Carbon emissions in countries that failed to ratify the Intended Nationally Determined Contributions: A case study of Kyrgyzstan

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Abstract: The Paris Agreement aims to increase global participation in climate change actions, yet attentions are not equally given among countries. The knowledge gap remains in understanding the structure and drivers of the emission in small developing countries. Eighteen countries have failed to ratify their Intended National Determined Contributions (INDCs) as an officially recognized emission target. Among these countries, we chose Kyrgyzstan as a case to construct its emission inventories from both production-based and consumption-based perspectives and to identify the drivers of emission changes using structural decomposition analysis (SDA). The empirical results revealed that CO_2 emissions in Kyrgyzstan depicted a wavelike rise from 2007 to 2015, whilst the production structure contributed to 14% of the production-based CO_2 emission growth from 2012 to 2015. As a net emission importer, Kyrgyzstan transferred large quantities of CO_2 emissions to China and Russia through imports. However, if all manufacturing imports were produced within Kyrgyzstan, the emission would be over five times compared to the current level. It is helpful to reduce global emissions for Kyrgyzstan to import goods from other countries whose carbon intensities are lower. Overall, this study highlights the need to focus on these countries' failure to ratify INDCs while calling the Paris Agreement to provide a better understanding and mitigation mechanism for these small developing countries.

Keywords: CO_2 emissions inventory; Embodied emission; Inequality; Input-output table; Kyrgyzstan

1. Introduction

The Paris Agreement has adopted a 'bottom-up' approach to increase the participation rate of parties in addressing climate change. Under this scheme, countries set their National Determined Contributions (NDCs) and increase their effort every five years (Wei et al., 2018). However, this proposal gave insufficient attention to small developing countries, resulting in 18 nations (i.e., Angola, Equatorial Guinea, Eritrea, Guinea-Bissau, Iran, Iraq, Kyrgyzstan, Lebanon, Liberia, Libya, Oman, Russia, San Marino, South Sudan, Suriname, Turkey, Uzbekistan, and Yemen) not being officially approved by their government as NDCs despite submitting the Intended National Determined Contributions (INDCs). Without ratifications, the emission target of INDCs will not legally restrict the countries' emissions. All the above-mentioned 18 countries with unratified INDCs are developing countries, and many of them are small countries with limited knowledge of their emission pattern. As the few countries without ratified emission targets under the Paris Agreement, their environmental cost was relatively low. According to the pollution haven hypothesis, these countries with less stringent carbon regulation will have a high possibility to attract more industrial investment, therefore, have a higher emission. To inform future climate negotiation, fundamental research on the emission structure and emission flows of these countries must be conducted, therefore provide a better understanding of why these countries failed in the ratification of INDCs and how to encourage their actions in mitigation. In addition, developing countries are getting more engaged in international trade (UNCTAD, 2017). Embodied emission in the export of developing countries increased by 46% between 2004 and 2011, while many energy-intensive industries are relocating from China and India to other developing countries (Meng et al., 2018). As these nations have no constraint in national emissions under the Paris Agreement, it is also worth investigating the impact if the country produces the currently imported products domestically.

Typically, CO_2 emissions can be accounted for from two perspectives, namely production-based and consumption-based (Cao et al., 2019). The former consider CO_2 emissions produced within the country, while the latter focuses on CO_2 emissions caused by national consumption. The current CO_2 emission accounting for these small developing countries mainly in the production-based perspective and are implemented by international institutes, including the Carbon Dioxide Information Analysis Center (CDIAC, 2016), Emissions Database for Global Atmospheric Research (EDGAR v4.3.2, 2016), and International Energy Agency (IEA, 2018). Although these international institutes have provided the statistics of CO_2 emissions at the national level, the drivers behind CO_2 emissions have not been thoroughly analyzed.

Compared with production-based accounting, consumption-based accounting transfers mitigation responsibility to CO_2 emission consumers (Peters and Hertwich, 2008) and provides a closer connection between CO_2 emissions and human well-being (Steinberger et al., 2012). These characteristics for the consumption-based perspective have garnered increasing attention in recent climate conferences (Zhang et al., 2017). However, CO_2 emissions accounting from the consumption-based perspective for small developing countries were still rare (Wiedmann, 2009). Most consumption-based accounting were conducted for developed countries, for example, the United States (Jones and Kammen, 2011), the United Kingdom (Barrett et al., 2013), Japan (Hasegawa et al., 2015), and emerging economies like China (Mi et al., 2016; Pan et al., 2008). While some studies had provided a glimpse of the national consumption-based emission for the globe (Davis and Caldeira, 2010; Skelton et al., 2011; Wang et al., 2019), limited research provided sectoral information on emission source, and the international trade relationships between these small countries were also masked. With limited territory, the energy structure of small developing countries is relatively single. These countries are more likely to develop based on their comparative advantage and import those commodities with comparative disadvantage (Vollrath, 1991). Therefore, understanding the drivers of CO_2 emission and accounting for the embodied emissions are extremely important for these small developing countries to deal with climate change (Yang et al., 2018).

To provide a better understanding of emission drivers, index decomposition analysis (IDA) and structural decomposition analysis (SDA) are two decomposition methods that are widely applied in this field (Su and Ang, 2017b). From the methodology perspective, these two methods share the same theoretical roots of index number theory (Rose and Casler, 1996), but IDA mainly focuses on activity-related factors and is less data-intensive (Xu and Ang, 2013). A few studies have conducted IDA for small developing countries. For example, Brizga et al. (2013) used IDA to decompose the emission changes of 15 former Soviet countries from 1990 to 2010 through the indicators of population, affluence, industrialization, energy intensity, energy mix, and carbon intensity. Pani and Mukhopadhyay (2010) further expanded the scope to estimate the driven factor of emissions in 114 countries during 1992-2004. However, only 9 of the 18 countries with unratified INDCs were covered in the previous research due to data availability. While IDA emphasizes either the aggregate quantity of emissions or intensity indicators (Su and Ang, 2017a), the impact of sectoral production on CO_2 emission can only be revealed by SDA and the input-output table (Su and Ang, 2012; Wang et al., 2017). Many studies have applied SDA to identify the emission drivers of developed countries (Baiocchi and Minx, 2010; Feng et al., 2015), especially China (Mi et al., 2017b; Xiao et al., 2016). However, due to data availability, there is limited literature using SDA to determine the underlying factors for the 18 countries with unratified INDCs.

Among the 18 countries, Kyrgyzstan is representative of its geographic location, energy and production structure, engagement of international trade, while it is also a member of the Former Soviet Union. Moreover, Kyrgyzstan is a typical landlocked country in Central Asia, with China to the east and Uzbekistan to the south. In the context of the limited territorial area, relatively simple energy and production structure, and heavy dependence on imports, the government has regarded economic expansion as one of the national development strategies. Moreover, among 9 World Trade Organization members of the 18 noted countries, Kyrgyzstan joins the organization in a relatively early stage (Åslund, 2003), whilst the National Statistical Committee of the Kyrgyz Republic has published the national input-output table from 2012-2015 (Pierobon, 2018), which provide a good data basis for our analysis. Therefore, this study chooses Kyrgyzstan as an illustrative case of the 18 unratified INDCs countries by comparing its production- and consumption-based emissions and identifying its emission drivers at the sectoral level.

This paper contributes to the understanding of the emission structure and drivers of the countries failed to ratify INDCs, as well as their role in international trade. By importing carbon-intensive products and exporting the comparative advantage products, Kyrgyzstan served as a net emission importer. Importing from “world’s factories”, such as China, will avoid higher global emissions by amplifying production scale advantages. However, this may also aggravate the inequality of CO_2 emissions - although the world may benefit from the production scale advantages of "world's factories", these "world's factories" will face more stringent emission reduction responsibilities which violate the principle of the production-based perspective. The remainder of this paper is organized as follows. Section 2 gives the methodology of input-output analysis and data sources used in this research. Section 3 discusses the results with respect to emission structures, emission drivers, and emission embodied in international trade. Finally, the conclusions and policy implications are summarized in Section 4.

2. Methodology and data

2.1 Overview of Kyrgyzstan

Kyrgyzstan is at a crucial geographical location in Central Asia, neighboring China in the east, Kazakhstan in the north, Uzbekistan in the west and Tajikistan in the south (Figure 1). From 2006 to 2015, energy production and consumption in Kyrgyzstan increased gradually, with coal as the major fuel type. Oil and gas were mainly imported. There is a valley in energy consumption in 2010, possibly because of the coup that distorted markets and stunted economic growth and energy consumption. In 2015, coal consumption plateaued, and the consumption of other fuel types also remained stable.

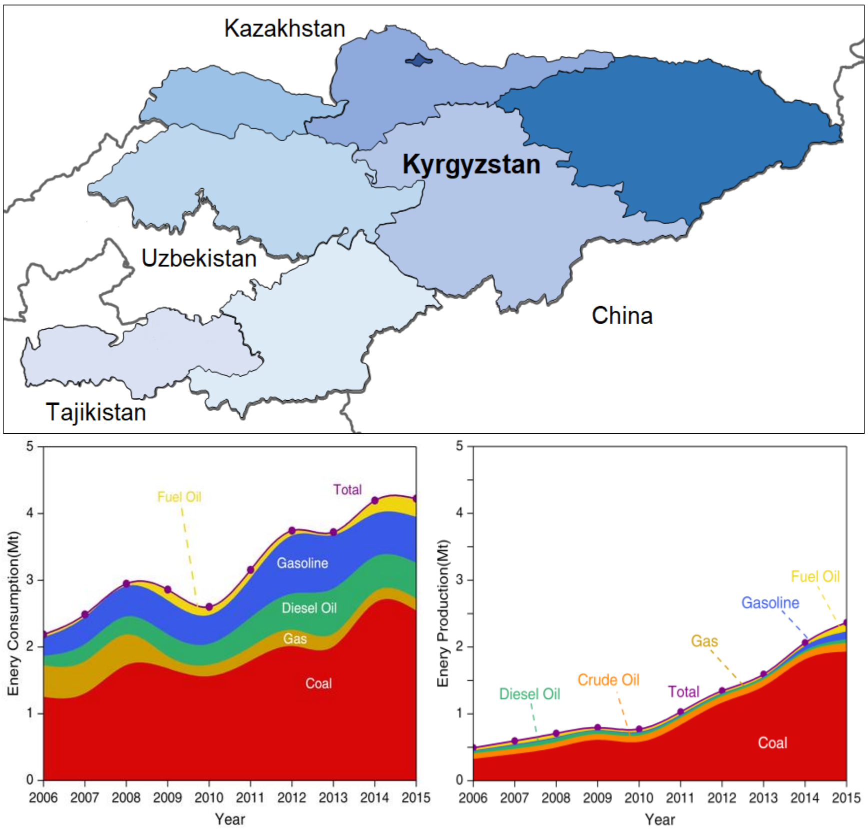

Figure 1 Kyrgyzstan energy production and consumption from 2006 to 2015

2.2 Data preparation

The activity data in physical units of energy consumption for industrial sectors were collected from Kyrgyzstan statistical yearbooks. The population data used for the SDA were obtained from the yearbooks, and the energy balance tables (EBTs) gave the amounts and sectoral compositions of energy consumption, as well as the changes or transformations in all energy types from 2012-2015. The cement production data were also collected from the statistical yearbooks. The input-output tables were obtained from the National Statistical Committee of the Kyrgyz Republic website (http://www.stat.kg/), with 34 sectors denoted. The multi-regional input-output table including international trade data for 2014 was from the Global Trade Analysis Project (GTAP) and divided into 57 sectors. Finally, all data were integrated into 10 categories based on sector definitions (see the Appendix), and the consumption-based emissions only span across 4 years (2012-2015).

2.3 Production-based CO_2 emissions accounting

Production-based inventory considers the local emissions produced within the nation. To provide production-based emission accounting, this study follows the most commonly used methods, namely the correlation coefficient method (Chang and Chang, 2016). The emission inventory included both the energy-related emissions from the combustion of fossil fuels and the process-related emissions from cement production, which discharges CO_2 through chemical reactions.

2.3.1 Energy-related emissions

According to the Intergovernmental Panel on Climate Change guidelines (Eggleston et al., 2006), energy-related CO_2 emissions (CE_{energy}) can be calculated as the energy consumption multiplied by the relevant emission factor (Shan et al., 2017), as shown in Equation 1.

$$CE_{energy} = \sum\sum CE_{ij} = \sum\sum AD_{ij} \times NCV_i \times CC_i \times O_i \tag{1}$$

where CE_{ij} presents the CO_2 emissions from the combustion of fossil fuel i in sector j and AD_{ij} refers to the intensity of human activities, which is measured by the amount of fossil fuel i combusted in sector j. In this study, 34 sectors and 8 fossil energy types were included in the EBTs of Kyrgyzstan. NCV_i, CC_i, and O_i are the net caloric value, carbon content, and oxygenation efficiency of fossil fuel i, respectively. The parameters used are set based on IPCC values.

2.3.2 Process-related emissions from the cement industry

Manufactures, mainly cement producers, also discharge CO_2 via chemical reactions; these emissions are called process-related emissions. Cement is produced from calcium carbonate by calcination at high temperatures, and this process discharges CO_2. The process can be expressed as $CaCO_3 \rightarrow CaO + CO_2 \uparrow$. Accordingly, CO_2 emissions from the process of cement production can be calculated by the product of manufacturing activity and the corresponding emission factor, as shown in Equation 2:

$$CE_{cement} = AD_{cement} \times EF_{cement} \tag{2}$$

where AD_{cement} refers to cement production and EF_{cement} is the emission factor of the chemical process of cement production. The emission factor was from the IPCC and is approximately 0.4985 tonnes of CO_2 per tonne of cement production.

2.4 Environmental input-output analyses and structural decomposition analysis

Environmental input-output analyses (EIOAs) are fundamental in SDA to determine the interdependence of industries. In an I-O table, the following relationship exists:

$$X = (I - A)^{-1} Y \tag{3}$$

where X is the total output vector, I is an identity matrix of appropriate size, A is a direct coefficient matrix with elements of inputs per unit of output, and Y is the final demand vector. $(I - A)^{-1}$ is the Leontief inverse matrix, which captures both the direct and indirect effects of final demands on the production outputs.

Based on the EIOAs, five factors are considered contributors to the emission changes: the population, efficiency, production structure, consumption patterns, and consumption volume (Mi et al., 2018). Using an SDA method, the emission changes can be decomposed as follows:

$$\Delta C = \Delta peLy_s y_v + p\Delta eLy_s y_v + pe\Delta Ly_s y_v + peL\Delta y_s y_v + peLy_s \Delta y_v \tag{4}$$

where Δ represents the change in a factor; p is the population in Kyrgyzstan; e is the direct emission intensity calculated based on the CO_2 emissions from a given sector divided by its total output; L is the Leontief inverse matrix, which is also denoted as $(I - A)^{-1}$; y_s represents the per capita consumption pattern; and y_v represents the per capita consumption volume. Each of the five terms in equation (4) reflects a contribution to national emission change influenced by a corresponding driving force if the remaining variables are held constant. As different SDA methods can lead to different decompositions results, this study follows the previous research (Mi et al., 2017a) and averages all possible first-order decomposition terms (5!=120 forms) to address the problem.

2.5 Consumption-based CO_2 emissions embodied in imports/exports

EIOA is also fundamental for calculating the environmental emissions embodied in economic activities, especially imports and exports. For Kyrgyzstan, the monetary balance is as follows:

$$x = Z + y + exp - imp \tag{5}$$

where *x* is the sectoral total output vector, *Z* is the intermediate (domestic and imported) industry demand matrix, *y* is the final demand vector (including household, government, and investment components), and *exp* and *imp* are the exports and imports of the country. After removing the import variables from *Z* and *y*, the balance becomes

$$x = Z_d + y_d + exp \tag{6}$$

$$imp = Z_{imp} + y_{imp} \tag{7}$$

where Z_d and y_d are the domestic parts of *Z* and *y*, and Z_{imp} and y_{imp} are the import parts. Thus, considering the emissions, the total (direct and indirect) quantity of domestic emissions required to produce a unit of final consumption is as follows:

$$c = e(I - A)^{-1} \tag{8}$$

where *e* is the direct emission intensity calculated based on the CO_2 emissions of a given sector divided by its total output *x*. The sectoral emissions are the production-based emissions discussed above. $L = (I - A)^{-1}$ is the Leontief inverse matrix, which encompasses the direct and indirect inputs required to produce one unit of final demand. The total quantity of direct and indirect domestic emissions required to produce a unit of an exported product is formulated as follows.

$$C_{exp} = \hat{e}(I - A)^{-1} e\hat{x}p \tag{9}$$

Similarly, if Kyrgyzstan produces the equivalent amount of product that is imported from other countries, this shift would result in energy consumption related to these products (in the household, government, investment and export sectors) and generate CO_2 emissions. If the quantity of imports is assumed as the final demand, the total direct and indirect emissions required to produce a given amount of product is formulated as follows:

$$C_{imp} = e(I - A)^{-1} imp \tag{10}$$

where C_{imp} represents the CO_2 emissions transferred from Kyrgyzstan to other countries.

3. Results and discussion

3.1 Production-based CO_2 emissions in Kyrgyzstan

By integrating the energy-related and process-related CO_2 emissions, production-based CO_2 emissions in Kyrgyzstan from 2007 to 2015 can be calculated. Because the actual energy utilization rate from Kyrgyzstan is not available, this study uses the default values reported by the IPCC while considering the upper and lower bound of each type of energy. As illustrated in Figure 2, the overall trend in CO_2 emission estimates in our research is consistent with that of the IEA and CDIAC, while the estimates by EDGAR are much lower but still within a reasonable range of uncertainty. Similar to the overall trend of our estimates, the upper and lower bounds both exhibit fluctuating growth from 2007-2013. However, the trend of the uncertainty interval differs in 2014, mainly because of the discrepancies in the emission factors. Compared with other energy sources, the emission factors of coal vary widely, and coal consumption, which is dominated by lignite consumption, accounts for a large proportion of primary energy consumption in Kyrgyzstan (see Figure 1).

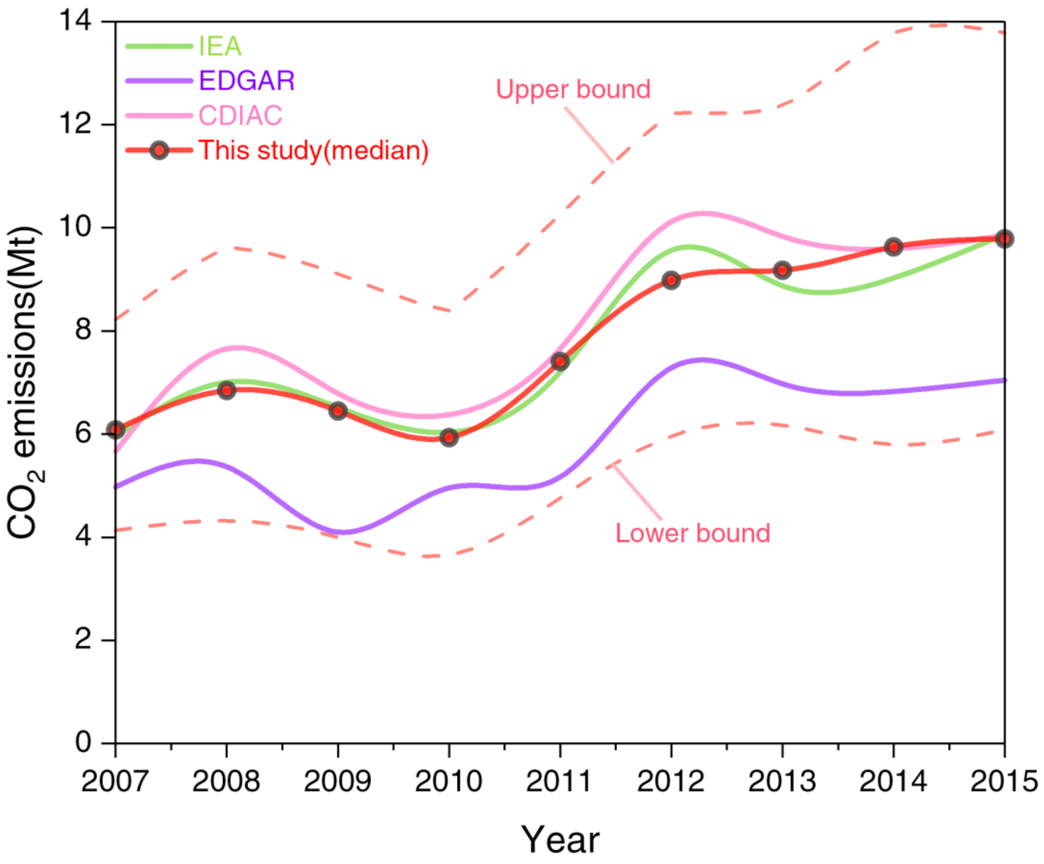

Figure 2 Estimates of production-based CO_2 emissions in Kyrgyzstan

Figure 3 depicts the variations in sectoral energy consumption and CO_2 emissions during the period of 2012-2015. Notably, the major CO_2 emission sectors in Kyrgyzstan are WRR (wholesale, retail and auto repair), MAN (manufacture), PGW (power, gas and water supply), and MIN (mining), accounting for 25.84%, 25.44%, 23.93% and 9.29% of the cumulative emissions from 2012 to 2015, respectively. The main reason why WRR has become the highest CO_2 emission sector is that tourism is a key development industry (Baum and Thompson, 2007), and road transport is the most important transportation mode in Kyrgyzstan (National Statistical Committee of the Kyrgyz Republic, 2018). Therefore, as a supplier of automotive fuel, WRR will inevitably consume a large amount of gasoline. With respect to the type of energy consumption in each sector, coal consumption is mainly distributed in PGW and MIN, and gasoline consumption is distributed in WRR. The remaining energy sources are used in secondary industries. With the steady development of the economy, the consumption of coal and diesel fuel is increasing to match the growing demands; however, gasoline consumption has decreased, and the consumption of crude, natural gas and mazut have been relatively stable.

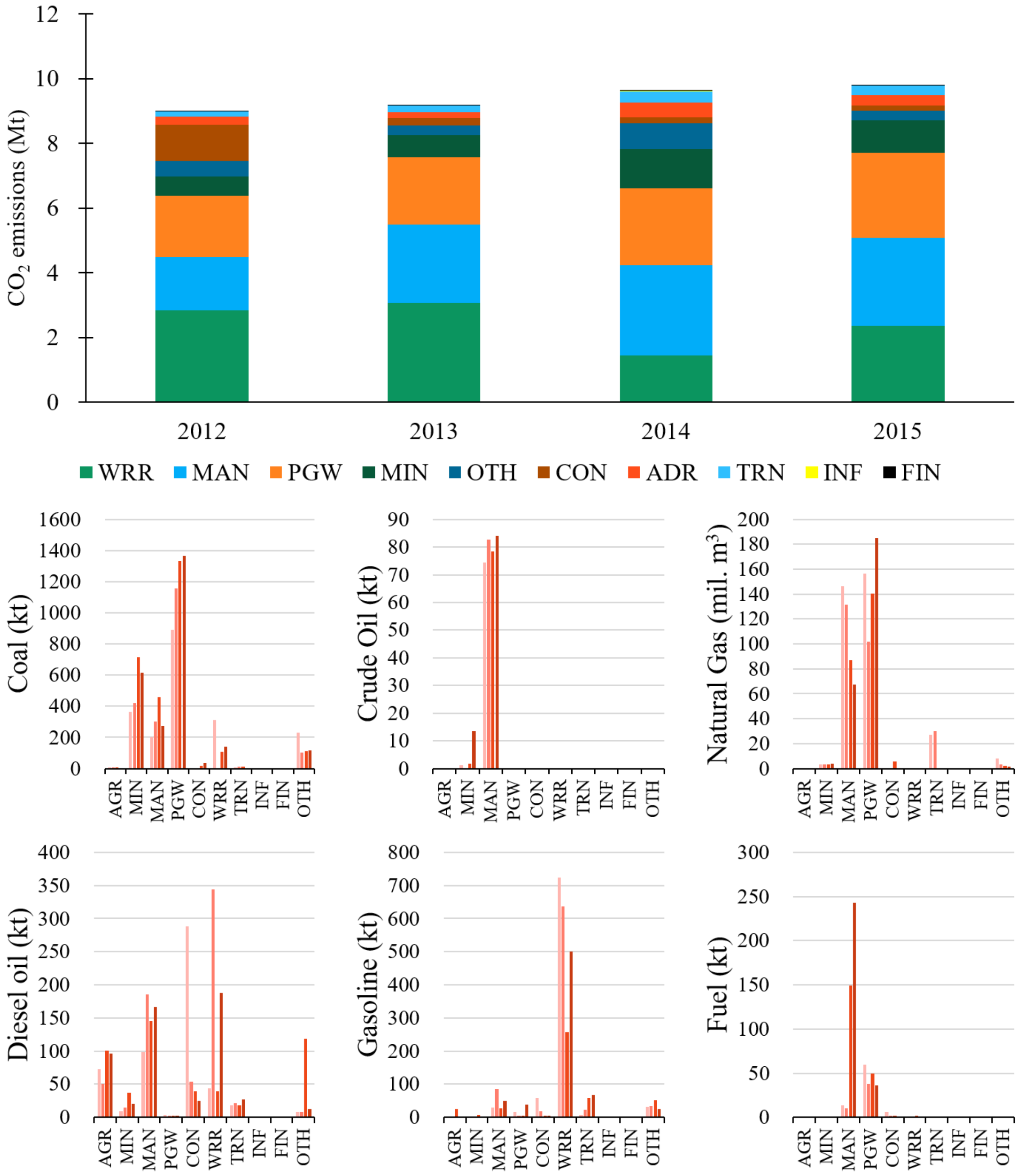

Figure 3 Sectoral energy consumption and CO_2 emissions

3.2 Determinants of emissions changes in Kyrgyzstan

From 2012 to 2015, the emissions in Kyrgyzstan slightly increased by 8.1%, from 8.99 Mt of CO_2 to 9.79 Mt of CO_2 (Figure 4, black curve). However, the contributions of determinants changed dramatically. The per capita consumption was the major driving factor from 2012 to 2014, increasing total emissions by 8.12% with other factors held constant from 2012 to 2013 and by 7.30% from 2013 to 2014. However, although total consumption decreased in 2015, other factors shifted to offset the emission growth at that time. Changes in the production structure led to a sharp increase throughout the period and drove 13.64% of the total emissions when holding other factors constant. Thus, the production structure became the major driving factor of emissions. If fossil-fueled development were to continue and similar trends occurred in other developing countries, a high global emission level and warming may be observed. Changes in efficiency and consumption patterns were two major factors that offset emissions from 2012-2015. Although changes in consumption patterns have typically served as drivers of emissions growth in other countries, such changes offset 9.6% of the emissions from 2012-2014 in Kyrgyzstan. Efficiency gains are often a major offsetting factor, but the corresponding effects were relatively limited given the technological development in the country in this case. Additionally, population growth constantly drives emissions growth, but the related impact was relatively low compared with those of other factors in this study.

It is worth noting that the production structure and consumption structure rapidly changed from 2014-2015. Considering the coal-dominant energy production structure, the country could be very susceptible to an economic shock. Because the production structure and consumption structure both reflect high carbon use trends and the contribution of energy-efficient production is relatively small, there is a high probability that the country will experience unsustainable fossil fuel-based development.

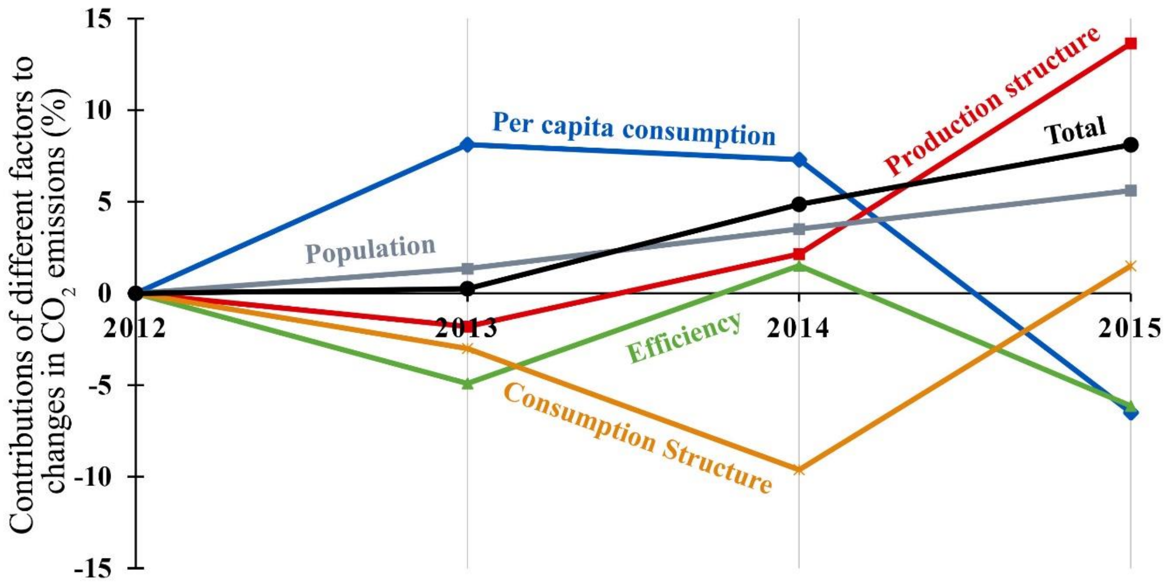

Figure 4 Contributions of different factors to changes in Kyrgyzstan CO_2 emissions between 2012 and 2015

3.3 Unequal embodied emissions in international trade

From 2012 to 2015, the CO_2 emissions embodied in exports and imports are shown in Figure 5. The emissions embodied in exports are mainly in the manufacturing (MAN), wholesale/retail/auto repairs (WRR) and mining (MIN) sectors, and all the totals are less than 1 Mt. Assuming that all imports are produced within Kyrgyzstan, the products accounted for nearly 5 Mt of emissions from the manufacturing sector only, and emissions embodied in imports (as consumption) from other sectors are far greater than the emissions embodied in exports. Except for the emissions embodied in the imports of power/gas/water supply (PGW), which have increased annually, those of AGR (agriculture), MIN, MAN, WRR and TRN (transportation) decreased in 2014 or 2015. This trend indicates that Kyrgyzstan has intended to develop its national industry and lower its dependence on imports, which would excite the domestic economy while potentially increase the production-based emission within the country. Under this assumption, Kyrgyzstan may achieve an export-import balance of embodied CO_2 in the future.

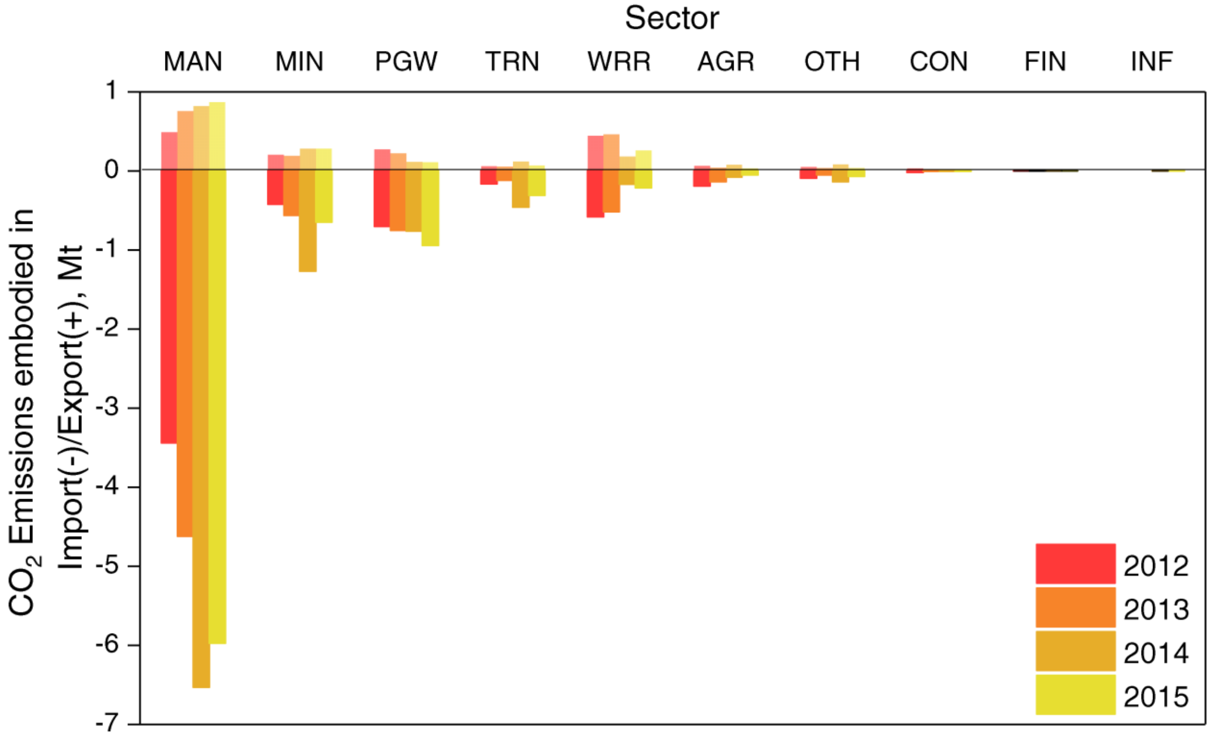

Figure 5 CO_2 emissions embodied in exports and imports from 2012-2015

Combining the GTAP trade data with the input-output table of Kyrgyzstan, the embodied emissions of the major "trade partners" of Kyrgyzstan in 2014 are present in Figure 6, including China, Russia, Kazakhstan, European Union, Turkey, Korea, United States, Switzerland, and the United Arab Emirates. China is the largest source of import-based embodied carbon, i.e., Kyrgyzstan avoids a large portion of CO_2 emissions (nearly 4 Mt) by importing from China. Russia and Kazakhstan, both close to Kyrgyzstan, follow. In this sense, the emissions embodied in the imports of Kyrgyzstan are unequal for its surrounding larger countries. Kyrgyzstan's exports are mostly to European countries, including Switzerland and EU countries, and to neighbors, such as Kazakhstan. These exports have relatively high embodied emissions (less than 1 Mt), which is unequal for Kyrgyzstan as the less developed economy. Generally, Kyrgyzstan transferred more emissions outside of its borders in 2014.

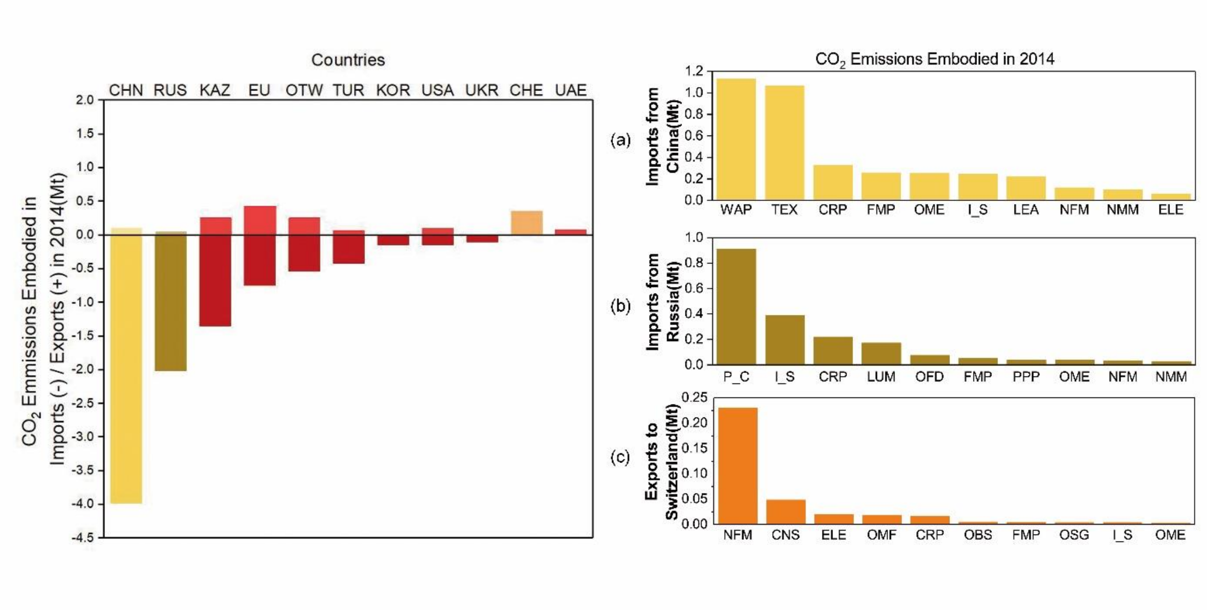

Figure 6 Embodied CO_2 emissions of the major trade partners of Kyrgyzstan in 2014. Subfigures (a), (b), and (c) show the top 10 sectors of CO_2 emissions embodied in the trade with Switzerland, China, and Russia in 2014. The abbreviations for sectors are given in SI2.

Among all countries, the net embodied emission is highest from Kyrgyzstan to Switzerland. Taken Switzerland as an example destination of Kyrgyzstan exports, this study has found that metal (NFM; here, gold accounts for over 99% of the total value (CEPII, 2019)) exports are the major source of embodied emissions, as shown in Figure 6(c). Specifically, Kyrgyzstan generates 230 kt of CO_2 emissions via the production of metals that is exported to Switzerland, followed by construction-related products that embodied 48 kt of CO_2 emissions. From this perspective, although Kyrgyzstan is hardly an export giant, its raw material exports to highly developed countries with less developed technology that continually discharges CO_2 within the country. In addition, as shown in Figure 5, the emission embodied in raw materials' exports is showing an increasing trend from 2012 to 2015. In Figure 6(a) and 6(b), the CO_2 emissions embodied in imports from China and Russia are detailed into sectors. China and Russia are both large countries geologically close to Kyrgyzstan with more advanced production technologies than Kyrgyzstan; still, these technologies discharge CO_2 emissions. In 2014, Kyrgyzstan avoided nearly 6 Mt domestic CO_2 emissions via importing from China and Russia, which accounted for nearly 2/3 of the production-based CO_2 emissions of that year. The embodied emissions in imports from China are mainly in wearable products (WAP, over 1 Mt), textile products (TEX, over 1 Mt), chemical products (CRP), metal products (FMP) and machinery equipment (OME). Russia exports petroleum and coal products (P_C, nearly 1 Mt), ferrous metals (I_S) and chemical products (CRP, including pharmaceutical products and fertilizers) to Kyrgyzstan, helping to avoid large emissions in Kyrgyzstan. Other trade partners account for much lower quantities of CO_2 emissions embodied in imports than China. As China and Kyrgyzstan continue to trade more with a five-year annual growth rate of 5% (Statistics, 2018), the carbon transfer from Kyrgyzstan to China will likely increase, indicating that inequality of embodied CO_2 emissions between the two countries will remain there. However, the economic profits and the Open Door policy will render China to continue acting as a large supplier as well as the emission receiver for small developing countries such as Kyrgyzstan.

4. Conclusions and policy implications

The bottom-up structure of the Paris Agreement aims at encouraging countries to take actions to mitigate emissions. However, knowledge gaps remained in understanding the structure and drivers of emissions in small developing countries, which resulted in 18 countries failing to ratify the INDCs. Due to data availability, this study chose Kyrgyzstan as a representative country. Comparing both the production-based and consumption-based emission inventories for Kyrgyzstan, the results show that Kyrgyzstan served as a net emission importer. By importing carbon-intensive products from other countries, the production-based emission in Kyrgyzstan is relatively low, which could be one of the reasons why the country failed in INDC ratification. Many previous studies of consumption-based accounting pointed out the inequality of developed countries transferring emissions to developing countries. There is growing recognition that developing countries are also transferring emissions among themselves. By looking into the embodied emission between Kyrgyzstan and Russia/China, this study reinforces the recognition of this south-south trade embodied emission. Results show that this emission transfer can somehow be beneficial to global emissions, as the nation (Kyrgyzstan) will emit more if it produced the imported products domestically. A large amount of Kyrgyzstan's emission is transferred to other countries, especially to China and Russia, in wearable and chemical product products. If all manufacture imports were produced within Kyrgyzstan, the products would account for nearly 5 Mt of additional emissions. However, while most climate negotiation disproportionately emphasis on supply than demand, this beneficial emission transfer will aggravate the inequality in emission reduction by adding more burden to the producing countries.

On the other hand, Kyrgyzstan has intended to develop its national industry in order to lower its dependence on imports, which will potentially increase the production-based emission within the country. The emissions embodied in exports are much less and mainly associated with metal exports to European countries. According to the SDA results, the contribution of production structure to carbon emission has increased gradually during 2012-2015, while the contribution of consumption structure was also witnessed a sharp increase during 2014-2015. As the contribution of energy efficiency is relatively small compared with the growth of production structure and consumption structure, there is a high probability that the country will experience unsustainable fossil fuel-based development in the future.

In the aspect of combating climate change, this emission transfer is not a bad thing for the small developing countries, though inequality exists between small developing countries and large developing countries. With a coal-dominated energy production, the country may produce more emissions if all imports are produced domestically. Therefore, the Paris Agreement should build an open international trade environment to promote emission transfer among countries. Moreover, guiding the sustainable development of national production is also necessary for countries who decided to develop their national industry, and considering a broader emissions trading scheme would also matter (Li et al., 2019). This is because changes in the production structure play an important role in driving emissions, and there is an urgent need to promote cleaner production in these small developing countries to avoid fossil fuel-based development, which can have severe global consequences. Due to the data availability issue, this study only provides the results of Kyrgyzstan which could serve as a reference for others to future research.

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Appendix

1. Sector definitions and abbreviations

Abbreviation	Sector
AGR	Agriculture, forestry, and fishing
MIN	Mining
MAN	Manufacture
PGW	Power, gas and water supply
CON	Construction
WRR	Wholesale, retail and auto repair
TRN	Transportation and storage
INF	Information and communication
FIN	Financial intermediaries and Insurance
OTH	Other sectors (including cleaning, waste treatment, hotel, real estate, public administration, education, health, arts, etc.)

2. Product abbreviations for emissions embodied in international trade (consistent with GTAP)

Abbreviation	Products	Abbreviation	Products
NFM	Metals, n.e.c.	OME	Machinery and equipment, n.e.c.
CNS	Construction	WAP	Wearable apparel
ELE	Electronic equipment	TEX	Textiles
OMF	Manufacturing, n.e.c.	LEA	Leather products
CRP	Chemicals, rubber, and plastic products	NMM	Mineral products, n.e.c.
OBS	Business services, n.e.c.	P_C	Petroleum and coal products
FMP	Metal products	LUM	Wood products
OSG	Public administration, defense, education, health	OFD	Food products, n.e.c.
I_S	Ferrous metals	PPP	Paper products and publishing