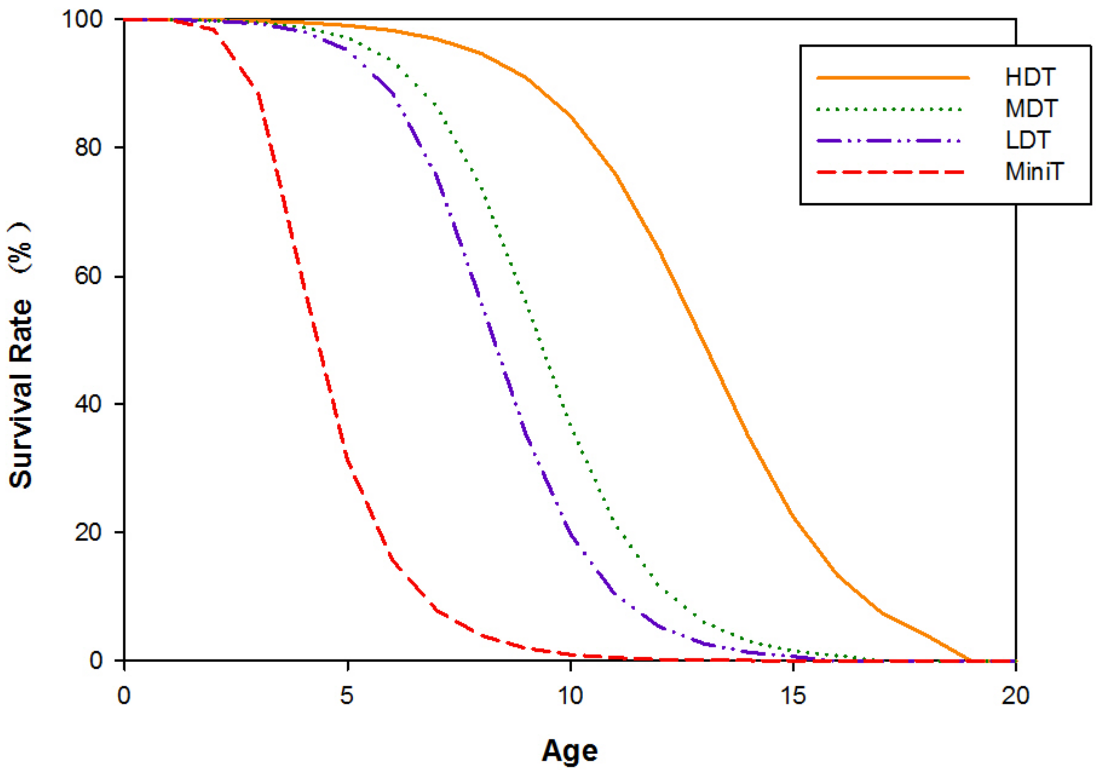

Fig. 2.

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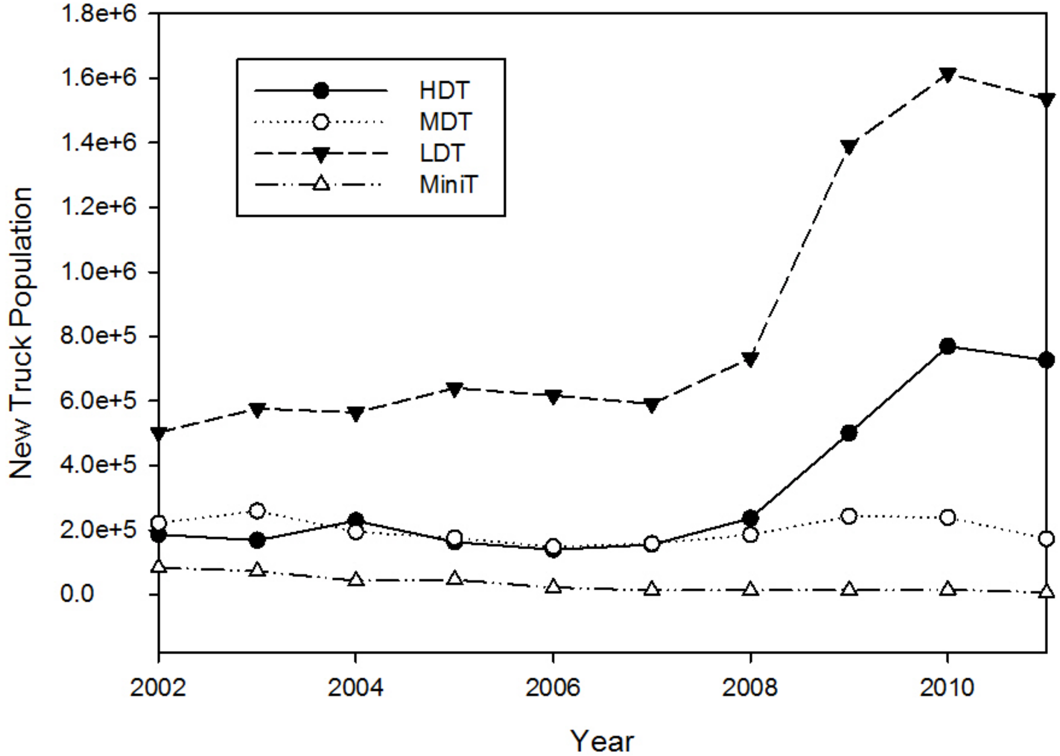

Fig. 3.

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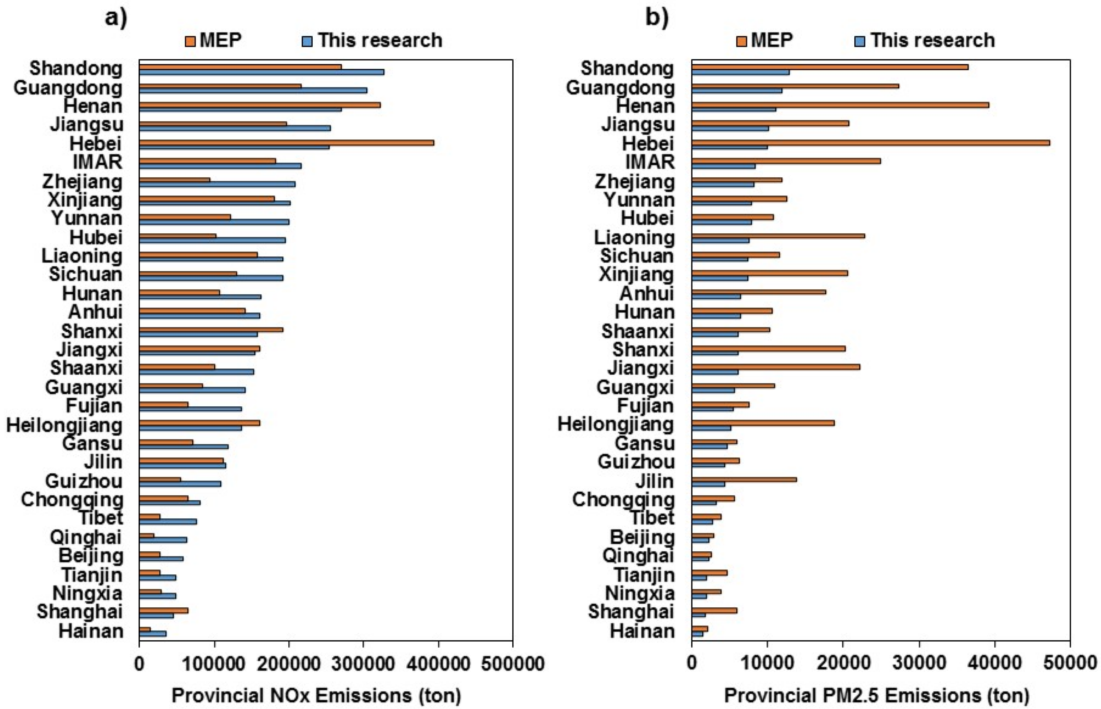

Fig. 4.

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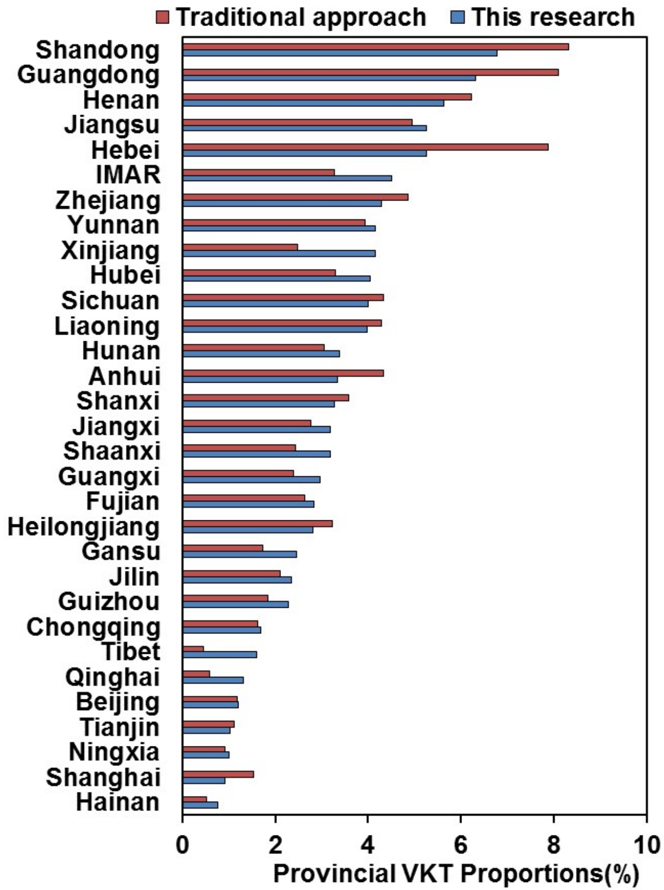

Fig. 5.

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