Service Sector Liberalization and Firms' Carbon Emission Intensity Reduction: Evidence from China

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Abstract

This paper investigates the impact of service sector liberalization on downstream manufacturing firms' carbon emission intensity reduction in China. We quantify China's service sector liberalization through its policy changes towards foreign direct investment (FDI), and build a composite index of manufacturing firms' exposure to service sector liberalization through the inter-industry economic linkages. We find that service sector liberalization significantly reduces downstream manufacturing firms' carbon emission intensity. Our results are robust with alternative measures of emission intensity reduction, service liberalization, and after correcting endogeneity. We also find that firms' productivity enhances service liberalization's impact on the reduction. Further, firms' carbon emission reduction response to service sector liberalization is heterogeneous: the impact is 157% larger for large firms than for small- and medium-sized firms, 89% larger for SOEs than for non-SOEs, and 110% larger for firms operating in pollution heavy industries than those in other industries.

Keywords: Services liberalization; CO_2 Emission Reduction

1. Introduction

This paper studies the effects of China's service sector liberalization on its manufacturing firms' carbon emission intensity, defined as carbon emission per unit of output, using a sample of industrial firms from 1998 to 2006. The study is motivated by the transformative liberalization policies for China's service sectors, the increasing usage of service products in manufacturing firms' production process, and government's growing emphasis on green development to curb carbon emission. Protecting the environment gradually appeared on top of China's policy agenda during the 1990s and early 2000s, after China enjoyed two decades of continuous fast economic growth to meet the basic needs of its large population with relatively loose environmental measures when coal and fossil primarily fueled its economic miracles. Chinese government's embrace of green-development strategy to tackle pollution was a policy response to its citizen's desire for clean air consistent with their increased living standard and life quality. Reducing carbon emissions from the manufacturing sector has been a top policy focus, as a large percentage of China's carbon emissions comes from its manufacturing sector (36% in 2019, for instance), despite the remarkable progress made—China's carbon emission per unit of GDP fell by 40% from 2001 to 2020 (International Energy Agency, 2022).[1]

This paper contributes to the discussion by examining how service liberalization reduces manufacturing firms' carbon emission intensity through the inter-industry economic linkages. The core argument here is twofold. The first, and most fundamental, point is that producing service products is generally less polluting than producing manufacturing goods. As such, when manufacturing firms substitute more-polluting industrial inputs with less-polluting service products in their production process, their carbon emission intensity reduces. The second point is how manufacturing firms can benefit from the dynamics of service sector liberalization. Liberalization measures leads to intensified competition, competition leads to innovation, and innovation in turn leads to firms producing more varieties of high-quality and low-cost service products to woo customers. Continuous service sector liberalization provides ongoing steady stream of high-quality products with declining prices. Through the inter-industry economic linkages, the fruits of service sector liberalization will be felt by downstream manufacturing firms, which, in this case, is examined by the reduction in their carbon emission intensity.

China's liberalization of its service sector has been comprehensive and transformative, though at times gradual, starting from a near total control by state-owned and collectively-owned enterprises in the late 1970s. Among the various policy measures, the progressive liberalization can be summarized with two big components: initially allowing private capital to enter service sectors, and then opening up to foreign direct investment (FDI). Service liberalization, just as liberalization in any other industries in China, has made service industries very competitive: new varieties of good-quality products with low price pop up frequently, a phenomenon found in many other studies (Correa-López and Doménech, 2019; Arnold et al., 2011). Today, most service sectors in China are

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[1] Authors' own calculations based on data from carbon accounts and datasets. All industries emitted about 9,795 million tons of CO_2, with 3,526 million tons from manufacturing industries.

highly competitive with firms of all forms of ownership (state-owed, private-owned or foreign-controlled) operating side by side, competing and serving customers with innovative methods and best products.[2]

While the impact of service sector liberalization on manufacturing firms is through inter-industry economic linkages, the mechanism can be differentiated as direct and indirect, both of which is discussed briefly here (in great length in the next section). The direct effect is through substitution: substituting more-polluting manufacturing inputs with less-polluting service products as intermediate inputs. Clearly, the more the substitution, the larger the carbon intensity reduction effects, which is a process called input servitization. The indirect effects are through spillovers attributed to firms' productivity gains (arising from service products' high-quality) and firms' increased ability to invest more on green tech technologies (arising from savings in purchasing low-cost service products), both of which are not captured by monetary transactions.

We quantify service sector liberalization during the sample period based on China's policy changes towards foreign direct investment (FDI). China's policy objective towards FDI has always been multifaceted: attracting foreign capital and technology to contribute to its economic development, while preventing huge worker layoffs (unemployment) and simultaneously building up domestic capacity for sustainable growth. The central government's policy decisions of when an industry is made open to FDI, and on the threshold of maximum foreign equity in their affiliates across different industries are a direct result of that objective. The general consensus is that once an industry is open to FDI, the resulting competition is going to be intensifying. The larger foreign equity shares are allowed in foreign affiliates, the more intense the competition in that industry. It is thus logical and fitting to argue that China's FDI policy serves as a barometer for the development level of its domestic firms and the degree of liberalization. Our sample period, 1998 to 2006, witnessed China's heightened negotiations especially on its degree of openness to FDI to join the World Trade Organization (WTO) and its fast-paced efforts to fulfill its commitment to be more open to FDI once being a member of the WTO since 2001. It saw large increase of FDI's presence—in 1998, the share of GDP from foreign affiliates was 18%, and by 2006, it had risen to 31% (Enright, 2016, pp.53). Based on China's FDI frequent policy changes in the 1998-2006 period, we develop a time-series index for each service sector to quantify its liberalization.

We capture manufacturing firms' exposure to service sector liberalization by building a composite index, constructed as the weighted average of each service sector's liberalization with weights being their respective input shares in manufacturing firms. By design, manufacturing firms' exposure reflects both the extent of service sector liberalization and their usage of service products as intermediate inputs.

Our study builds on two strands of the literature: the impact of service sector liberalization on manufacturing firms and factors affecting firms' carbon emission. Numerous studies have shown

[2] On January 2, 2021, the Economist published an article, "Why Retailers Everyone Should Look to China", summarizes the innovations and creativeness of the market and the competition among giants.

that service sector liberalization generates tremendous effects to downstream manufacturing industries through the input-output economic linkages, including on productivity (Arnold et al., 2011, 2016; Beverelli, et al., 2017) and better export performance (Bas, 2014; Bai, et al., 2022; Lee, 2019), among many other aspects. Our focus on firms' carbon emission intensity is a nice addition. Regarding factors affecting firms' carbon emission, scholars have identified several, including technological progress (Acemoglu et al., 2012), energy structure (Moutinho et al., 2014), financial development (Shahbaz et al., 2018), trade portfolio (Zhang and Zhang, 2018), export performance (Richter and Schiersch, 2017) and FDI (Wang, et al., 2021). Our work makes a novel contribution to the topic by focusing on service sector liberalization.

We find that service sector liberalization significantly reduces downstream manufacturing firms' CO_2 emission intensity. Our results are robust with alternative measures of emission reduction, with different measures of service liberalization, and with endogeneity correction. The effects of service liberalization increase with firms' productivity. In addition, firms' responses are heterogeneous: larger firms experience more reduction in carbon emission intensity than small and medium-sized firms; state-owned firms and firms operating in pollution heavy industries experience larger reduction in carbon emission reduction than others.

The remainder of the paper is structured as follows. Section 2 discusses service sector liberalization, Section 3 describes the main variables and the empirical strategy, Section 4 presents the main results, Section 5 conducts additional analyses, and Section 6 concludes.

2. China's Service Sector Liberalization and the Effects on Manufacturing Firms

China's service sectors have gone through a real transformation, which is actually similar as what its manufacturing sectors have, albeit with an initially slower pace. Its policies towards FDI have been dynamic and evolving, reflecting its changing development priorities. In 1979, when the Chinese government enacted its first piece of law on FDI—the *Law of the People's Republic of China upon Sino-Foreign Joint Ventures*, FDI was only allowed to form joint ventures with their Chinese counterparts, but only as minority equity shareholders (no more than 49%). Several years later in 1986, China enacted the *Law of the People's Republic of China upon Sino-Foreign Cooperative Enterprises*, and in 1988, the *Law of the People's Republic of China upon Foreign Wholly Owned Enterprises*. During China's intensive negotiations with the world's major economies to shore up its bid to join the WTO, further opening up its industries to FDI was a major policy step. In 1995, China promulgated the "*Foreign Investment Industrial Guidance Catalog*" (the *Catalog*). The *Catalog* serves as the overarching directory and guideline for FDI to invest in China with Chinese Industry Clarification (CIC) approximately at the detailed 4-digit level, which includes 332 service industries and 424 manufacturing industries. The *Catalog* groups industries in four categories as the *Permitted*, *Encouraged*, *Restricted*, and *Prohibited*, with different policies in each category towards FDI. The *Permitted* is the default group including all other industries not explicitly listed under one of the other three groups. In summary, the *Encouraged* category includes high-tech industries and industries which are deemed to need enhancing their competitiveness. The *Restricted* category includes industries which are deemed to be technologically behind the world's major competitors, or have severe implications for the environment. The pace towards FDI is gradual and slow. The *Prohibited* industries are those that are not open to FDI at all. The scope of foreign affiliates in each category is also different. The scope is subject to the standard business approval process for foreign affiliates in the *Permitted* category and *Encouraged* category, and foreign affiliates are able to expand their business scope even after receiving the approval. In the *Restricted* category, foreign investors are required to explicitly define their business operation timeline, and the approval process involves a higher administrative level.

The list of industries in each category in the *Catalog* reflects the government's vision and delicate balance to attract foreign capital for development, confidence in domestic firms' ability to learn from and to compete with foreign affiliates, and the protection believed to be necessary for certain industries to shield them from foreign competitions. China revises the *Catalog* typically every 3 to 5 years. Revision to the *Catalog* not only reflects Chinese government's changing policies for FDI, but also serves as a barometer for the extent of liberalization and the development level of its domestic firms in those industries. That is why some observers view the *Catalog* as an instrument of China's industrial policy (Ross and Zhou, 2012). During the heightened negotiations for China's seemingly impending accession to the WTO, China promulgated a revision to the *Catalog* in 1997 to make industries generally more open to FDI. Upon China's WTO accession in 2001, there was a revision in 2002 and then again in 2004. Each subsequent revision is generally more welcoming to FDI, indicating increased liberalization. These revisions are also the necessary moves to fulfill China's WTO commitment to gradually liberate its service industries highlighted in *The Schedule for Specific Commitments in Service of the People's Republic of China* (the *Schedule*), which contains specific timelines for service industries to be open to FDI post the WTO accession. Movement of an industry from one category to another clearly indicates a policy change towards FDI. For instance, if an industry is in the "*Prohibited*" in 1997, but is under the "*Restricted*" in 2002, it signals that FDI can at least start investing in the industry, a big liberalization step.

Through series of liberalizing policies to FDI, China's service sectors have become very competitive, with frequent unveiling of new high-quality and low-price services such as China's e-commerce industry, the most innovative and competitive in the world. Producing service products are generally less polluting than that for industrial ones, and accordingly, the increased usage of service products in downstream manufacturing industries would mitigate their pollution emission intensities. The mechanism is both direct and indirect. The direct channel is straightforward: when firms substitute manufacturing inputs with less-polluting service products in their production, they release less carbon emissions into the air. In addition, increased usage of service inputs also reduces firms' negative externalities of production on the ecosystem (Reiskin et al., 1999). Further, when manufacturing firms outsource their in-house customer service to upstream professional service firms, it will also contribute to carbon intensity reduction, as professional service firms are generally more efficient in utilizing resources (Arnold et al., 2011).

The indirect mechanism of input servitization on firms' carbon emission reduction is through spillovers attributed to firms' productivity gains arising from service inputs' high-quality, and the increased ability to invest more on green tech technologies arising from cost-saving service inputs' low-price, both of which are not captured in monetary transactions in purchasing service products. On spillovers related with productivity gains, examples include firms' enhanced resource utilization rate, increased product performance, and fast technological progress, any one of which could contribute to reduction in carbon emission (intensity) (Moutinho et al., 2014; Su and Ang, 2015; Chen et al., 2017; Huang et al., 2022; Zhao and Chen, 2021; Shapiro and Walker, 2018; Huang et al., 2019). The spillover effects can also be realized through firms' access to the knowledge embedded in service products, which become a part of firms' knowledge accumulation through reverse engineering. Knowledge accumulation generates positive impact on firms' motivation to conduct more innovations (Bas and Strauss-Kahn, 2015). And when innovations are applied in the production process, they would further enhance firms' production process efficiency, leading to more reduction in carbon emission (intensity).

On spillovers arising from firms' cost reduction due to the increasing usage of low-price service inputs, the mechanism is through enhanced financial ability. Cost saving allows firms to invest more on renewable energy and gives them additional ability to pursue more energy efficient innovative projects (Clarkson et al., 2011; Alam et al., 2022). And it is indeed the case that firms likely invest on environmetal protection and ernegy efficiency (Bourlès et al., 2013; Fernandes and Paunov, 2012; Alessandri and Pattit, 2014), with more cash at hand.

3. The Main Variables

Our main variables include firm-level and industry-level controls, together with a slew of fixed effects, to be discussed below.

3.1. Measuring Manufacturing Firms' Exposure to Service Sector Liberalization

Measuring manufacturing firms' exposure to service sector liberalization takes two steps: quantifying service sector liberalization (SSL) and building a *composite service liberalization index* (*CSLI*) to capture firms' exposure to SSL. CSLI is constructed as the weighted average of service industries' liberalization index (SSL), with weights being their respective shares in firms' intermediate inputs, commonly referred to the input-output table, π.

For the input-output table, ideally, we would prefer to use firm-level input ratio from each service industry, but no statistical agency collects this fine level of data. In China, we can get access to industry-province level input-output table. Using it assumes that firms operating in the same industry-province follow the same input ratios in sourcing their intermediate inputs, which itself is a strong assumption but a standard practice in the literature, due to common data limitations.[3] The industry-province input-output table is roughly at CIC 2-digit level, with 13 service sectors, and is only available for year 2002, the middle of the sample period. While using them takes away the dynamic changes in input-output tables during the sample period (the process of input servitization),

[3] See, for instance, Wang (2010) in its measurement of industries' exposure to FDI through inter-industry linkages.

it brings one tremendous benefit: it conveniently avoids firms' endogenous choice by increasing their service inputs from year to year in econometric analysis. Year 2002 is the middle year, which can be viewed as the average input-output ratios for each industry-province pair during the sample period. Variations in π across provinces reflect their respective extents of input servitization.

To quantify service sector liberalization, we assign a numerical value between -1 and 0 for each service industry based on the maximum foreign equity shares allowed in foreign affiliates operating in that industry. The more restriction foreign investors face, the lower the assigned value, and the less liberalization for the industries. We assign a value to each of the 332 service industries in the *Catalog*, combined with information obtained from the *Schedule* which also specifies the upper bound of foreign equity shares allowed together with open to FDI timeline. Essentially, we code a value of -1 for the *Prohibited* industries, -0.75 for the *Restricted* industries, and -0.50 for the *Permitted* industries. For the *Encouraged* industries, we code a value of -0.25 if foreign equity shares are not allowed to reach 100%, and a value of 0 if they can be 100% (i.e., wholly foreign owned). This coding mechanism is similar in spirit to the construction of OECD's FDI Regulatory Restrictiveness Index (Kalinova et al., 2010).

During the sample period between 1998 and 2006, we obtain three sets of values for service industries based on the revisions to the *Catalog* in 1997, 2002 and 2004. If an industry's opening status to FDI remains the same between any two consecutive revisions, its coded values don't change. To be consistent with the industry classification used in provincial input-output table, we aggregate service industries from the CIC 4-digit (332 service industries) to 2-digit (13 service sectors). We thus obtain three sets of service sector liberalization indices for the 13 industries for years 1997, 2002 and 2004 respectively, which are our measurement for *SSL*. For the years between any two *Catalog* revisions, SSL takes on the values based on the previous version of the *Catalog*. As such, for each service sector, SSL in years 1998, 1999 and 2001 takes on the value based on the 1997 *Catalog*, years 2002 and 2003 on the 2002 *Catalog*, and years 2004, 2005 and 2006 on the 2004 *Catalog*. Table 1 lists the values for SSL for each of the 13 service sectors for years 1998, 2002 and 2004 respectively.

A few observations are worth discussing. First, there are wide variations across the 13 service sectors. It is also notable that the vast majority of the SSL indices can't be divided evenly by .25, precisely due to the aggregation from CIC 4-digit to 2-digit level. Second, every service sector became more open to FDI from 1998 to 2004: among which 11 had consecutive liberalization from 1998 to 2002, and then from 2002 to 2004, and 2 (Transportation and Warehousing; Wholesale and Retail) initially went for more stringent regulations from 1998 to 2002, but then went with large liberalization from 2002 to 2004. Third, the liberalization pace (the difference of SSL between 1998 and 2004 for each sector) is not uniform across sectors. In particular, the pace is very fast for sectors including Leasing and Business Services, with the index being from -.50 in 1997 to -.30 in 2002 for Leasing and Business Service sector. The between and within variations illustrate the extent of service liberalizations across industries, a reflection of China's staged openness to FDI.

With *SSL* and π, we now construct *CSLI*—manufacturing firms' exposure to service industry liberalization—as the following:

$$CSLI_{jpt} = \sum_s SSL_{spt} \times \pi_{sjp} \tag{1}$$

Where notations j, p, s and t indicate respectively manufacturing industry, province, service sector and year. *SSL* is service sector liberalization index, which is time variant and π is the input ratio of service industry s in manufacturing industry j and province p, which is time-invariant. As such, the magnitude of *CSLI* depends on the degree of service sector literalization, *SSL*, and the input shares by the downstream manufacturing industries, π.[4] For each j-p pair, variations in $CSLI$ across years solely come from variations in *SSL*. For each province p, variations from 1998 to 2006 in *CSLI* come from changes in service sector liberalization (*SSL*) and the variations of the input-output table, π, across provinces.

Figure 1 plots the average values of *CSLI* for each province across all industries in 1998 against those in 2006. We discuss three observations. First, there are large variations across provinces, which implies the large variations in π. Second, increase in service liberalization is apparent in all the provinces—all the dots lie below the 45-degree line. The further away below the 45-degree line, the larger the increase in service liberalization. As such, the change is the largest for Qinghai (the lower far left corner). Third, the locations of the provinces in the graph indicates their different extent in service inputs usage—the further away from the origin, the larger the provinces' input servitization. Among them, Hainan province stands out in the far right, while Xinjiang and Fujian are clustered in the far-left corner.

3.2. Firm-level Variables

Our dependent variable and a few controls are constructed at the firm-level. We merge the Annual Industrial Firm Survey (the *Survey*) with the Industrial Firms' Pollutant Discharge Database (the *Pollutant Database*). Firms in the *Survey* include all state-owned enterprises and other ownership types if their annual revenue is above RMB 5 million. The *Survey* includes data on firms' balance sheet and operations. The *Pollutant Database* is the most comprehensive in China and is widely used by researchers on firm-level environmental issues (Tang et al., 2021; Wu et al., 2022; Lin and Xu, 2022). Below, we discuss the variables in turn.

ln (*CO_2/Output*): this is the dependent variable, measured as the natural log of firms' total CO_2 emissions per unit of output—CO_2 emission intensity. To calculate firms' total CO_2 emissions, we use two pieces of information: firms' fossil fuel consumption extracted from the *Pollutant Database*, times their respective CO_2 emission factors, extracted from the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) and China's Energy Statistics Yearbook.[5] This is a common method adopted by researchers, see for instance, Jaraite-Kažukauske and Di Maria (2016) and Richter and Schiersch (2017). The carbon emission factor for natural gas is 1.996 Kg

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[4] This composite measure at the industry level is commonly used in the FDI literature when measuring upstream or downstream industries' effects (Arnold et al., 2011, 2016; Bas, 2014; Beverelli et al., 2017; Wang, 2010, 2013).

[5] The Greenhouse Gas Protocol (2001) grouped firms' carbon emissions in three scopes. Scope One is firms' direct carbon emission arising from fuels owned or controlled by the firm. Scope Two is firms' indirect carbon emission arising from firms' purchasing of external resources. Scope Three is all other indirect carbon emissions not accounted for. Here, our calculation is based on Scope One.

CO_2/Kg, for coal 1.978 Kg CO_2/Kg, for crude oil 3.237 Kg CO_2/Kg, and for diesel 3.161 Kg CO_2/Kg. For each firm-year, we calculate its CO_2 emission intensity by dividing its total CO_2 emission by output, taken from the *Survey*. The clear advantage of using emission intensity is that it factors in firm size, since larger firms tend to emit more pollutants (in levels), despite generally being more efficient in energy use, due to their large base. In the regression, we exclude any firm-level observations with non-positive CO_2 emissions.

Firms' CO_2 emission intensity exhibits a downward trend from 1998 to 2006. Figure 2 plots the average for firms in the five most carbon emission intensive industries respectively for years 1998, 2002 and 2006.[6] The graph shows that, the immediate expansionary stage of China's industrial sectors after joining the WTO in 2001 led to a temporary increase in their carbon emission intensities. Gradually, their carbon emission intensity started to see reductions.

Firm-level controls include firms' size (the natural log of its total assets), age (the natural log of its years in business), leverage ratio (total debts divided by total assets), subsidy status (indicator: receiving government subsidy—1 versus no—0), and profit rate (total profits divided by total sales). We expect that firms which are larger, older, with lower leverage ratio and higher profit rate tend to be in better position to introduce carbon-reduction measures than others.

3.3. Other Controls

Two core industry level characteristics are included to control industry heterogeneity—industry size and Herfindahl-Hirschman Index (HHI). The former is to control the industry size effects on firms' carbon emission, and the latter industry's competition structure. Table 2 documents the descriptive statistics for the major variables.

In addition, we include province-, industry- and year-fixed effects in the regressions. Province fixed effects are to control provincial variations (assumed to be fixed during the sample period). China's top-down policy-led uneven development across provinces during the sample period is well-documented, which would generate impacts on firms' mindset regarding environmental protection. In addition, provinces had discretion in implementing central-government economic policies and initiatives (Bao et al., 2019), which would exert different impacts on firms' incentives to curb carbon emission.

Industry fixed effects are to control industry heterogeneity which are not captured by size and HHI. For instance, during the sample period, although every industry witnessed large expansion (captured by size), some industries were given more favorable policies for faster developments by the central government which affected their incentives to be more environmentally friendly.

Year fixed effects are to control the ongoing and fast-changing policy environments in China during the sample period. Each year witnessed implementations of new economic policies,

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[6] They are: non-metallic mineral products, chemicals, textile industry, metal smelting and rolling processing and petroleum processing and coking. They are the top five manufacturing sectors with the highest carbon emissions in 2006 based on data from the Carbon Emission Accounts and Datasets.

enactments of new environmental regulations and openings of new railroad lines, whose impact on firm carbon emission intensity can be controlled using year fixed effects.

3.4. The Estimation Strategy

The main estimation equation is the following:

$$\ln(CO_2/\text{Output})_{ijpt} = \alpha + \beta CSLI_{jpt} + \gamma X'_{ijt} + \delta Z'_{jt} + \varphi_p + \varphi_j + \varphi_t + \varepsilon_{ijpt} \qquad (2)$$

$CO_2/Output_{ijpt}$ is CO_2 emission intensity for firm i in manufacturing industry j and province p and year t. $CSLI_{jpt}$ denotes the composite service liberalization index in manufacturing industry j and province p in year t. X'_{ijpt} is a vector of firm-level controls and Z'_{jt} are industry-level controls. φ_p, φ_j and φ_t indicate province, industry, and year fixed effects respectively.

In the regressions, we cluster the standard errors by industry-province pairs since firms operating in the same province-industry *p-j* pair have the same exposure to *CSLI*. Coefficient β is the core interest. Below, we turn to the main regression results.

4. The Main Results

We start with the baseline results and then proceed with controlling endogeneity and using alternative measures for firms' pollution intensity and for service sector liberalization.

4.1. The Baseline Results

Table 3 documents the baseline results. The 1st column leaves out industry-level controls and the 2nd column with them. Regardless, year-, industry- and province-fixed effected are always included. Comparing the results in Column (1) with those in Column (2) yields no big differences. We now explain the major results presented in Column (2).

The coefficient on *CSLI* is statistically different from zero at the 1% level, which means that service sector liberalization generates significant impact on downstream firms' CO_2 emission intensity through the inter-industry economic linkages. The coefficient of -2.265 implies that, on average, when regulations on upstream service sectors loose by 0.1 unit, firms' carbon emission intensity would decrease by approximately 22.65% (=0.1*2.265*100%). Given the construction of *CSLI*, two conclusions can be referred. *Ceteris paribus*, if, across the board, firms increase their service input ratios by 10%, the resulting carbon emission intensity reduction is about 22.65%. Similarly, if openness towards FDI for all service industries relax by one tier (the coded value increase by 0.25) across the board, it leads to 56.63% reduction in downstream manufacturing firms' carbon emission intensity. During the sample period, the average value of *SSL* for the 13 service sectors increases by about .12 unit (from -0.57 in 1998 to -0.45 in 2006), which translates into 27.18% reduction in downstream firms' carbon emission intensity.

Regarding firm-level controls, the results are mostly as expected. Increases in firm size, experience (age) and profitability all significantly reduce their carbon emission intensity. Receiving government subsidy also significantly reduces firms' carbon emission intensity. Firms' leverage ratio does not seem to matter. The results are largely in line with those reported in the previous literature (Alam, Safiullah and Islam, 2022; Richter and Schiersch, 2017; Yu et al., 2021). Larger firms generally have more resources to devote to emission reduction measures; more experienced firms (age) seem to be better in emission intensity reduction. Higher profitability likely indicates more investment on emission reduction.

At the industry level, expansion of industry increases firms' CO_2 emission intensity, but market concentration (the HHI index) decreases it. The seemingly at odds results reflect the specific period of China's fast development. When an industry expands, especially when it happens during the high-growth period to meet people's basic needs, news firms, especially these small and medium sized ones, enter the industry which typically do not have a high environmental standard. Competition among all firms, big or small, for market share dilutes the pressure on carbon emission intensity. However, when an industry is more concentrated (increases in HHI index), it provides an opportunity for governments to exert pressure on them regarding environment protection, which, under peer pressure, might lead to all firms adopt similar measures, resulting carbon emission intensity reduction for all firms.

4.2 Robustness Analyses

This subsection conducts a few robustness analyses which either lend support to our main results, or offer additional evidences. We discuss each in turn.

4.2.1 Is Endogeneity a Concern?

In the study, $CSLI$ is an aggregate measure at the province-industry level, and the dependent variable, CO_2 emissions intensity, is at the firm level. Within this setting, firms tend to view industry-level service sector liberalization as exogeneous. Further, using constant input-output table (π) to build *CSLI* eliminates firms' endogenous decision to use more service inputs in the first place. Having said this, a weak argument could still be made that firms which are more conscious on carbon emission would exert influences on governments to further liberalize service industries. However, we suspect that these firm-level efforts would not make a big difference during the sample period—a period where the central government's economic policies were generally top-down in their push to join the WTO, and in their efforts to fulfill China's commitment post the WTO accession. Nonetheless, we resort to a formal approach involving instrumental variables (IVs) to control the potential endogeneity impact.

The chosen IV has to meet two conditions: correlated with China's service industry liberalization but uncorrelated with Chinese firms' carbon emissions. To that end, we choose the FDI Regulatory Restrictiveness Index for India's service sectors compiled by the OECD. India and

China, two of the largest and neighboring developing countries in similar development stages in the 1980s, have been studied extensively by researchers to compare their economic development trajectories and potentials (Bosworth et al., 2008; Arnold et al., 2016). In particular, in the quest for FDI, China and India are often viewed as competitors. Their respective policies toward FDI might reflect the competition. In that regard, it could be reasonable to assume that China's policies to attract FDI could be influenced by India's to some degree. However, there can be hardly any plausible argument to link India's FDI restrictiveness with Chinese firms' carbon emission intensity.

Note that the range for OECD's regulatory restrictiveness index is different from ours. To make it more compatible, we first re-scale India's to the range of -1 and 0. We then use the industry-province input-output, π, to calculate new series of $CSLI$, indicated as *CSLI-India*. In the first stage, we use *CSLI-India* to explain *CSLI* (the original one), reported in column (1) in Table 4. In the second stage, we use the predicted values from stage one, $\widehat{CSLI}$, to explain firms' carbon emission intensity, results reported in Column (2).

The coefficient on *CSLI-India* is positive and significant at the 1% level, implying that one unit change in *CSLI-India* leads to .96 unit change in China's *CSLI*. In Column (2), we also conduct tests for the validity of the IV. The Anderson-Rubin Wald test is to assess the validity of the IV, and the test statistics rejects the null hypothesis of implausible instrumental variable (Anderson and Rubin, 1949). The Stock-Wright LMS statistic is for weak instruments, and the test statistic rejects the null hypothesis that the instruments are weak (Stock and Wright, 2000).[7]

The coefficient on $\widehat{CSLI}$ is negative and significant, indicating that service sector liberalization leads to manufacturing firms' carbon emission intensity, through the inter-industry economic linkages. Further, the magnitude of the coefficient (-2.162) is comparable with the ones obtained in Table 3 (-2.265), suggesting that endogeneity is not a big concern in this setting. In what follows, we will resort to the OLS regressions for further analyses.

4.2.2 Using Alternative Measures for Pollution Intensity and Service Liberation

This sub-section explores alternative measures for pollutant emission and for service sector liberalization, with the associated results reported in Table 5.

On the alternative measure for pollution, we replace carbon emission intensity with firms' SO_2 emission intensity (Column 1). The rationale is the following. Firms also release SO_2 during their production process, which is, in fact, one other big source of pollution in China (Yang et al., 2016). If service liberalization mitigates firms' CO_2 emission, we expect it would generate impact on their SO_2 emission intensity as well. To test this hypothesis, we use the similar technique to construct firms' SO_2 emission intensity as its total SO_2 emission over output. With SO_2 emission intensity as the new dependent variable, we re-run the regression, with the newly obtained results in Column

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[7] The critical value at 10% significance level is 0.016. We reject the weak instrumental variable hypothesis as the obtained chi-square value exceeds the critical value.

(1).[8] The coefficient on *CSLI* is negative and significant, implying that, through the inter-industry economic linkages, service sector liberalization generates significant impact to decrease firms' SO_2 emission intensity. The result here indicate that with 0.1 unit increase in *CSLI*, firms' SO_2 emission intensity reduces by 20.32%. The findings not only support our baseline conclusion, but also present additional evidence.

Column (2) proceeds with an alternative measure for service industry liberalization. Here, we adopt the FDI Restrictiveness Index developed by OECD for China, which, by the way, has been used by other researchers (Bai, et al., 2022 for instance). We first rescale this index between the range of -1 and 0, and then apply the weights of the input-output table to calculate firms' exposure to service sector liberalization, indicated as *CSLI-OECD* to differentiate from our original measure. The estimated coefficient is negative and significantly different from zero at the 1% level, suggesting that service industry liberalization leads to decrease in manufacturing firms' CO_2 emission intensity. The magnitude of the coefficient implies that, with 0.1 unit relaxation in FDI restrictiveness, firms' carbon emission intensity will reduce by 15.17%.

4.2.3 Liberation Post China's WTO Accession

During the sample period, liberalization occurred prior to China's accession to the WTO to lay the foundations, and after the accession to fulfill China's commitment under the WTO membership. The liberalization pace was fact and the scope was wide. Given that WTO membership has been transformative for China's economy, it is often tempting for researchers to examine whether the trend to affect firms' performances has changed before and after this milestone. An argument can be made that with faster and bolder service sector liberalization, the impact on firms' carbon emission intensity might be on a higher trend. At the same time, liberalization towards FDI also happens for manufacturing industries. For instance, the 2002 version *Catalog* significantly relaxed FDI restrictions for a quarter of the manufacturing sectors at CIC4-digit level: among the 424 manufacturing industries at the CIC4-digit level, 112 are under the *Encouraged* category. These liberalizing policies were kept intact in the 2004 version. Manufacturing industries went through a real fast expansionary stage post 2001. Along with the fast expansion is the increasing pressure on pollution when firms compete with each other for customers, which might offset the mitigation effects from increased service liberalization. Against this backdrop, there is a no priori reason to argue whether the trend will be different, which renders it an empirical investigation.

We create an indicator, *Post_WTO*, with the value of 1 for years 2002-2006, and 0 otherwise. We add the interaction term, *CSLI*Post_WTO*, in the regression, with results reported in Column (3) in Table 5. The magnitude for the coefficient on *CSLI* alone does not change as much, compared with the baseline result, and the coefficient on *CSLI*Post_WTO* is positive, but not significantly different from zero. The results suggest that the effects of service sector liberalization on firms' carbon emission intensity reduction are not altered by China's WTO accession.

[8] Firm-level SO2 emissions are from China Industrial Firms Pollutant Discharge Data.

4.2.4 Industry-Level Analysis

Column (4) experiments with industry level emission intensity. The purpose is twofold. It aggregates individual firm' ability on the one hand, and can show, for the industry as a whole, the average effects of service liberalization on manufacturing industries on the other. Industry-level CO_2 emission intensity is the sum of firms' CO_2 emission divided by the sum of firms' output operating in the province-industry-year.

The estimated results show that, at the industry level, increases in service sector liberalization leads to manufacturing sectors' carbon emission intensity. The magnitude is much smaller than that obtained at the firm-level, as expected, due to the average effects of firms' ability (small versus large, for instance).

5. Firms' Heterogeneous Responses

This subsection delves deeper to explore firms' heterogeneous responses across a few dimensions including firm productivity, ownership, size, and their operating industries.

Productivity Heterogeneity. We have stated earlier that firm productivity is an important factor leading to direct and indirect effects on emission intensity reduction. Here, we examine its heterogenous effects. The essence of the argument is that service sector liberalization and firm productivity are mutually enhancing, and thus the impact of service sector liberalization on firms' carbon emission could be further enhanced by firms' productivity increase. To test the hypothesis, we introduce an interaction term of *CSLI* with TFP (total factor productivity). The TFP measure is calculated based on the method in Richter and Schiersch (2017), which treats energy as a separate input item. In our case, we directly factor in firms' CO_2 emissions derived from their energy consumption. This measure not only captures firms' productivity, but also takes into account the efficiency of a firm's energy consumption in the production process.

We add the interaction term, *CSLI***TFP*, together with *TFP* itself, in the regression, with the corresponding results reported in Column (1) in Table 6. The coefficient on *CSLI* alone ceases to be significant, but the coefficient on the interaction term, *CSLI***TFP*, is negative and significantly different from zero. So is the coefficient on TFP. Together, they indicate that the effects of *CSLI* on firms' carbon emission intensity reduction increases with firms' productivity, and more productive firms see larger reduction in their CO_2 emission intensity.

Firm ownership. As frequently examined by researchers studying the Chinese economy, firms' ownership structures often prove to make a difference in various firm decisions due to the intrinsic differences between state-owned enterprises (SOEs) and non-SOEs. On average, SOEs could have more favorable access to government assistance, but they are also more susceptible to government pressure to fulfill certain economic targets than non-SOEs. For instance during the sample period, to prevent unusually high level of unemployment, SOEs were prevented from laying off their surplus workers, but they were given a lifeline when they were in financial distress. Similarly, one can argue that various levels of government might pressure SOEs to meet their environmental target.

To capture whether SOEs exhibit a different trend than non-SOEs, we introduce a firm ownership indicator, *SOE*, with the value of 1 if a firm is identified in the *Survey* as state-owned and 0 otherwise. We add the interaction term, *CSLI*SOE* in the regression, with newly obtained results reported in Column (2) in Table 6. The negative and significant coefficients on *CSLI* (-1.576) and *CSLI*SOE* (-1.399) indicate that service sector liberalization generates different effects on SOEs and non-SOEs. *Ceteris paribus*, if service sector liberalization index moves up by 0.1 unit, then CO_2 emissions intensity reduction will increase by 15.76% for non-SOEs and 29.75% (equal to .1*(1.576+1.399)) for SOEs. In other words, the effects of service liberalization are 49% larger for SOEs than for non-SOEs.

Firm size. Thus far, we control firms' size effects on carbon emission through a covariate, by implicitly assuming that service sector liberalization affects large and small firms in a common trend. Here, we relax that assumption by allowing that large firms, as opposed to small and medium sized firms, follow a different relationship, and there are valid reasons to consider that. For instance, there might be inherent differences between large and small firms in their *ability* to reduce carbon emission as large firms typically possess certain level of bargaining power and could be able to amplify the reduction in input costs resulting from upstream liberalization (Correa-López and Doménech, 2019). Or because large firms have more resources to resort to green-tech innovations. In fact, the results on ownership type differences also shed some light on the argument, as SOEs are generally much larger than many non-SOEs, though there are large privately owned (Alibaba) or foreign affiliates (Walmart).

To test that heterogeneity, we put firms into two groups, large versus medium and small, based on the *Provisions on Classification Standards for Small and Medium-sized Enterprises* by China's National Bureau of Statistics. Large firms are those with more than 1,000 employees or more than RMB 40 million in annual revenue, with the rest being termed as small- and medium-sized enterprises (SMEs). We create a size indicator, *Large*, with the value of 1 for large firms and 0 for SMEs, and add the interaction term, *CSLI*Large*, in the regression with results reported in Column (3) in Table 6.

The negative and significant coefficients on *CSLI* and *CSLI*Large* indicate that service liberalization generates significant effects on manufacturing firms' carbon emission intensity. The coefficients indicate that, *ceteris paribus*, the impact of service sector liberalization on large firms is 157% larger for large firms than for SMEs (4.187 versus 1.627).

Operating Industries. Column (4) in Table 6 explores industry heterogeneity. Due to the nature of their production process, some industries are more polluting than others. The common very heavy polluting industries are non-metallic mineral products, chemicals and petroleum processing and coking. During the sample period, with the flood of liberalization measures, marginal effects on carbon emission reduction might be larger for heavy-polluting industries than for others, due to their high pollution level in the first place. To test this low-hanging fruit hypothesis, we create an industry cluster indicator, *Heavy-Indicator*, with the value of 1 for the aforementioned industries and 0 otherwise. We add the interaction term, *CSLI* Heavy-Indicator*, in the regression, with the newly obtained results reported in Column (4) in Table 6.

The message from the results is clear. For firms operating in the heavy polluting industries, the effects on carbon emission intensity of service liberalization are twice as large as those operating in other industries (the coefficient of 3.74=1.782+1.958 versus 1.782). With 0.10 unit increase in the liberalization index, carbon emission intensity will decrease by 17.8%, as opposed to 37.40% for the heavy-polluting firms.

6. Conclusion

The study focuses on the impact of service sector liberalization on manufacturing firms' carbon emission intensity reduction from 1998 to 2006 in China. The period witnessed China's tremendous efforts to liberalize its service sector in its bid to join the WTO and to fulfill its commitment under the WTO. Service sector liberalization leads to increased competition, and competition leads to firms producing more varieties of good-quality products with declining prices. Producing service products is less polluting than for manufacturing goods. Accordingly, increased usage of service products in manufacturing industries would have an impact on their pollution intensity reduction, the focus of our study—the inter-industry economic linkages. We quantify service sector liberalization based on China's policy changes towards FDI, and build a composite index to measure manufacturing firms' exposure to service liberalization as a weighted average of service sector liberalization with weights as their input shares.

We find that service sector liberalization significantly reduces downstream manufacturing firms' carbon emission intensity. Our results are robust with alternative measures of emission intensity reduction, service liberalization, and after correcting endogeneity. We also find that firms' productivity enhances service liberalization's impact on the reduction. Further, firms' carbon emission reduction response to service sector liberalization is heterogeneous: the impact is 157% larger for large firms than for small- and medium-sized firms, 89% larger for SOEs than for non-SOEs, and 110% larger for firms operating in pollution heavy industries than those in other industries.

References

Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The environment and directed technical change. *The American Economic Review, 102*(1), 131–166. doi:10.1257/aer.102.1.131

Alam, M. S., Safiullah, M., & Islam, M. S. (2022). Cash-rich firms and carbon emissions. *International Review of Financial Analysis, 81*, 102106. doi:10.1016/j.irfa.2022.102106

Alessandri, T. M., & Pattit, J. M. (2014). Drivers of R&D investment: The interaction of behavioral theory and managerial incentives. *Journal of Business Research, 67*(2), 151–158. doi:10.1016/j.jbusres.2012.11.001

Anderson, T. W., & Rubin, H. (1949). Estimation of the parameters of a single equation in a complete system of stochastic equations. *The Annals of Mathematical Statistics*, *20*(1), 46-63. doi:10.1214/aoms/1177730090

Arnold, J. M., Javorcik, B. S., & Mattoo, A. (2011). Does services liberalization benefit manufacturing firms? Evidence from the Czech Republic. *Journal of International Economics, 85*(1), 136–146. doi:10.1016/j.jinteco.2011.05.002

Arnold, J. M., Javorcik, B., Lipscomb, M., & Mattoo, A. (2016). Services reform and manufacturing performance: Evidence from India. *The Economic Journal, 126*(590), 1–39. doi:10.1111/ecoj.12206

Bai, Z., Meng, S., Miao, Z., & Zhang, Y. (2022). Liberalization for services foreign direct investment and product mix adjustment: Evidence from Chinese exporting firms. *Review of International Economics, 31*(2), 363-388. doi:10.1111/roie.12629

Bao, Q, Wang Y and Xie H. (2019). From Honeymoon to Divorce: Institution Quality and Foreign Investors' Ownership Consolidation in China, *Economic Inquiry*, 57(1): 372-390, 2019.

Bas, M. (2014). Does services liberalization affect manufacturing firms' export performance? Evidence from India. *Journal of Comparative Economics, 42*(3), 569–589. doi:10.1016/j.jce.2013.06.005

Bas, M., & Strauss-Kahn, V. (2015). Input-trade liberalization, export prices and quality upgrading. *Journal of International Economics, 95*(2), 250–262. doi:10.1016/j.jinteco.2014.12.005

Beverelli, C., Fiorini, M., & Hoekman, B. (2017). Services trade policy and manufacturing productivity: The role of institutions. *Journal of International Economics, 104*, 166–182. doi:10.1016/j.jinteco.2016.11.001

Bosworth, B., & Collins, S. M. (2008). Accounting for growth: comparing China and India. *Journal of Economic Perspectives*, *22*(1), 45-66. doi: 10.1257/jep.22.1.45

Bourlès, R., Cette, G., Lopez, J., Mairesse, J., & Nicoletti, G. (2013). Do Product Market Regulations in Upstream Sectors Curb Productivity Growth? Panel Data Evidence For OECD Countries. *The Review of Economics and Statistics, 95*(5), 1750–1768. doi:10.1162/REST_a_00338

Carbon Emission Account & Datasets.https://www.ceads.net/user/index.php?id=130&lang=en

Chen, Z., Zhang, J., & Zheng, W. (2017). Import and innovation: Evidence from Chinese firms. *European Economic Review, 94*, 205–220. doi:10.1016/j.euroecorev.2017.02.008

Clarkson, P. M., Li, Y., Richardson, G. D., & Vasvari, F. P. (2011). Does it really pay to be green? Determinants and consequences of proactive environmental strategies. *Journal of Accounting and Public Policy, 30*(2), 122–144. doi:10.1016/j.jaccpubpol.2010.09.013

Correa‐López, M., & Doménech, R. (2019). Service regulations, input prices and export volumes: Evidence from a panel of manufacturing firms. *The Journal of Industrial Economics, 67*(2), 328–371. doi:10.1111/joie.12201

Enright, M.J. (2016). Developing China: The Remarkable Impact of Foreign Direct Investment (1st ed.). *Routledge.* doi.org/10.4324/9781315393346

Fernandes, A. M., & Paunov, C. (2012). Foreign direct investment in services and manufacturing productivity: Evidence for Chile. *Journal of Development Economics, 97*(2), 305–321. doi.org:10.1016/j.jdeveco.2011.02.004

Huang, J., Yang, T., & Jia, J. (2019). Determining the factors driving energy demand in the Sichuan–Chongqing region: An examination based on DEA-Malmquist approach and spatial characteristics. *Environmental Science and Pollution Research, 26*(31), 31654–31666. doi:10.1007/s11356-019-06258-9

Huang, Y., Zhang, Y., Xiang, Y., & Dong, X. (2022). Has servitization reduced the embodied carbon emissions of manufacturing export trade? Evidence from 38 countries. *Environmental Technology & Innovation, 28*, 102950. doi:10.1016/j.eti.2022.102950

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www. ipcc-nggip.iges.or.jp/public/2006gl/.

Jaraite-Kažukauske, J., & Di Maria, C. (2016). Did the EU ETS make a difference? An empirical assessment using lithuanian firm-level data. *The Energy Journal, 37*(1), 1–23. doi:10.5547/01956574.37.2.jjar

Kalinova, B., Palerm, A., & Thomsen, S. (2010). *OECD's FDI restrictiveness index: 2010 update*: OECD.

Lee, W., 2019. Services Liberalization and Global Value Chain Participation: New Evidence for Heterogeneous Effects by Income Level and Provisions. *Review of International Economics, 27*(3), 888-915. https://doi.org/10.1111/roie.12402.

Lin, B., & Xu, C. (2022). Does environmental decentralization aggravate pollution emissions? Microscopic evidence from Chinese industrial enterprises. *Science of The Total Environment,* 829, 154640. doi.org/10.1016/j.scitotenv.2022.154640

Moutinho, V., Robaina-Alves, M., & Mota, J. (2014). Carbon dioxide emissions intensity of Portuguese industry and energy sectors: A convergence analysis and econometric approach. *Renewable and Sustainable Energy Reviews, 40*, 438–449. doi:10.1016/j.rser.2014.07.169

Reiskin, E. D., White, A. L., Johnson, J. K., & Votta, T. J. (1999). Servicizing the chemical supply chain. *Journal of Industrial Ecology, 3*(2-3), 19–31. doi:10.1162/108819899569520

Richter, P. M., & Schiersch, A. (2017). CO 2 emission intensity and exporting: Evidence from firm-level data. *European Economic Review, 98*, 373–391. doi:10.1016/j.euroecorev.2017.07.011

Ross L. & Zhou K. (2012), China Release New Foreign Investment Catalog(2011 Edition). *Wilmer Hale*. https://www.wilmerhale.com/en/insights/publications/china-releases-new-foreign-investment-Catalog-2011-edition-january-12-2012 (accessed on 3 Nov. 2023)

Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018). Environmental degradation in France: The effects of FDI, financial development, and energy innovations. *Energy Economics, 74*, 843–857. doi:10.1016/j.eneco.2018.07.020

Shapiro, J. S., & Walker, R. (2018). Why Is Pollution from US Manufacturing Declining? The Roles of Environmental Regulation, Productivity, and Trade. *American Economic Review, 108*(12), 3814–3854. doi.org:10.1257/aer.20151272

Stock, J. H., & Wright, J. H. (2000). GMM with weak identification. *Econometrica*, *68*(5), 1055-1096. doi: 10.1111/1468-0262.00151

Su, B., & Ang, B. W. (2015). Multiplicative decomposition of aggregate carbon intensity change using input–output analysis. *Applied Energy,154,* 13-20. doi.org/10.1016/j.apenergy.2015.04.101

Tang, M., Li, Z., H u, F., Wu, B., & Zhang, R. (2021). Market failure, tradable discharge permit, and pollution reduction: Evidence from industrial firms in China. *Ecological Economics,* 189, 107180. doi.org/10.1016/j.ecolecon.2021.107180

Wang, Y. (2013). "Exposure to FDI and New Plant Survival: Evidence from Canada", *Canadian Journal of Economics*, 46(1): 46-77.

Wang, Y. (2013). "FDI and Productivity Growth: The Role of Vertical Linkages", *Canadian Journal of Economics*, 43(4): 1243-72.

Wang, Y., Liao, M., Wang, Y., Xu, L., & Malik, A. (2021). The impact of foreign direct investment on China's carbon emissions through energy intensity and emissions trading system. *Energy Economics, 97*, 105212. doi:10.1016/j.eneco.2021.105212

Wu, C., Su, N., Guo, W., & Wei, W. (2022). Import competition and the improvement in pollutant discharge from heterogeneous enterprises: Evidence from China. *Journal of Environmental Management,* 310, 114809. doi.org/10.1016/j.jenvman.2022.114809

Yang, X., Wang, S., Zhang, W., Li, J., & Zou, Y. (2016). Impacts of energy consumption, energy structure, and treatment technology on SO2 emissions: A multi-scale LMDI decomposition analysis in China. *Applied Energy*, 184, 714-726. doi:10.1016/j.apenergy.2016.11.013

Yu, J., Shi, X., Guo, D., & Yang, L. (2021). Economic policy uncertainty (EPU) and firm carbon emissions: Evidence using a China provincial EPU index. *Energy Economics, 94*, 105071. doi:10.1016/j.eneco.2020.105071

Zhang, Y., & Zhang, S. (2018). The impacts of GDP, trade structure, exchange rate and FDI inflows on China's carbon emissions. *Energy Policy, 120*, 347–353. doi:10.1016/j.enpol.2018.05.056

Zhao, D., & Chen, J. (2021). An analysis of the impact of service inputs in manufacturing industries on eco-efficiency: Evidence from China. *Environmental Science and Pollution Research, 28*(43), 61825–61840. doi:10.1007/s11356-021-15092-x

Table 1. Service Sector Liberalization Index

List of Service Sectors	Liberalization Index		
	1998	2002	2004
Transportation and Warehousing	-0.51	-0.57	-0.42
Postal Service	-0.67	-0.58	-0.58
Information Transmission, Software and Information Technology Services	-0.57	-0.50	-0.48
Wholesale and Retail	-0.51	-0.57	-0.45
Accommodation and Catering	-0.50	-0.38	-0.38
Finance	-0.69	-0.59	-0.54
Real Estate	-0.55	-0.30	-0.30
Leasing and Business Services	-0.50	-0.34	-0.21
Scientific Research, Technical Services and Geological Prospecting	-0.49	-0.45	-0.44
Residential Services, Repairs and other Services	-0.49	-0.48	-0.47
Education	-0.66	-0.46	-0.46
Health Security and Social Welfare	-0.63	-0.36	-0.36
Culture, Sports and Entertainment	-0.71	-0.68	-0.67

Figure 1. ***CSLI*** **indices Across Provinces, 1998 versus 2006**

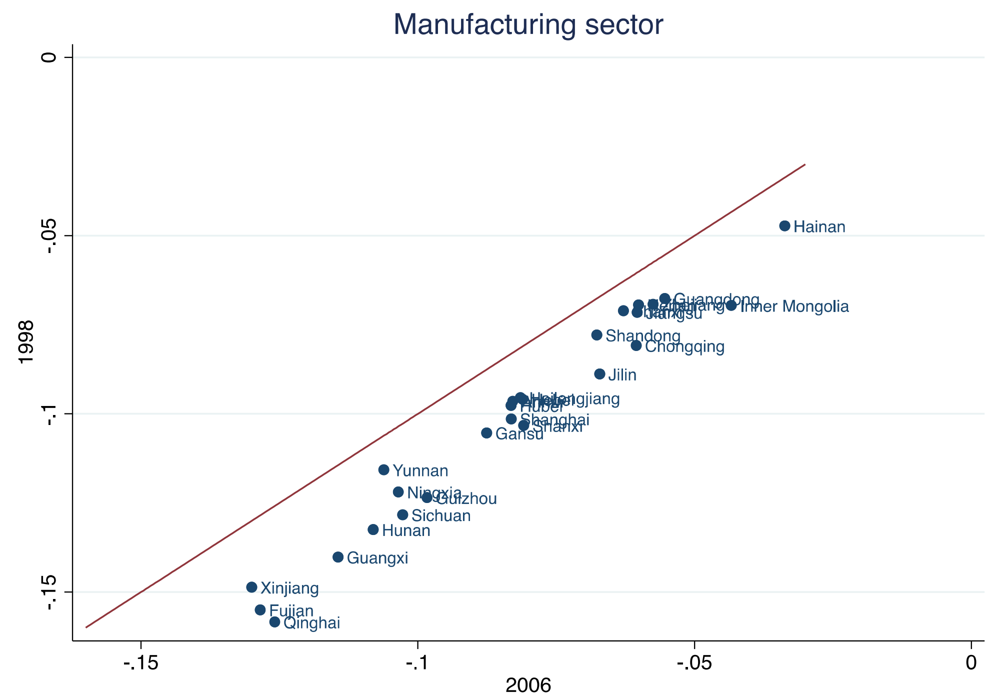

Figure 2. Carbon Emission Intensity in Selected Manufacturing Sectors

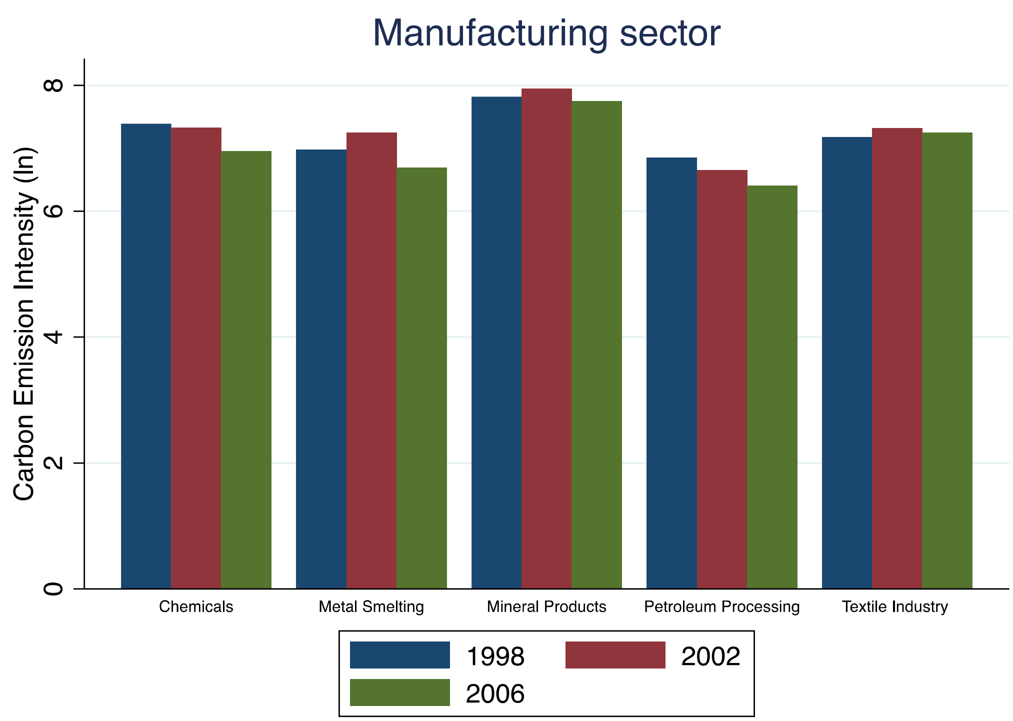

Table 2. Descriptive Statistics of the Main Variables

Variable	Description	Observation	Mean	S. D.	Min	Max
Dependent variables						
$\ln(CO_2/Output)$	Natural log of firm's carbon emission intensity	166966	6.990	1.660	-5.648	19.285
$\ln(CO_2/Output)\_Ind$	Natural log of carbon emissions at the sectoral level	3705	13.45	2.859	3.878	20.8317
Independent variables						
CSLI	Composite service liberalization index	166966	-.090	.034	-.42	-.01
Firms controls						
ln*Size*	Natural log of firm total assets	165899	9.536	1.687	0	18.154
ln*Age*	Natural log of firm age	166771	2.494	1.024	0	7.602
Leverage	Total debts divided by total assets	166484	.676	.288	0.038	1.626
Subsidy	Dummy variable of subsidy status	166966	.195	.396	0	1
Profit-Rate	Total profits divided by total sales	166145	-.014	0.161	-1.001	0.258
Industry controls						
ln*Ind_Scale*	Natural log value of industry output	146102	17.450	1.277	9.216	20.759
HHI	Herfindahl-Hirschman Index	166966	0.025	0.037	0	1

Table 3. The Main Results

Variables	(1)	(2)
CSLI	**-2.260*****	**-2.265*****
	(0.790)	(0.775)
Firm controls		
ln*Size*	-0.098***	-0.101***
	(0.010)	(0.010)
ln*Age*	-0.028***	-0.022**
	(0.010)	(0.010)
Leverage	0.053	0.041
	(0.039)	(0.039)
Subsidy	-0.059**	-0.060**
	(0.024)	(0.024)
Profit rate	-1.014***	-1.031***
	(0.047)	(0.048)
Industry controls		
ln*Ind_scale*		0.056***
		(0.020)
HHI		-1.388***
		(0.317)
Constant	7.534***	6.679***
	(0.134)	(0.395)
Year Fixed Effects	Y	Y
Industry Fixed Effects	Y	Y
Province Fixed Effects	Y	Y
Observations	165,387	144,821
Adjusted R-squared	0.219	0.223

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses are clustered by industry-province, where the industry classification is specified by I-O table industry level.

Table 4. Controlling Endogeneity

	(1) *First-stage*	(2) *Second-stage*
$\widehat{CSLI}$		**-2.162*** **
		(0.818)
CSLI-India	**0.961*** **	
	(0.013)	
Firm Controls	Y	Y
Industry Controls	Y	Y
Year Fixed Effects	Y	Y
Industry Fixed Effects	Y	Y
Province Fixed Effects	Y	Y
Observations	144,821	144,821
Weak instrument test		
Anderson-Rubin Wald test	(6.980)***	
Stock-Wright LM S statistic	(8.700)***	

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses are clustered by industry-province, where the industry classification is specified by I-O table industry level.

Table 5. Alternative Measures of Pollution and Service Liberalization

	(1)	(2)	(3)	(4)
	$\ln(SO_2/Output)$	$\ln(CO_2/Output)$	$\ln(CO_2/Output)$	$\ln(CO_2/Output)\_Ind$
CSLI	**-2.032****		**-2.379*****	**-0.074*****
	(0.800)		(0.788)	(0.014)
CSLI-OECD		**-1.517*****		
		(0.557)		
CSLI**Post_WTO***			**0.429**	
			(0.463)	
Firm Controls	Y	Y	Y	N
Industry Controls	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Industry Fixed Effects	Y	Y	Y	Y
Province Fixed Effects	Y	Y	Y	Y
Observations	144,629	144,821	144,821	3,705
Adjusted R-squared	0.266	0.222	0.222	0.784

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses are clustered by industry-province, where the industry classification is specified by I-O table industry level.

Table 6. Firms' Heterogeneous Responses

VARIABLES	(1) Productivity	(2) SOE	(3) Size	(4) Heavy-polluting Industries
CSLI	**-1.263**	**-1.576***	**-1.627****	**-1.782****
	(0.862)	(0.857)	(0.813)	(0.828)
CSLI x Productivity	**-2.240****			
	(0.974)			
CSLI x SOE		**-1.399***		
		(0.782)		
CSLI x Large			**-2.560***	
			(1.370)	
CSLI x Heavy_Indicator				**-1.958***
				(1.080)
Productivity	-0.244**			
	(0.098)			
SOE		-0.025		
		(0.073)		
Large			-0.520***	
			(0.147)	
Heavy_Indicator				0.709***
				(0.140)
Firm and Industry Controls	Y	Y	Y	Y
Year, Industry and Province Fixed Effects	Y	Y	Y	Y
Observations	126,174	143,853	145,170	144,821
Adjusted R-squared	0.223	0.224	0.218	0.223

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses are clustered by industry-province, where the industry classification is specified by I-O table industry level.