International trade and carbon emissions: The role of Chinese institutional reforms

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Abstract

Carbon dioxide (CO_2) emissions embodied in Chinese exports to developed countries have grown rapidly since 1995. We test to what extent institutional reforms in China during the 1990s and 2000s can explain this increase. We identify five sets of institutions that may explain the increase: weak environmental institutions, trade liberalization, regulatory reform, institutional risk, and exchange rate policy. Our results show that Chinese trade liberalization has the largest effect on emissions, followed by the exchange rate policy, and weak environmental institutions. None of the other sets of institutions has a significant effect on Chinese CO_2 exports.

Keywords: CO_2 emissions; Trade; Policy reforms; Globalization; China; Carbon leakage

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1. Introduction

Developed countries' carbon dioxide (CO_2) emissions have either declined or grown moderately since the 1990s (World Input-Output Database[1]). However, the carbon footprint, that is emissions embodied in the goods and services consumed, has increased (World Input-Output Database). Part of the increase is explained by an increase in imported goods from China (Druckman and Jackson, 2009; Peters et al, 2012). The Chinese CO_2 intensity is relatively high, which causes developed countries carbon footprint to grow when its imports from China grows. For example, emissions produced in the United States grew by 5% between 1995 and 2008, while emissions embodied in consumption grew by 15% as emissions indirectly imported from China grew by 156% (World Input-Output Database). Approximately 10% of all emissions embodied in consumption in the United States in 2008 were emitted in China. Estimates showed that up to one-third of all Chinese CO_2 emissions in 2008 were indirectly exported to other countries (Weber et al, 2008; Yunfeng and Laike, 2010).

The causes behind the increase in Chinese emission exports are still inconclusive. Some have pointed towards the increase in overall trade levels following China's entry into the WTO in 2001 (Vennemo et al, 2008), while others highlight the weakness of Chinese environmental institutions[2], which causes an outsourcing of dirty production to China (Babiker, 2005; Ren et al, 2014). Others, however, dispute the size of the effect of weak environmental laws on the amount of CO_2 embodied in Chinese exports (see, e.g., Barker et al, 2007).

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[1] http://www.wiod.org/new_site/home.htm

[2] With institutions we mean "the rules of the game" (see North, 1990). In the term institutions we also include policies. Theoretically, there is a difference between institutions and policies, yet practically it is difficult to separate the two.

Studies on the relationship between institutions and foreign trade in general have shown that de-regulated labor and financial markets (Costinot, 2009), protection of property rights, strength of contract law (Nunn, 2007), and the independence of the judicial system (Ma et al, 2010) significantly affects both the volume and the composition of trade between two countries (Nunn and Trefler, 2014). Indirectly these institutions therefore also affect the amount of CO_2 embodied in that trade. Trade between developed and developing countries are especially affected by institutions as trade between two countries is positively correlated with how similar the two countries institutions are (Francois and Manchin, 2013). Institutional reform in the developing country that reduces the institutional differences compared to developing countries consequently leads to more foreign trade.

China has undergone major institutional change since the late 1970s that has transformed the economy from a largely closed, state-controlled, and planned economy to a relatively open and market-based economy (see, e.g., Nee and Opper, 2012; Coase and Wong, 2013). Beyond establishing a market economy, these reforms have also reduced the difference in institutions between China and developed countries.[3] The extent of the institutional reforms suggests that they may have contributed significantly to the increase in CO_2 emissions exported from China to the developed world.

The purpose of this paper is to disentangle how different Chinese institutional reforms have affected the amount of CO_2 embodied in its exports to 19 developed countries between 1995 and 2008. We identified five sets of institutions and institutional reforms that may affect the level of embodied emissions: (i) environmental institutions; (ii) trade liberalization; (iii) quality of market regulation; (iv) institutional risk; and (v) the Chinese exchange rate policy. Our results show that trade liberalization is the key institutional reform driving the increase in

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[3] Although the differences have diminished, substantial differences still exist in the institutional set-up.

emission exported from China, followed by the Chinese exchange rate policy and relatively weak Chinese environmental institutions. Environmental institutions have a relatively modest effect on emission imports overall, but the effect is stronger for imports from CO_2-intensive industries, such as basic and fabricated metals. From a policy perspective, our results suggest that the growth rate in emission imports is likely to decline once the effect of trade liberalization has faded away. Chinese emission exports may even decline under certain circumstances.

The rest of the paper is organized as follows: Section 2 outlines our hypotheses; Section 3 discusses the data and method; Section 4 contains the results; and Section 5 concludes the paper.

2. Trade, carbon emissions, and institutional reforms: five hypotheses

How much CO_2 emission a country's foreign exports embody depends on both the volume and the composition of trade. More trade naturally leads to a higher level of embodied CO_2. And exports of heavy manufacturing products leads to embodied CO_2 compared to lighter manufacturing or service products. The volume of trade between two countries depends on factors such as the size of the two economies, the geographical closeness, and the value of the exchange rate (Overman et al, 2003). The composition of trade is affected by countries' comparative advantage, which, in turn, is linked to its endowment of natural resources, labor, capital, and technology (Helpman and Krugman, 2002).

Institutions play an important role in both facilitating foreign trade (Levenchenk, 2007; Nunn, 2007; Ranjan and Lee, 2007) and determining a country's comparative advantage (Feenstra et al, 2013; Nunn and Trefler, 2014). Countries with liberalized trade institutions trade more than countries that impose various forms of trade restrictions. However, trade institutions are far from the only institutions that affect foreign trade. Strong contract law and an independent judicial system also increase trade (Nunn, 2007; Ma et al, 2010). Developed and de-regulated financial markets enhance manufacturing exports (Beck, 2002) especially of capital-intensive manufacturing exports (Rajan and Zingales, 1998). De-regulated labor market regulation improves the allocation of labor and skills between firms and increases the complexity of the goods the country exports (Costinot, 2009). All these institutions can therefore affect the indirect trade of CO_2 emissions by affecting foreign trade flows.

Based on the literature on institutions and foreign trade, and the literature on Chinese institutional reforms, we identified five sets of institutions, and the reforms thereof, that may explain part of the increase in exported emissions from China to developed countries: (i) environmental institutions; (ii) trade liberalization; (iii) quality of market regulation; (iv) institutional risk; and (v) the Chinese exchange rate policy.

2.1 Environmental institutions and their enforcement

Relatively stringent environmental institutions in one country can cause a direct or indirect outsourcing of dirty production to countries with weaker environmental institutions (Cole, 2004). In the direct case, firms in countries with stronger institutions re-allocate their production to country with weaker institutions. In the indirect case, firms in countries with weaker institutions increase their global market share at the expense of firms in countries with stringent institutions. But, there is no physical re-allocation of firms.

In China, policy makers have prioritized economic development ahead of environmental concerns at least until the 11th Five-Year Plan between 2006 and 2011 (He et al, 2012). Therefore, Chinese environmental institutions have remained relatively weak despite some tightening towards the end of the 2000s. Contributing to the weakness of the environmental institutions is the irregular enforcement of them. The implementation of environmental institutions is often left to local authorities (Carter and Mol, 2007) who are rewarded based on their economic performance and not on the state of the environment (Landry, 2005; Bo, 2004;

Li, 1998). Personal rewards can thus be obtained by attracting foreign firms and investments by refraining from implementing existing environmental laws and regulations, thereby reducing the effect of existing institutions (Long et al, 2013). Moreover, state-owned enterprises often have sizeable political influence over local authorities, which they sometimes use to reduce or even avoid environmental taxes and regulations altogether (Wang et al., 2003; Wang and Jin, 2007; Wang and Weeler, 2003). State-owned enterprises are more likely to be active in heavy manufacturing than light manufacturing (China Statistical Bureau[4]), further enhancing the negative environmental effects of weak implementation of existing institutions.

Environmental institutions in developed countries have become more stringent since the 1990s (Botta and Kozluk, 2014). A notable example of the strengthening of the environmental institutions is the European Union's Emission Trading System (EU ETS), which began its first trading period in 2005. The differences in environmental institutions and their enforcement between China and the developed world are large and were diverging well into the 2000s (Botta and Kozluk, 2014). Weaker environmental institutions have lowered the cost of production in China especially in CO_2-intensive industries such as the metal and chemical industries and given China a competitive advantage in these industries.

Our first hypothesis is:

H1. *Relatively weak environmental institutions, and enforcement, in China compared to developed countries have increased the amount of CO_2 embodied in Chinese exports to these countries.*

2.2 Trade liberalization

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[4] http://www.stats.gov.cn/english/

China pursued a policy of self-sufficiency from the communist revolution in 1949 until the beginning of economic reforms in 1978 (Young, 2000). For example, only 12 state-owned firms were allowed to engage in foreign trade in 1978 (Imbruno, 2016). An open-door policy was initiated in the 1980s, first leading to the creation of a few special economic zones in provinces along the east coast where foreign firms were allowed to trade (Vennemo et al, 2008; Demurger et al, 2002). Trade barriers were drastically reduced in the 1990s, and by the mid-1990s more than 35,000 firms were engaged in foreign trade (Imbruno, 2016). The trade liberalization process culminated with China's entry into the World Trade Organization (WTO) in December 2001 (Vennemo et al, 2008).

Trade volumes obviously increase following trade liberalization. Starting from a low level, the growth in trade is likely to be high initially, especially after China's entry into the WTO, until a new equilibrium has been reached. The rapid growth of imported emissions from China, thus, in part, reflects a transition phase between two equilibriums. The main question is how much of the increased trade and emission levels are linked to trade liberalization polices.

Our second hypothesis is:

H2. *Trade liberalization has increased the volume of trade between China and developed countries and, thus, increased the level of Chinese CO_2 exports.*

2.3 Level of regulation

Efficient allocation of capital and labor enhances the economy's efficiency and, thus, its ability to compete internationally (Levchenko, 2007). Less regulated economies tend to be more productive than highly regulated or state-planned economies; consequently, they engage more in foreign trade (Feenstra et al, 2013), particularly in advanced manufacturing products (Nunn, 2007; Ma et al, 2010).

In terms of CO_2 emissions, market regulations have two conflicting effects. First, fewer regulations increase the efficiency of the economy allowing the country to compete internationally and gain export shares (volume effect). Second, capital and labor is re-allocated when the economy is de-regulated to sectors where the country has a competitive advantage (composition effect). For developed countries this usually means a reduction of the average CO_2 intensity of its exports as the country becomes less dependent on exports of natural resources (Nunn, 2007). The overall effect of regulation levels depends on whether the volume or the composition effect dominates.

From the late 1970s onwards, China has undergone a gradual reform process that has liberated the previously state-planned economy and turned it into a “socialist market economy” (Nee and Opper, 2012). Examples of reforms include financial sector liberalization (Andersson et al, 2016) and labor market de-regulation (Xin, 2012). The previously high levels of state involvement in the economy used to cause economic inefficiencies (Su and He, 2012; Lardy, 2014); for example, greater use of production resources (Talukdar and Meisner, 2001; Wang and Jin, 2007). Over time, these inefficiencies have declined, not least due to the rapidly expanding private sector (Lardy, 2014). The productivity and competitiveness of the Chinese economy has, in other words, increased leading to more exports and more CO_2. However, because China has a competitive advantage in labor intensive products the volume effect is potentially countered by the composition effect as the Chinese economy has re-structured following de-regulations (Vennemot et al, 2008).

Our third hypothesis is:

H3. *Regulatory reforms in China have increased trade volumes and changed the composition of trade between China and developed countries. The effect of these reforms depends on whether the volume or the composition effect dominates.*

2.4 Institutional risk and inefficiencies

Political and economic risks have a negative effect on the economy in general (Acemoglu et al, 2005) and on foreign trade and foreign direct investments in particular (Dunning, 1993; Jadhav, 2012). The free market economy requires a set of institutions to function, such as property rights, contract law, and an independent judiciary. Without such institutions, the risk of government interference in the economy or takeovers of private property increases, which reduces foreign trade (Jadhav, 2012; Nunn and Trefler, 2014). Existing but inefficient institutions can have a similar negative effect on foreign trade as non-existing institutions have on trade (Campos et al, 1999; Wei, 2000).

In the communist era before 1978, institutions to support a free market were naturally lacking. In addition, the government used to rely on directives rather than legislation to implement its policies allowing the government to rapidly change policy (Blecher, 2003). The emergence of free markets and a private sector economy was never part of a directly government sponsored policy (Nee and Opper, 2012). Therefore, the creation of supporting institutions has been slow and full of policy reversals (Blecher, 2003). Constitutional equality between private and state-owned firms was granted in 2004. China's first property rights law, which granted protection against expropriation by the state, was first enacted in 2007 (Nee and Opper, 2012). Most private firms had to operate outside the state's allocation system of capital and labor making it difficult for those firms to operate (Lardy, 2014; Andersson et al, 2016). Institutional risk were in other words high far into the 2000s.

Our fourth hypothesis is:

H4. *Institutional risk in China has declined over time. The level of trade and the amount of CO_2 exported from China has, therefore, increased.*

2.5 Exchange rate policy

China has been accused of manipulating the value of their exchange rate and keeping its value artificially low (Frankel and Wei, 2007) to boost Chinese exports. Estimates of the size of the undervaluation varies, but most studies point towards an undervaluation between 20% (Chang and Shao, 2004; Goldstein and Lardy, 2006) and 50% (Coudert and Couharde, 2007). A change in the exchange rate policy was initiated in 2005, which reduced the undervaluation. But the exchange rate remains undervalued according to most estimates.

Trade increases with an undervalued currency. However, the effect on CO_2 exports is potentially limited. The appreciation of the Renminbi after the change of the exchange rate regime in 2005 was found to mostly affect lighter manufacturing sectors with a lower CO_2 intensity, such as the textile industry compared heavier manufacturing with a higher CO_2 intensity (Eichengreen and Tong, 2015). The reasons behind this result is; i) the textile industry is export dependent to greater extent than heavier manufacturing in China (Thorbecke and Zhang, 2009), and ii) heavier manufacturing is still dominated by directly or indirectly state-owned firms (China Statistical Bureau). These firms are often subject to political interference and are not always profit making. They consequently respondent less to market signals such as changing prices than private firms (Bergsaager and Kerppoo, 2013; Hu et al, 2006; Nee et al, 2007).

Although the exchange rate has a larger effect on lighter manufacturing, the effect on CO2 could still be significant. The lighter manufacturing industry causes emissions indirectly through its consumption of electricity. China’s electricity production is relatively carbon intensive (Su and Tomson, 2016). Changes in lighter manufacturing output thus cause a change in CO_2 emissions through changes in electricity consumption.

Our fifth hypothesis is:

H5. *An undervalued Chinese exchange rate has increased Chinese exports and, therefore, the level of CO_2 embodied in Chinese exports. The effect of the exchange rate is stronger for lighter rather than heavier manufacturing.*

3. Methodology

We test our five hypotheses using a panel data model consisting of 19 developed countries covering the period from 1995 to 2008. Of the 19 countries, 14 belong to the European Union (see Table 1).[5] The choice of countries and time period is dictated by data availability. Emissions data is available for the period 1995 to 2009, but due to the severe effects of the financial crisis on the global economy in 2009 we exclude this year from the analysis. The large decline in output and foreign trade in 2009 could otherwise bias our results.

[TABLE 1]

Our hypotheses are tested against both the total amount of CO_2 embodied in Chinese exports, and against the amount of CO_2 embodied in exports from three CO_2-intensive industries: basic and fabricated metals; other non-metallic minerals; and chemicals and chemical products. These three sectors are also relatively capital intensive compared to other sectors. Based on our hypotheses, we expect a stronger effect of environmental institutions and on these three CO_2-intensive industries rather than on emission imports overall. We expect the effect of environmental institutions to be especially strong for the metal industries, since the Chinese steel industry uses relatively CO_2 inefficient production technologies compared to developed countries (Fan et al, 2016). The trade liberalization effect is expected to be stronger for total emissions than for the three CO_2-intensive industries, since China's comparative

[5] All countries that joined the European Union prior to 1996 were included in the panel except Luxembourg, which was excluded due to lack of data.

advantage lies in labor-intensive not capital-intensive industries. Similarly, the exchange rate effect is expected to be stronger for total emissions than for the three CO_2 and capital-intensive industries due to China's comparative advantage in other industrial sectors.

3.1 Data

The level of carbon emissions embodied in imports from China is estimated using harmonized input-output tables from the World Input-Output Database (WIOD).[6] [7] The input–output tables allow us to estimate the amount of emissions embodied in a country's final consumption and to determine from which country and which industry the emissions originated, having taken the entire value chain into account. Included in the database is 35 industries and 40 countries[8] (for more information see, e.g., Timmer, 2012).

Environmental institutions are measured using the OECD's Environmental Policy Stringency Index, which is a composite index based on a wide set of indicators (see Botta and Kozluk, 2014).[9] By using a composite index, we model the effect of the overall stringency of

[6] The construction of the database was funded by the European Commission, and has been used in several previous studies of CO_2-trade (Arto and Dietzenbacher, 2014), comparative advantage (Brakman and Van Marrewijk, 2016), and the global value chain (Dietzenbacher, et al, 2013; Baldwin and Gonzales, 2015; Los, Timmer and de Vries, 2015).

[7] A detailed description of the data sources for all variables is available in Appendix A.

[8] The database consists of 39 countries. The final entry, the Rest of the World, includes all other countries not directly included in the database.

[9] Previous studies that have used these two indices to study, for example, the effect of environmental institutions on R&D and productivity growth are Milani (2016) and Albrizio et al (2016), respectively.

environmental institutions and not the effect of any one particular institution/policy. The stringency of individual institutions is often highly correlated (Botta and Kozluk, 2014), and it is difficult to distinguish the effects of one particular institution. However, in order to fine-tune the analysis, we split the the OECD Policy Stringency Index into two sub-indices measuring market-based and non-market-based environmental institutions. These two sub-indices are sufficiently uncorrelated to be able to differentiate between their two effects in a regression model.

Specifically, the market-based index is constructed using data on taxes on pollution, such as taxes on CO_2, NO_x, and SO_x, and subsidies for environmentally friendly activities, such as feed in tariffs and premiums for wind and solar power. The non-market-based index is based on command- and control regulations, such as emission limits on NO_X, SO_X, and PM_X. Each index is normalized and takes values between 0 and 6. A higher number implies more stringent environmental institutions. An overview of the variables included in the two indices is shown in Appendix A. A detailed description of the index is available in Botta and Kozluk, (2014).

Hypotheses 2–4 are tested using data from the Economic Freedom Network (Gwartney, Lawson and Hall, 2013).[10] The Network produces five indices, each measuring one specific dimension of institutions (see Appendix B). To test hypothesis 2, we use the index called "Freedom to trade internationally," which measures the level of trade liberalization. To test hypothesis 3, we use two indices: "Regulation" and "Legal system and property rights." These two indices measures the how regulated the economy is, if property rights are protected

[10] Previous studies using the Fraser index to measure economic institutions and model institutional change include Aisen and Veiga (2013), Andersson (2016), and Farhadi, Islam and Moslehi (2015).

and how independent the judicial system is from military and political interference. To test hypothesis 4, two indices are used: "Size of government" and "Sound money." The size of government index measures the level of government spending and taxation, and the sound money index measures the stability of prices and the financial system. All five indices take values between 0 and 10 where a higher number represents less regulated, higher quality, and freer institutions. A detailed description of how they have been constructed is available in Gwartney, Lawson and Hall (2013).

Hypothesis 5 is tested using exchange rate data from the World Development Indicators. This database provides both the actual exchange rate and an estimate of the long-run equilibrium exchange rate. We use the difference between the two to measure the degree of over/undervaluation of a currency. The World Development Indicators is also used to collect data on real GDP growth, which we include as a control variable in the model.

3.2 Econometric model

Our dependent variable is the growth rate in embodied emissions in Chinese exports. We consider in separate regression models the effect of institutions on the total amount of embodied emissions, emission embodied in exports the Chinese metal industry, the Chinese chemical industry and the Chinese other non-metallic mineral industry. Specifically, we model the (log) growth rate in imported emissions from China; that is, $\Delta \ln(C_{it})$, where *i* denotes country and *t* time.

As explanatory variables, we included our institutional variables and real GDP growth. Institutions are modeled as the relative change in the institutional quality in China compared to the institutional quality in its developed trading partner; that is, $\Delta\ln\left(\frac{P_{j,China,t}}{P_{jit}}\right)$ where P is one of the institutional variables. The value of the institutional variables for China is below those of the developed country for all variables and time periods. Over time the distance has become smaller though. A higher value of our relative institutional variables therefore implies that Chinese institutions have become more similar to those in the developed world.

Currency over/undervaluation is measured by how much the exchange rate deviates from the purchasing power parity (PPP) rate. The PPP rate measures the exchange rate that would make the price level equal to that in the United States. An exchange rate higher than the PPP rate implies that prices are higher than in the United States and the currency is thus overvalued. Similarly, an exchange rate lower than the PPP rate implies that the exchange rate is undervalued. Specifically, we use the following variable $\Delta \ln\left(\frac{E_{China,t}/PPP_{China,t}}{E_{i,t}/PPP_{i,t}}\right)$ where E denotes the spot exchange rate and PPP exchange rate. Also, included in the model is GDP growth in the importing country. Higher GDP growth is assumed to increase imports.

Our estimated model is given by:

$$\Delta \ln(C_{it}) = \alpha_0 + \sum_{j=1}^{7}\sum_{l=1}^{4}\beta_{js}\Delta\ln\left(\frac{P_{j,China,t-s}}{P_{j,i,t-s}}\right) + \sum_{n=0}^{4}\alpha_{1n}\Delta\ln\left(\frac{E_{China,t}/PPP_{China,t}}{E_{i,t}/PPP_{i,t}}\right) +$$

$$\sum_{m=0}^{4}\alpha_{2m}\Delta\ln\left(GDP_{jt-m}\right) + \theta_i + f_t + \varepsilon_{it} \quad (1)$$

where θ_i is a country-specific effect controlling for all time-invariant factors that affect trade; for example, geographical distance to China and endowment of natural resources. The fixed time effects, f_t, control for common economic shocks that affect all countries equally; for example, the global business cycle. All explanatory variables are lagged up to 4 years to account for a possibly slow reaction of emission imports and the explanatory variables.

3.3 Descriptive statistics

CO_2 emissions embodied in imports from China are illustrated in Figure 1 for three developed countries: United States, EU14, and Japan. For simplicity, we show the EU14 countries as a entity in the Figure. However, in the estimations, each EU country is treated as a separate cross-sectional unit. Figure 1 illustrates an index that takes the value of 100 in 1995.

Embodied emissions imported by the United States' from China grew by 12% between 1995 and 2001. For the EU14 imported emission grew by 1% during the same time period, while Japanese emission imports fell by 14%. There is a major increase in embodied emission thereafter. The increase equals 128% for the United States, 62% for the EU14, and 191% for Japan between 2001 and 2008. Most of the increase in embodied emission thus took place after China's entry into the WTO. However, the 2001 to 2008 period also includes other important institutional reforms such as the protect property rights, reduced regulation, and a decline in the Chinese state's direct involvement in the economy during the early parts of the 2000s.

[FIGURE 1]

A majority—54%—of the indirectly imported emissions originates from the Chinese electricity, gas and water supply (Table 2). The energy sector is dominated by state- and local-government-owned enterprises, which own 90% of all assets in the industry and 100% of the electricity grid. Political interference in the sector is common, which has led to poor energy efficiency (Su and Thomson, 2016). As expected, a large share of the emissions also originates from the basic metals and fabricated metals sector (13%); other non-metallic minerals (6%); and chemicals and chemical products (7%). The remaining 31 sectors account for 20% of all exported emissions.

[TABLE 2]

The difference in the institutional variables between China and the developed countries has declined during the sample period for all variables, except environmental institutions. China is still lagging behind, though, despite institutional reforms. In percentage, the largest change in the institutional indices for China is in sound money, regulation, and freedom to trade internationally (Table 3). Non-market environmental institutions have not changed at all, while market-based institutions have become slightly more stringent, but remain very lax compared to developed countries.

Among the developed countries, most changes in the institutions were small, except for the environmental institutions. Both market and non-market-based environmental institutions became twice as stringent during the sample period for both the United States and the EU14. The Chinese exchange rate was undervalued, according to our measure, by as much as 68% during the 1990s. Steady appreciation, thereafter, reduced the undervaluation to 43% in 2008.

[TABLE 3]

5. Results and discussion

We begin by estimating the model for total amount of embodied emission. The model includes a large number of parameters (39), which may reduce the accuracy of the results. We therefore begin by testing if all lags of the explanatory variables are significant or if some of the lags can be removed from the regression model. Using statistical tests, we find that time lag 1 and 2 of the institutional variables are never statistically significant. The time lag between institutional change and change in emissions is between 3 and 4 years. For the exchange rate variable and the GDP growth, the effect is simultaneous and the time lags are always insignificant. Therefore, we removed lags 1 and 2 for the institutional variables and lags 1 to 4 for the exchange rate and real GDP growth from the model. The regression results from the reduced model are available in Table 4. The full results are available upon request.

[TABLE 4]

The regression results support three of our five hypotheses. Weak Chinese environmental institutions (non-market-based) have a positive effect on the level of embodied emissions (see Model 1). Chinese trade liberalization policies also positively contribute to the growth in traded emissions. The exchange rate has a negative effect, which shows that an undervalued

Renminbi increases emissions by increasing the competitiveness of Chinese firms compared to firms in other countries. However, during our sample, the Renminbi became less undervalued. Therefore, the appreciation of the currency dampened the growth in embodied emissions rather than causing it to grow even faster. The other two hypotheses—regulatory reforms and institutional risk—are not supported by the results.

Next, we estimate the effect of institutional reforms on the three CO_2-intensive industries; basic and fabricated metals (Model 2), other non-metallic minerals (Model 3), and chemicals and chemical products (Model 4). Environmental institutions, both market and non-market-based, affect embodied emissions originating from the Chinese metal industries but not emissions from the other two sectors. The parameters for market-based environmental institutions are smaller than for non-market-based environmental institutions, which suggest that the non-market-based institutions cause a greater carbon leakage effect than market-based institutions. However, it is important to note that our sample only covers the first trading period of the EU ETS between 2005 and 2007. The time lag of 3–4 years between institutional change and changes imply that the effect of the EU ETS is not fully captured in our analysis.

For the non-metallic metal industry, trade liberalization has a positive effect on emission exports from China, while none of the institutional measures affects chemicals and chemical products. The exchange rate and real GDP growth is insignificant in all three models.

In Model 5, we exclude emissions from the three CO_2-intensive industries and model emissions from all other Chinese industries. Electricity, gas, and water supply account for 73% of these emissions. The regression results are almost identical to the results for total emissions (see Model 1). Our results suggest that the main driver of emission exports is trade liberalization, creating an opportunity to trade with China, which did not exist before.

Coupled with economic growth, this increased overall trade volumes and the emissions embodied in that trade. Our results show that environmental institutions have contributed to increasing the amount of emissions embodied in Chinese exports. However, our results do not suggest that production is allocated to China to allow firms to avoid environmental institutions in developed countries. Instead, our results suggest that Chinese electricity prices are kept low by allowing this sector to emit more or less freely, which, in turn, creates a competitive advantage for all Chinese firms. Therefore, the effect of weak environmental institutions is indirect by lowering the price of energy used in production, rather than direct by allowing firms to pollute more.

The parameter estimates say little about how much each of the significant variables contributed to the growth in emissions. Therefore, we calculated the average contribution of each significant variable to the growth in total emissions during our sample period using the results from Model 1. For simplicity, we calculated the average effect for three countries—the United States, the EU14, and Japan—and not for all the individual countries included in our sample. The results are shown in Table 5.

[TABLE 5]

Embodied emissions have grown by 7% per year on average for both the United States and the EU14, and 2% per year on average for Japan. Trade liberalization explains between 1.4 and 1.6 percentage points of that growth, while the relatively weak environmental institutions in China are between 0.3 and 0.4 percentage points. Combining these two institutional variables explains between 25% and 30% of all growth in the embodied emissions. The appreciation of the Renminbi reduced emission imports from China by between −1.6 and −1.0 percentage points for the United States and the EU14, while the effect was larger in absolute value for Japan (−3.1 percentage points). The single most important factor driving emission growth was not institutional reform but economic growth. The percentage points between 1.9

(Japan) and 4.9 (United States) are explained by income growth; however, the effect of the institutions was certainly not negligible.

6. Conclusions and Policy Implications

The amount of CO_2 embodied in imports from China has grown rapidly since the 1990s. Our results have highlighted the importance of institutional change in explaining this growth. For a long time, China was a closed economy. An increase in trade and, therefore, an indirect increase in embodied emissions were only expected once China opened up to foreign trade. During the analyzed sample period, 1995–2008, approximately 20% of the growth in Chinese emission exports to the United States and the EU14 is explained by trade liberalization. The trade liberalization effect, however, is likely to decline in the future once the world economy has adjusted to the new Chinese open-door policy. According to our results, we can expect a decline of the growth rate in emission exports from China by some 1.5 percentage points once the new equilibrium has been established.

Differences in environmental institutions also contributed to the growth of imported emissions from China, but the effect was moderate. Only about 5% of the total increase emissions are due to relatively weak Chinese environmental institutions. The effect is slightly stronger in the metal industries where China uses relatively CO_2-intensive production methods compared to other countries (Fan et al, 2016). The Chinese industrial sector that contributes most to the emissions is the electricity, gas, and water supply. Reforms that increases efficiency and reduce political interference in this sector will rapidly reduce the level of CO_2 emissions embodied in developed countries' imports from China. A gradual change in policy emphasizing environmental concerns more than before (Lo, 2012; He et al., 2012) indicate that such a change of policy is underway. The OECD environmental stringency index supports the view that there has been a shift in policy emphasis. The non-market-based index has increased from an index number of 0.875 to 2.25 between 2008 and 2012. Even though the gap between developed countries and China is still large (the United States scores an index number of 4.25), it is closing.

Overall, our results suggest that the growth rate in emissions embodied in trade between China and developed countries will decline once the effect of Chinese trade liberalization fades away off. It could even become negative if and when China addresses the CO_2 inefficiency in the electricity gas and water supply sector. Thus, there is no conflict between greater trade with China and efforts to reduce the carbon footprint in developed countries.

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Table 1

Countries included in the study

Australia	Netherlands
Austria	Portugal
Belgium	South Korea
Canada	Spain
Denmark	Sweden
Finland	United Kingdom
France	United States
Germany	
Greece	
Ireland	
Italy	
Japan	

Table 2

Chinese industries from which most of the emissions were imported in 2008 (%)

(1) Electricity, gas, and water supply	54.0
(2) Basic metals and fabricated metals	13.0
(3) Chemicals and chemical products	6.5
(4) Other non-metallic minerals	6.4
(5) Mining and quarrying	3.8
(6) Air transport	1.9
(7) Textile and textile products	1.8
(8) Other industries	12.5

Table 3
Descriptive statistics of the policy indices

	1995	2002	2008	1995	2002	2008
	OECD environmental policy stringency index					
	Market			Non-market		
China	.083	.083	.167	.875	.875	.875
EU14	.867	1.186	1.689	1.533	2.100	3.217
United States	.583	.583	1.183	1.625	1.625	3.125
Japan	1.000	.917	.883	1.625	1.875	2.500
	Fraser index					
	Freedom to trade internationally			Regulation		
China	5.88	6.69	6.84	4.69	5.49	6.17
EU14	9.01	8.87	8.14	6.38	7.12	6.97
United States	8.83	8.46	8.21	8.29	8.57	8.19
Japan	7.82	7.99	7.26	6.73	7.32	7.70
	Legal system and property rights			Size of government		
China	5.49	5.23	5.94	4.02	3.31	3.28
EU14	8.33	8.11	8.12	4.12	4.87	5.03
United States	8.76	8.17	7.38	6.88	7.05	6.88
Japan	4.95	5.51	6.07	4.95	5.51	6.07
	Sound money					
China	5.77	8.22	8.13			
EU14	9.47	9.61	9.49			
United States	9.76	9.80	9.69			
Japan	9.72	9.43	9.77			

Note: EU14 includes all EU countries that joined the Union before 1996 except Luxembourg.

Table 4
Regression results

Variable	Time lag	All imported emissions from China	Basic and fabricated metals	Other non-metallic metal	Chemicals and chemical products	Other imported emissions
		M1	M2	M3	M4	M5
Market EP	t-3	.01 (.02)	.01 (.02)	-.02 (.04)	.03 (.03)	.00 (.02)
	t-4	.01 (0.01)	**-.10***** **(.04)**	.00 (.04)	.01 (.03)	.01 (.01)
Non-market EP	t-3	**-.07***** **(.02)**	**-.14**** **(.06)**	.02 (.06)	.03 (.05)	**-.07***** **(.02)**
	t-4	.01 (.02)	**-.15**** **(.06)**	-.02 (.06)	-.01 (.05)	.01 (.03)
Freedom to trade internationally	t-3	.18 (.25)	1.13 (.96)	**1.43**** (.72)	.54 (.61)	.19 (.26)
	t-4	**.86***** **(.25)**	-.76 (1.00)	-.38 (.89)	-.52 (.75)	**.83***** **(.27)**
Regulation	t-3	.06 (.15)	.51 (.44)	-.26 (.43)	.12 (.36)	.09 (.16)
	t-4	.02 (.17)	.01 (.44)	-.15 (.45)	.17 (.38)	-.05 (.18)
Size of government	t-3	-.04 (.15)	-.28 (.30)	.28 (.28)	.26 (.23)	-.03 (.17)
	t-4	.09 (.09)	.35 (.35)	.17 (.28)	-.06 (.24)	-.04 (.15)
Legal system and property rights	t-3	.09 (.09)	-.20 (.37)	.45 (.33)	-.30 (.27)	.06 (.10)
	t-4	.19 (.20)	-.10 (.50)	.06 (.38)	.11 (.32)	.17 (.22)
Sound money	t-3	-.03 (.21)	-.70 (.80)	-.86 (.81)	-.40 (.68)	-.04 (.23)
	t-4	-.09 (.34)	.16 (.78)	.84 (.79)	.05 (.66)	-.11 (.35)
GDP growth	t	**1.63***** **(.38)**	.58 (.69)	-.71 (.66)	.07 (.55)	**1.62***** **(.40)**
Exchange rate	t	**-0.48***** **(0.08)**	-.27 (.20)	-.33 (.21)	-.05 (.17)	**-.49***** **(.08)**
constant		-.01 (.03)	.08 (.06)	.11* (.07)	.08 (.06)	-.01 (.03)
Fixed country effects		Y	Y	Y	Y	Y
Fixed time effects		Y	Y	Y	Y	Y
Adjusted R2		.791	.451	.409	.473	.765
Schwarz information criteria		-1.747	-.140	-.040	-.374	-1.597
Durbin-Watson		2.040	1.923	2.051	2.452	2.095
Jarque-Berra		0.123	5.868*	4.517	4.993*	.043

Note: ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. Parameter significance at the 5% significance level is highlighted in bold.

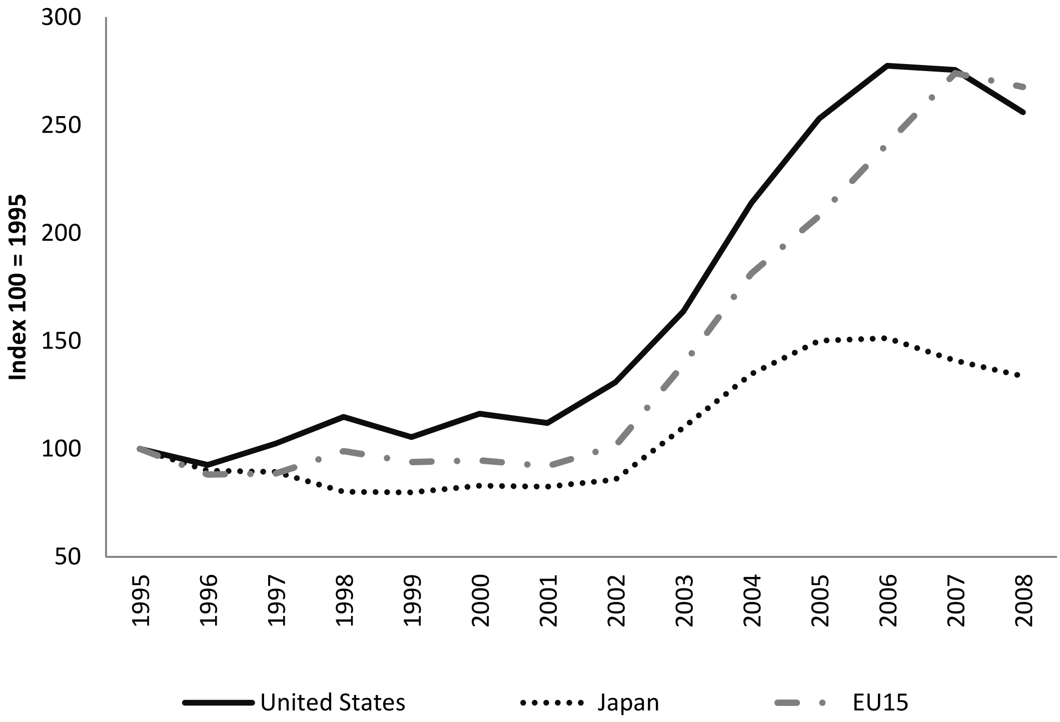
Table 5

Decomposed growth rates of emission imports. Average per year (%)

	Environmental policy (1)	Trade liberalization (2)	GDP growth (3)	Exchange rate (4)	Unexplained (5)	Total (6)
EU14	0.4	1.6	3.4	-1.0	3.0	7.3
USA	0.3	1.4	4.9	-1.6	1.9	6.9
Japan	0.2	1.4	1.9	-3.1	1.8	2.1

Note: Summing the values in columns 1 to 5 gives the total growth rate shown in column 6.

Fig 1. Imported emissions from China, 1995–2008. (Index 100 = 1995).



Appendix A. Variable description and data sources

Variable	Data source
(1) Imported emissions	World Input-output database. Genty (2012); Timmer (2012) http://www.wiod.org/new_site/home.htm
(2) OECD environmental policy stringency index	Botta (2014) https://stats.oecd.org/Index.aspx?DataSetCode=EPS
(3) Fraser index of economic freedom	Gwartney et al (2015) http://www.freetheworld.com/
(4) Real GDP growth	World development indicators http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators
(5) Exchange rate and PPP exchange rate	World development indicators http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators

Appendix B. Description of the policy indices

Fraser index	
Freedom to trade internationally	i) tariffs; ii) regulatory trade barriers; iii) black market exchange rates; and iv) controls of movements of capital and people
Regulation	i) credit market regulations; ii) labor market regulations; and iii) business regulations
Size of government	i) size of government spending, transfers, and investments; and ii) top marginal tax rate
Legal system and property rights	i) judicial independence; ii) impartial courts; iii) protection of property rights; iv) military influence in politics; v) integrity of legal system; vi) legal enforcement of contracts; vii) regulatory costs; viii) reliability of the police; and ix) business costs of crime
Sound money	i) money growth; ii) standard deviation of inflation; iii) inflation rate; and iv) freedom to own foreign currency bank accounts
OECD environmental policy stringency	
Market based	i) taxes and charges directly applied to the pollution source; ii) taxes and charges applied on input or output of a production process; iii) subsidy for environmentally friendly activities; and v) deposit-refund systems
Non-market based	Command- and control regulations

Source: Gwartney et al, (2015); Botta and Kozluk (2014).