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Abstract

This study is motivated by recent trends in the US economy which seem inconsistent with the prediction of traditional Heckscher-Ohlin trade theory. With increased imports from China, this theory tells us that the structure US manufacturing should move toward more energy-intensive industries and as a result, energy use in the US industries should increase. However, energy consumption by US manufacturers has declined by 3.8% from 2002 to 2006 and the real value of manufacturing output has increased about 10% for the same period. To investigate the effect of trade with China on energy use in US manufacturing, I modify the H-O model by adding an energy tax. This model predicts that the energy tax magnifies the negative effect on energy use caused by factor substitution between and within the US manufacturing industries. Therefore, even though the output effect is still positive in energy-intensive industries, the overall effect of increasing imports from China can be negative. To help understand the magnitude of the energy-use response to an increased Chinese import penetration, I construct a computable general-equilibrium (CGE) model of the US economy using the US input-output table for base year 2005. Specifically, what level of energy tax would offset the increasing effect of trade with China on energy use? I show that increasing imports from China combined with an energy tax can produce outcomes consistent with the actual data: decreasing energy consumption yet increasing output. In particular, total energy use in the manufacturing sector can fall at the same time as US welfare increases due to its improved terms of trade. This result tells us that an energy tax that offsets the otherwise energy-increasing effect of Chinese import penetration is likely small and is unlikely to reduce welfare. I numerically estimate these effects using US manufacturing industry-level panel data of 1997 to 2005. I also decompose the effect of increasing imports from China on energy use of US manufacturing into a factor substitution effect and an output scale effect. Because import penetration may be endogenous, I instrument for Chinese import penetration using Chinese share of world trade. My results indicate that overall, increasing imports from China raise consumption of fuel and electricity. As in the simulation model, the marginal effect of Chinese import penetration is small, about 0.05% to 0.08%, but statistically significant. Interestingly, the directions of the factor substitution effects on fuel and electricity are opposite. Increasing imports from China causes a decrease in the factor ratio of fuel over labor, but an increase of electricity over labor. This result suggests that as a result of increasing imports from China, electricity replaces labor, unlike fuel.

Keywords: Energy use; US manufacturing; Imports, China

JEL Classification: F18, Q4, Q56.

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1 Introduction

Motivated by the fact that current trends of energy use in US manufacturing are not consistent with predictions of traditional trade theory based on factor endowments, I examine the relationship between energy use in US manufacturing and increasing imports from China. Imports from China have been dramatically increasing for the last several decades. US imports from China totaled \$399.3 billion in 2011, a 9.4% increase (\$34.4 billion) from 2010, and up 299% since 2000[1]. Traditional Heckscher-Ohlin trade theory tells us that US manufacturing should move toward more energy-intensive industries and as a result, energy use in the US industries should increase when Chinese import penetration is high[2]. However, recent trends suggest a different story. As shown in Figure 1, energy use in US manufacturing has been declining since 1998, while the real value of manufacturing output has been increasing. Manufacturing fuel consumption has declined 3.8% from 2002 to 2006, whereas the real value of manufacturing output has increased about 10% for the same period. Figure 2 shows the difference between labor-intensive industries and energy-intensive industries. Labor-intensive industries include textile and apparel, and energy-intensive industries include petroleum and chemicals. Overall, Chinese import penetration to the US has increased for both industries, but clearly labor-intensive industries face higher import penetration from China compared to energy-intensive industries. Faced with higher import penetration from China, labor-intensive industries in the US would shrink, and energy-intensive industries should expand according to current theory. However, energy use in energy-intensive industries has not kept pace with output as these industries have grown. Figure 2(c) clearly illustrates this change. This trend may be caused by energy regulations of US Environmental Protection Agency (EPA). Policies to reduce energy use in US manufacturing is one of debates between EPA and US manufacturers. These regulations and policies cause US manufacturers to reduce energy use through increasing efficiency or improving 'greener' technology[3].

To investigate the effect of trade on energy use, I modify the Heckscher-Ohlin model by adding an energy tax in the North. This represents a more stringent environmental policy of the North.

[1]Source: Office of the United States Trade Representative, http://www.ustr.gov/countries-regions/china.

[2]US is an energy-abundant country and the energy price is cheaper than other countries. Therefore, US relatively specialized in energy-intensive industries compared to China. On the other hand, China has cheap labor and comparative advantage in labor-intensive industries.

[3]For example, Porter (1991) argues that environmental regulations are actually as a net positive force driving private firms energy-efficient and the economy as a whole to become more competitive in an open economy.

Conceptually, the energy tax is an useful proxy for domestic environmental policies that result in higher energy costs. Using this model I show that the effects of increasing imports from the South can be decomposed into two parts: a change in output caused by comparative advantage (positive effect) and changes in factor substitution caused by factor price equalization and an energy tax (negative effect). Without an energy tax, the output effect dominates and total energy use in the North increases due to trade with the South. However, this model predicts that the energy tax magnifies the negative effect on energy use caused by factor substitution between and within the US manufacturing industries. Therefore, even though the output effect is still positive in energy-intensive industries, the overall effect of increasing imports from China can be negative. Specifically, energy-intensive industries reduce energy use more than other sectors in response to the energy tax. On the other hand, increased output and welfare caused by trade are consistent even with energy tax. I test the model's predictions using a computable general equilibrium (CGE) approach calibrated to the US input-output table for the base year 2005 and simulate several scenarios related to increased imports from China and the energy tax. My simulation results are consistent with the predictions of the model. I find that the effect of trade with China is a small increase in energy use in the US manufacturing sector. On the other hand, the effect of an energy tax can be quite large. As a result, even a small energy tax can offset the positive effect of imports from China.

Additionally, using US manufacturing panel data from 1997 to 2005, I decompose the effect of increasing imports from China on energy use into an output scale effect and a factor substitution effect. My empirical results also indicate that overall, increasing imports from China raise consumption of fuel and electricity. As in the simulation model, the marginal effect of Chinese import penetration is small, about 0.05% to 0.08%, but statistically significant. Interestingly, the directions of the factor substitution effects on fuel and electricity are opposite. Increasing imports from China causes a decrease in the factor ratio of fuel over labor, but an increase of electricity over labor. This result suggests that as a result of increasing imports from China, electricity may replace labor, unlike fuel.

Even though a number of studies have examined the relationship between trade and environmental issues, the effects of trade on energy use have not been fully explored. Cole (2006) points out that it is important to understand the extent to which trade influences the common underlying cause of air pollutants, namely national and international energy use. Based on the theoretical model of Antweiler et al. (2001), he empirically shows that trade liberalization is likely to increase per capita energy use for the mean country within the sample. His results also indicate that regulations and technological improvements are not keeping pace with the growth of GNP.

An extensive literature documents the effect of import penetration from low-wage countries on labor market outcomes, in particular employment and wages. These studies consistently find that increasing import penetration reduces employment and real wages [Revenga (1992), Hine and Wright (1998)]. Hine and Wright (1998) examine the relationship between trade with low wage economies and UK manufacturing. Their results suggest job loss and lower real wages as a result of increasing imports. Bernard et al. (2006) investigate the relationship between imports from low-wage countries and the reallocation of the US manufacturing sector within and across industries at the plant level. They find that plant survival and growth are negatively associated with industry exposure to imports from low-wage countries. Since energy is also an important input to manufacturing, it is surprising that the relationship between imports and energy use is rarely examined.

Unlike Cole (2006), this paper focuses on the effect of increasing imports from China on the US manufacturing sector, rather than the effect of general trade liberalization on national energy use. In addition, I investigate how policies to reduce national energy use may offset the effect of trade. Finally, I decompose the trade effect into two effects: a factor substitution effect and an output scale effect resulting from trade with China.

The rest of this paper is organized as follows. In Section 2, I describe the theoretical framework using a modified H-O model with energy tax. Section 3 calibrates the model using the US input-output table for the base year 2005. In Section 4, using US manufacturing panel data, I decompose the effect of trade with China into a factor substitution effect and an output scale effect depending on energy types (fuel vs. electricity).

2 Theoretical Framework

In this section, I modify the Hechscher-Ohlin model by adding an energy tax as a government policy to reduce energy use in response to increased imports from the South. This gives the prediction of the determinants of energy use in the manufacturing sector in an open economy.

2.1 Description

- There are two countries: the North and the South(*).
- There are two production sectors: Manufacturing and Energy.
- In the manufacturing sector, there are n industries. Manufacturing goods are produced by combining two inputs: energy and labor. The factor prices are given as w, m respectively for labor and energy. The factor-price ratio is $\frac{w}{m} > \frac{w^*}{m^*}$.
- The energy sector produces Y_E in the domestic country using a given resource(R) and capital(K). The energy output is transformed into domestic use and export (E_{EX}) and the domestic use is demanded only by manufacturing producers.
- Production in both sectors is assumed as constant returns to scale and perfect competition.
- For all sectors, manufacturing goods and energy are traded. The Armington aggregation is assumed for imported goods.
- The consumer's utility is decided only by consumption of manufacturing goods. The imported and domestic goods in a sector i are not perfectly substituted. They are aggregated by the Armington assumption.
- The energy tax, t_E increases the energy price m to $m(1 + t_E)$. $(0 \leq t_E \leq 1)$

2.2 Production: Manufacturing sector

Let Y_i be the output level of manufacturing industry i, and L_i and E_i be the two inputs, labor and energy, respectively.

$$Y_i = L_i^{\alpha} E^{(1-\alpha_i)} \tag{1}$$

Minimizing the cost function, the energy demand function is derived as a function of the factor-price ratio and output.

$$E_i(Y_i; w, m) = \left(\frac{1-\alpha_i}{\alpha_i}\right)^{\alpha_i} \left(\frac{w}{m}\right)^{\alpha_i} Y_i \tag{2}$$

The manufacturing output is traded. That is, I assume that the manufacturing output is transformed to domestic consumption and exports using constant elasticity of transformation. They are perfectly transformable for producers. Therefore,

$$Y_i = C_i^D + EX_i \tag{3}$$

2.3 Production: Energy sector

Energy is produced by a given resource and capital in the economy.

$$Y_E = R^{\psi} K^{(1-\psi)} \tag{4}$$

The energy output is transformed into domestic uses in the manufacturing sector and exports. The energy producer is indifferent between the domestic and foreign markets. Therefore, they are perfectly transformed.

$$Y_E = \sum_i E_i^D + E_{EX} \tag{5}$$

Energy is also imported. Imported energy is used only by manufacturers. For manufacturers, domestic energy and imported energy are not perfectly substituted. That is, I assume Armington elasticity between two types of energy. This means that the elasticity of substitution, $\frac{1}{1-\rho}$ is greater than one.

$$E_i = ARM(E_i^D, E_i^M) = [\xi_i E_i^{D\rho} + (1-\xi_i) E_i^{M\rho}]^{\frac{1}{\rho}} \tag{6}$$

2.4 Consumption

The consumer demands only manufacturing goods. The utility function is given by the Cobb-Douglas function,

$$U = \prod_i C_i^{\gamma_i} \qquad\qquad \sum_i \gamma_i = 1 \tag{7}$$

By maximizing the consumer's utility, the consumption level of a manufacturing sector i is

$$C_i = \frac{\gamma_i}{P_i^A} \cdot I \tag{8}$$

where I is the total expenditure on goods from sector i and P_i^A is the price index of Armington composition of goods from sector i. The consumption of goods from sector i is combined with the domestically produced goods and imported goods of the sector.

$$C_i = ARM(C_i^D, C_i^M) = [\mu_i C_i^{D\rho} + (1-\mu_i) C_i^{M\rho}]^{\frac{1}{\rho}} \tag{9}$$

The elasticity of substitution is $\sigma = \frac{1}{1-\rho}$. The domestically produced goods and imported goods can be derived as a function of total consumption of the sector.

$$\begin{aligned} C_i^D &= \left(\frac{\mu_i P_i^A}{P_i^d}\right)^{\frac{1}{1-\rho}} C_i \\ C_i^M &= \left(\frac{(1-\mu_i) P_i^A}{(1+\tau_i) P_i^m}\right)^{\frac{1}{1-\rho}} C_i \end{aligned} \tag{10}$$

2.5 Solutions

First of all, the amount of imported goods is decided by the relative price ratio between domestic goods and imported goods, and consumption share between these goods. Using equation (10), I can rewrite the imported manufacturing goods of sector i as

$$C_i^M = \left[\frac{P_i^d}{(1+\tau_i) P_i^m}\right]^{\frac{1}{1-\rho}} \left(\frac{1-\mu}{\mu}\right)^{\frac{1}{1-\rho}} C_i^D \tag{11}$$

The total derivative of energy demand function for the manufacturing sector i is

$$dE_i(Y_i; m, w) = \Omega \cdot d(w/m) + \Lambda \cdot dY_i \qquad \text{where} \quad \Omega, \Lambda > 0 \tag{12}$$

$$\begin{aligned} d(\tfrac{w}{m}) &= A \cdot dP_i^m && \text{where} \quad A > 0 \\ dY_i &= B \cdot dP_i^m && \text{where} \quad B < 0 \\ dP_i^m &= C \cdot dC_i^m && \text{where} \quad C < 0 \end{aligned} \tag{13}$$

To examine the effect of imports on energy use,

$$\frac{dE_i(Y_i; m, w)}{dC_i^M} = \underbrace{\Omega \cdot A \cdot C \cdot \frac{d(w/m)}{dC_i^M}}_{\text{factor substitution effect}} + \underbrace{\Lambda \cdot B \cdot C \cdot \frac{dY_i}{dC_i^M}}_{\text{output scale effect}} \tag{14}$$

When imports from the South increase, the effect on energy demand can be divided into two components: the factor substitution effect and the output scale effect. The first term in equation (14) shows the substitution effect between factors caused by changing the factor-price ratio between energy and labor. According to the factor price equalization, imports from the South lower the relative wage in the North. Regardless of the characteristics of a sector such as factor intensity, a changed input-price ratio leads to an increased demand for labor and reduced use of energy. The second term in equation (14) shows the output scale effect caused by trade. Openness to the South will alter the output level of each sector in a manner that depends on the price ratio of domestic goods to imported goods. Total consumption of sector i is increased by the decreased price index of sector i, which causes the output level in sector i to increase. The output scale effect of energy demand dominates the factor substitution effect. Therefore, it causes that the North to use more energy after trading. However, if the North imposes an energy tax on energy demand for production, the energy price is changed to $m(1 + t_E)$ from m. This policy augments the factor substitution effect, and the factor substitution effect and the output scale effect work in the opposite direction. Depending on sector characteristics such as energy intensity, energy use in each sector could increase or decrease with an additional energy policy.

3 Computable General Equilibrium

3.1 Calibration

In this section, I specify the CGE model and calibrate the model to the US economy using the US input-output table for the base year 2005[4]. This allows me to analyze the effect of increased imports from China on energy use in the US manufacturing sector and how the energy tax offsets the effect of trade with China.

3.1.1 The Structure of the CGE Model

Figure 3(a) provides an overview of the CGE model with the flows of goods and factors in an economy. The domestic output of sector i, Y_i, is transformed into the domestic consumption, DU_i, and exports, EX_i. Domestic consumption is also divided into two categories: intermediate inputs,

[4] See appendix for the description of data.

II and final consumption[5], FC_i^D. Utility is decided by aggregating all final consumption of outputs from all sectors. Additionally, consumers are also demanding the imported goods of each sector. Taxes are excluded in this part.

Figure 3(b) shows the structure of the production side in more detail. The output of sector i is produced by energy, intermediate inputs and composite factor. Labor (L_i), capital (K_i) and service intermediate inputs (SR_i) are aggregated into the composite factor. This composite factor is combined with intermediate inputs from other sectors (II_i) and energy (E_i) to produce the final output. There are two types of energy and intermediates inputs: domestic and imported.

3.1.2 The Functional Forms of CGE Model

To calibrate the model using the IO table, I construct all specific functional forms of each sector. Calibrated forms of the functions of each sector are shown below.

Production The production functions for all sectors are assumed to be CES with multiple levels of nesting. This application is typical in the representation of energy demand in production[6].

$$C_i = SR_i^{\alpha_{sr}} L_i^{\alpha_l} K_i^{\alpha_k} \quad \text{where} \quad \alpha_{sr} + \alpha_l + \alpha_k = 1 \tag{15}$$

$$II_i = min[II_{ji}] \tag{16}$$

At the first level, primary factors such as labor (L) and capital (K), and other service sectors (SR) are used for the composite factor (C) in the Cobb-Douglas form with the constant returns to scale[7]. All intermediate inputs to a sector i from a sector j are aggregated in Leontief form by assumption. This form does not allow substitution between intermediate inputs, but significantly reduces the complexity of the model[8]. The composite factor and intermediate inputs (II) are combined in the constant elasticity substitution (CES) form.

[5] In the original IO table, the final consumption is also divided into private consumption, government consumption and investment. However, in this model, I assume that the consumer demand all these types of consumption, so I do not introduce the government and investment. Therefore, the consumer also collects all tax revenue later.

[6] There are many studies using the nested production function in energy demand. See Manne and Richels (1990).

[7] That is, $a_{sr} + a_l + a_k = 1$.

[8] Hosoe et al. (2010).

$$Y_i = A_i\left[\delta\left(\frac{E_i}{\bar{E}_i}\right)^{\rho} + (1-\delta)\left[\beta\left(\frac{II_i}{\bar{II}_i}\right)^{\epsilon} + (1-\beta)\left(\frac{C_i}{\bar{C}_i}\right)^{\epsilon}\right]^{\rho/\epsilon}\right]^{1/\rho} \tag{17}$$

The composite factor and intermediate inputs are combined in a CES aggregation and the two combined are further aggregated with energy in CES form again. The elasticities of substitution, $\sigma 1$ and $\sigma 2$ in Figure 3(b) are respectively $\frac{1}{1+\rho}$ and $\frac{1}{1+\epsilon}$. For the benchmark analysis, I assume these elasticities are both 0.5.

Consumption The utility function is assumed to be Cobb-Douglas function with constant returns to scale.

$$U = \prod_i^n \left(\frac{FC_i}{\bar{FC}_i}\right)^{\gamma_i} \qquad \text{where} \quad \sum_i^n \gamma_i = 1 \tag{18}$$

The utility is maximized subject to the budget constraint.

Trade Because I conduct the model in an open economy, all production factors as well as final products are traded with other countries. At the same time, the differences between domestically produced/consumed goods and exported/imported goods have to be considered. Through the CGE model, I assume that they are imperfectly substitutable with each other. This assumption, commonly known as the Armington assumption, is broadly used in CGE models of an open economy (Armington (1969)).

$$E_i = \left[\lambda_i\left(\frac{E_i^D}{\bar{E}_i^D}\right)^{\rho_E} + (1-\lambda_i)\left(\frac{E_i^M}{\bar{E}_i^M}\right)^{\rho_E}\right]^{\frac{1}{\rho_E}} \tag{19}$$

$$II_{ji} = \left[\kappa_{ji}\left(\frac{II_{ji}^D}{\bar{II}_{ji}^D}\right)^{\rho_{II}} + (1-\kappa_{ji})\left(\frac{II_{ji}^M}{\bar{II}_{ji}^M}\right)^{\rho_{II}}\right]^{\frac{1}{\rho_{II}}} \tag{20}$$

In the IO table, three energy sectors (fuel, electricity and petroleum) are considered as energy inputs. I add up these three types of energy in this model, then aggregate with the imported energy inputs. An intermediate inputs to a sector i from a sector j is the aggregation of domestically produced and imported intermediate inputs. The degree of difference between domestic and imported inputs can be measured by a parameter such as the elasticity of substitution in constant elasticity of substitution (CES) function. Smaller elasticities mean that the two goods are too different to substitute with each other. From equations (19) and (20), these elasticities of substitution between domestic and imported inputs are $\sigma_E = \frac{1}{1+\rho_E}$ for energy and $\sigma_{II}=\frac{1}{1+\rho_{II}}$ for intermediate inputs.

These Armington elasticities for energy and intermediate inputs are equally assumed as 0.2 for the calibration, but this is changed in sensitivity analysis later. The final consumption of a sector i is also an Armington composition of domestic and imported goods.

$$FC_i = \left[\mu_i \left(\frac{FC_i^D}{\bar{FC}_i^D}\right)^{\rho} + (1-\mu_i)\left(\frac{FC_i^M}{\bar{FC}_i^M}\right)^{\rho}\right]^{\frac{1}{\rho}} \tag{21}$$

Again, I fix the elasticity of substitution between domestically produced and imported final consumption to be 0.2.

Output of each sector is assumed to transform into domestic use and export with constant elasticity of transformation (CET). The elasticity of transformation is η=$\frac{1}{1+\phi}$.

$$Y_i = \left(\theta_i DU_i^{\phi_i} + (1-\theta_i)EX_i^{\phi_i}\right)^{\frac{1}{\phi}}$$

I assume that the domestic use and export are perfectly substitutable each other, so I can rewrite the CET function above as a linear function.

$$Y_i = DU_i + EX_i \tag{22}$$

3.1.3 Calibration of the CGE Model

The parameters in the functions are decided by the reference quantity from the IO table. In fact, all reported information from the IO table is values of price $\times$ quantity. However, by setting all the prices at unity, then values in the IO table can be considered as quantity figures. Through the calibration, we can get the parameters in the CGE model. These parameters are fixed after the calibration. All parameters decided by the calibration are listed in Table 2. In equations (17) to (21), the parameters with a bar in the functional forms refer to the initial values from the data. Now, I can obtain the changed value of prices and quantity caused by simulations of changes in the exogenous variables using the specified functions.

For simplicity, I assume that this economy is small enough that it does not have a significant impact on the rest of the world. The point of the small economy assumption is that the export and import prices are exogenously given for this economy. To isolate and estimate the effect of

Chinese import penetration on the US energy use in the manufacturing sector by counter-factual simulations, all other factors are held constant.

3.1.4 General Equilibrium

A general equilibrium model considers the competitive behavior of each agent in the economy. Consumers earn income from wages and returns to capital and maximize their utility by demanding final goods. Producers use inputs and supply goods in the market. Production inputs are from consumers or other producers. Each sector producer is aiming to maximize profit.

The general equilibrium is defined by three conditions derived from solving the model: zero profit, market clearing and income balance. Zero profit conditions state that cost of production and output tax equals value of output. For my model, the zero profit conditions should be satisfied for all production sectors, final consumption sector and trade sector. These conditions are associated with the level of each activity. The market clearing condition is that output equals intermediate use and final demands. In the model, all demanded final goods are equal to supplied goods, and the sum of supplied factor should be equal to factor demand in the market. Income balance condition states that the level of expenditure equals the value of the income of the consumer. Under these equilibrium conditions, the model is solved as a mixed complementarity problem (MCP) using the GAMS/MPSGE system described in Rutherford (1995).

3.2 Numerical Results

The purpose of this analysis is to try to isolate and estimate the effect of Chinese import penetration by counter-factual simulations. I introduce tax on energy use in US manufacturing in order to help understand the magnitude of the energy use response to increasing imports from China: What level of energy tax would offset this effect?

In Table 1, the selected values of elasticities of substitution for the basic simulation are reported. Table 4 shows the simulation scenarios related to increased imports from China and energy tax in the US. The 'benchmark' columns in Tables 5 and 6 show the benchmark quantity from the IO table. Industry 7, 'Refined petroleum products and nuclear fuel' is not reported in the results because this industry is considered as an energy sector, not a manufacturing sector.

For the first basic scenario, I consider the isolated effect of increasing imports from China due to a price shock. Because imports are endogenous, they respond to changing a parameter for the price of these imports. All other world prices are held constant. Decreasing the relative imported price of Chinese manufacturing sectors about 10% equally for all manufacturing industries results in increased imports from China to the US. The results of this basic scenario as changes in energy use in the manufacturing sector are presented in Table 5. Energy use in all industries is increased proportionally as a result of increased output of each industry. The changes in output are reported in Table 6. Specifically, industries in which the US has a relative comparative advantage, such as chemical or machinery, increase their outputs and use energy more, while labor-intensive industries which have a high level of imports from China reduce their outputs and use less energy. With the calibration specifications, 10% of the price shock on imports from China leads to about a 0.5% increase in energy use and output in US manufacturing. The magnitude of the effect of increasing imports from China is very small.

The second basic scenario is only considering the energy tax in manufacturing sectors. The column 'Basic II' of Table 5 shows changed energy use in each industry. 1% of the energy tax causes an increase of production cost; therefore, all industries are producing less than benchmark quantity. This is especially true of those that are highly energy-intensive which respond to energy tax more sensitively and reduce output much more than other industries. With increasing imports from China, total energy use in the US manufacturing sector is increased as theory predicts. On the other hand, energy tax definitely causes manufacturers to use less energy. This result is made obvious by the basic producer problems. Interestingly, manufacturers respond very sensitively to the energy tax such that only 1% of the energy tax reduces energy consumption by 1% while output decreases by 0.1%.

The last two columns of Tables 5 and 6 present how energy use changes in the case of combining the two effects above. These show results with the same proportional increase in imports from China (10% of price shock) and 1% of the energy tax for all sectors. Combined, these two scenarios of increasing imports from China and the energy tax can produce an outcome consistent with the actual data: decreasing energy consumption with increasing output. Interestingly, total energy use in the manufacturing sector can fall at the same time as the US welfare increases due to its improved terms of trade. That means that the energy tax can result in the benefits of trade liberalization and less anxiety over environmental problems associated with energy use. It bears a close relationship with what is occurring in the US economy, which cannot be explained by traditional H-O theory. But even without an offsetting energy tax, the effect of an increase in Chinese import penetration on energy use in the manufacturing sector is estimated to be very small as just noted.

3.3 Sensitivity Checks

Figure 4 shows the changes of energy consumption and output due to increased imports from China depending on the tax rate. Benchmark means without either Chinese imports shock or energy tax. 0% shows the results only of an increased imports from China as shown in the 'Basic I' columns in Tables 5 and 6. The remaining part of the graph shows how the energy tax offsets the increased energy consumption and output caused by Chinese import penetration. With specified functional forms, about 1% of the energy tax is fully offsetting the increased energy and keeping the increased output level. However, with the higher tax rate of about 5% in this figure, the output level gets lower than the benchmark. This means that too strict regulation loses the improved terms of trade in the US even though energy use stays low.

I change the elasticities of substitution in the production function for sensitivity checks. For the baseline analysis, I choose both $\sigma1$ and $\sigma2$ to be equal to 0.5. I simulate the same scenarios with the production function which has less substitutability between factors and more substitutability between factors, respectively[9]. The results are reported in Appendix. As factors are more substitutable, the effects of imports from China and energy tax are very vague. On the other hand, if factors are less likely to be substitutes, manufacturers respond to trade shock and energy tax more sensitively. Overall, except for the magnitude of effect, the results are consistent with the baseline analysis.

4 Empirical Analysis

In this section, I concentrate on how increased imports from China affects energy use in US manufacturing. In the simulation results above, it is shown that the effect is positive even though

[9] I choose 0.3 and 0.8 for these sensitivity analyses.

the magnitude is not large. Using the US manufacturing industry-level panel data from 1997 to 2005, I examine whether increasing imports from China significantly affect energy use and how the effects are different depending on energy sources. In addition, I decompose the effect of increasing imports from China on energy use in US manufacturing into an output scale effect and a factor substitution effect based on the theoretical framework.

4.1 Data

I construct a panel dataset by merging several datasets related to the US manufacturing industries for the period of 1997 to 2005. My base datasets are the Annual Survey of Manufacturers (ASM) collected by the Census Bureau and the NBER's collection described in Schott (2010). The industry classification of the dataset is based on 1997 North American Industry classification (NAICS) codes with 6 digits.

The first dataset, ASM, includes all characteristic variables on the manufacturing sector, divided into 473 industries by the NACIS 6-digit classification[10]. This data provides variables about energy use, such as the total cost of purchased fuels and the quantity of purchased electricity, as well as industrial characteristics such as output[11], employment and capital expenditure. Additionally, I merge the data from the Statistics of US Businesses (SUSB), including the numbers of firms or establishments in each industry of manufacturing, to the previous dataset. This data is also tabulated by industry classification based on NAICS codes with 6 digits[12]. It is difficult to examine exactly how existing firms change their decision about energy use based only on the data at the industrial level. Therefore, it is necessary to control for exit or entry effects caused by increasing competition by imports for each industry. The variable, the number of firms in each industry, can solve the problem caused by data limitation. This means that an increase in the number of firms implies entry must have occurred, and a decrease in the number of firms implies an exit of firms from the industry.

The trade data for the US manufacturing sector comes from the NBER's collection described

[10]This survey had also collected in previous periods. However, this survey was classified by SIC 4-digit classification instead of NAICS 6-digit classification before 1997. This prevents having a longer panel data from earlier years.

[11]I use the value of shipment as a variable on output.

[12]SUSB is annually collected by the Census Bureau. Even though SUSB has surveyed at NAICS 6-digit classification since 1998, the Economic Census has the variable, number of firms and establishments, in 1997. By merging these two sources, I can construct the variable from 1997 to 2005 for the panel dataset.

in Schott (2010). This is also constructed by NAICS 6-digit classification, and among 473 sectors, there are 385 sectors that trade with other countries. This data is used to construct the key independent variable, Chinese import penetration, meaning the ratio of manufacturing imports to total domestic supply for each industry.

$$\text{Chinese Import Penetration}(IP_{i,t}^{China}) = \frac{\text{Imports from China}}{\text{Domestic Output - Exports + Imports}} \tag{23}$$

4.1.1 Constructing Energy Price Index of US Manufacturing

This dataset has the limitation that the actual quantities of used energy are not observed. The existing variables related to energy use include only the total cost of purchased energy[13], the total cost of purchased fuel, and the quantity of purchased electricity. In fact, the quantity of energy use can be easily calculated if I have the energy price of each industry. Even though I cannot observe the energy price, I construct an energy price index to obtain the quantity of purchased energy (and fuel) in each industry using the given information. The energy price index is calculated by multiplying the average energy price in 1997 at NAICS 3-digit classification to the energy deflator ($pien_{i,t}$) at NAICS 6-digit classification for each year[14]. Using the estimated energy price of each industry ($\hat{P}_{i,t}^{E}$), the estimated quantity of energy is calculated by dividing the total cost of purchased energy ($TCE_{i,t}$) by the estimated energy price.

$$\begin{aligned} \hat{P}_{i,t}^{E} &= P_{z,1997}^{E} \cdot pien_{i,t} & \qquad z &= \text{NAICS 3-digit} \\ \hat{Q}_{i,t}^{fuel} &= \frac{TCE_{i,t}}{\hat{P}_{i,t}^{E}} - Q_{i,t}^{elect} & \qquad i &= \text{NAICS 6-digit} \end{aligned} \tag{24}$$

Figure 5 shows the comparison between the estimated average fuel price in manufacturing and the average fuel price for all industries from 1997 to 2005. The dash line shows average fuel price of all industries including agriculture, service, and manufacturing. The solid line is drawn to show the constructed energy price constructed above, and it shows only the average estimated energy price for the US manufacturing sector. Even though these lines are not comparing the price trends of the exact same range of industrial categories, the shape of the trend is very similar. These constructed

[13]In this dataset, energy means the sum of fuel and electricity.

[14]The average energy price in 1997 at NAICS 3-digit classification is from the manufacturing energy consumption survey (MECS) and the energy price deflator at NAICS 6-digit classification is included in the trade dataset of the NBER's collection.

variables of energy use are mainly utilized as dependent variables in the empirical analysis.

4.1.2 UN Comtrade Data

I also use the UN Comtrade database[15] to construct an instrumental variable because Chinese import penetration is potentially endogenous. UN Comtrade is an international database of 6-digit HS commodity level information on all bilateral imports and exports between any given pairs of countries. I extract the bilateral exports from China to the world for the period and aggregate from the 6-digit HS commodity level to the 6-digit NAICS industry level using the concordance of Pierce and Schott (2009). I will explain instrumental variable in detail later.

4.1.3 Descriptive Statistics

The descriptive statistics of the merged and conducted dataset is shown in Table 7. In the regression sample, I drop 36 industries which have negative or greater than 1 import penetration [16]. This gives me a sample of 3,465 trade observations among 4,257 industry observations in US manufacturing for the period from 1997 to 2005.

The main independent variable, Chinese import penetration to the US manufacturing sector varies depending on industries. Traditional labor-intensive sectors such as textile and apparel have absolutely high penetration from China and the rate of their increase is also relatively high. Interestingly, Chinese import penetration of some sectors such as printing, chemical, and machinery, rapidly increased during the period. The rate of increase of imports is even higher than traditional labor-intensive sectors. However, the absolute size of Chinese imports in these sectors is still very low[17].

Changes in energy use in US manufacturing is interesting. Table B.2 shows how energy use of the manufacturing sector has changed depending on energy types. In the case of fuel, as imports from China have increased, the fuel consumption by those industries has decreased. Generally, these two variables move in opposite directions as theoretically predicted. However, in the case of electricity, those who have faced high import penetration from China also use more electricity. For example, NAICS 314 (textile product mills) has increased electricity use by 0.39%. In fact, this is

[15] http://comtrade.un.org/db/

[16] By the definition of import penetration, this index cannot be negative or greater than 1.

[17] See Table B.1.

similar to what is shown in the IO table[18]. Consumption distributions of electricity and fuel are very different across manufacturing industries. Fuels are mostly concentrated in the industries, which are commonly considered to be energy-intensive industries, while electricity use is evenly distributed across all industries. These two points related to electricity demand in US manufacturing suggest that electricity and fuel may be dealt with differently by manufacturers as a production factor.

4.2 Empirical Strategy

To examine how the determinants of energy use in the US manufacturing sector respond to increasing imports from China, the empirical equation is specified as follows[19].

$$E_{i,t} = \alpha_0 + \alpha_1 \cdot IP^{China}_{i,t} + \alpha_2 \cdot LK_{i,t} + \alpha_3 \cdot V.ship_{i,t} + \alpha_4 \cdot (V.ship)^2_{i,t} + \alpha_5 \cdot LK_{i,t}V.ship_{i,t} + \\ \alpha_6 \cdot IP^{China}_{i,t} LK_{i,t} + \alpha_7 \cdot IP^{China}_{i,t} V.ship_{i,t} + \alpha_8 \cdot IP^{China}_{i,t} (LK)^2_{i,t} + \alpha_9 \cdot IP^{China}_{i,t} (V.ship)^2_{i,t} + \epsilon_{i,t} \tag{25}$$

The dependent variables ($E_{i,t}$) are variables about energy use in industry i at time t. $IP^{China}_{i,t}$ is the measure of imports penetration from China, which is the ratio of imports from China to total US domestic supply for industry i at time t. LK is the ratio of payroll to capital expenditure. $V.ship$ is the value of the shipment and its quadratic term is also included. For an alternative specification, total factor productivity (tfp) or the number of firms ($N.firm$) is included. The number of firms in each industry ($N_{i,t}$) helps control for the effect of exit and entry of firms by increasing competition induced by high import penetration. The error term ($\epsilon_{i,t}$) consists of industry fixed effect (θ_i), year fixed effect (ξ_t) and residual term ($v_{i,t}$). All variables are expressed in logarithms and the equation is estimated using fixed effects to control for aggregate variation in energy use and unobservable industry characteristics.

As mentioned in the data description, there are potential endogeneity issues with estimating the equation (24). That is, if there is an unobserved shock that increases energy use of domestic firms in an industry, and imports from China are likely to fall, then this causes a downward bias of the estimated effect. There may be counter examples to show that unobserved shocks could raise energy use and attract more imports from China than other types of imports. To correct for this

[18]See Table 2.

[19]This specification is similar to Cole (2006), but it is different in that industrial specific characteristics are considered.

endogeneity problem, I construct an instrumental variable, the Chinese trade share of world trade, which is not correlated with unobserved shocks. The overall increase in Chinese exports is driven fundamentally by the country's opening to the global economy because of ongoing liberalization by policy makers. Therefore, it is arguably exogenous. The industries in which China has a comparative advantage are the ones that supply most of Chinese exports. The US, one of the biggest trading partners with China, faces a disadvantage in her manufacturing industries due to increasing imports from China. Therefore, Chinese trade share of world trade could be used as an instrumental variable for import penetration from China into the US[20]. The Chinese trade share is the value of exports originating from China as a share of total world exports at the industry level.

As predicted in the simulation model, the marginal effect of increased imports from China is expected to be positive because the structure of the US manufacturing sector would move toward more energy-intensive industries with comparative advantage compared to Chinese manufacturing. Through the decomposition of the trade effect, the factor substitution effect is expected to be negative because factor mobility through this trade with China causes more demand of labor in US manufacturing, and the relative price of energy increses. More labor-intensive industries with high imports from China lead the industries to use less energy. The output scale effect is positive because more output requires more energy consumption as a production factor.

4.3 Empirical Results

The first three columns of Table 8 show the results of basic specifications with the pooled OLS. All specifications include year and industry fixed effects to control for industry-specific macro shocks and time-invariant unobserved variables. The quantity of purchased energy is used as the dependent variable. Because of the interaction terms, the coefficient of Chinese import penetration ('penCHN') itself does not explain the trade effect. To examine the trade effect, I calculate the marginal effect at the sample mean. The marginal effect of increasing imports from China is positive at all specifications, but these are statistically insignificant in the pooled OLS estimation. These results without the interaction terms are shown in Table B.3. The results also show that the trade effect is positive, but statistically insignificant. Unlike the theoretical prediction of the factor substitution effect, the results indicate that such industries facing higher import penetration from

[20] This follows the "value share" approach outlined by Bernard et al. (2006).

China use more energy. However, the marginal effects of factor substitution and output scale effect are both insignificant.

The last three rows in Table 8 show the results of the instrumental variable (IV) regression. In the results of the IV estimation, the marginal effect of an increased imports penetration from China is positive and statistically significant. This means that 1% of increased imports from China increase energy use by about 0.08% to 0.09% in the US[21]. This is consistent with the theoretical prediction and the simulation results in the previous section. These results indicate that the structure of US manufacturing has a comparative advantage against Chinese imports and moves toward more energy-intensive industries. In terms of the factor substitution effect, the IV estimation also does not show the negative effect as predicted. I examine this effect more carefully by separating the dependent variable by energy types in the next section.

4.4 Robustness Checks

4.4.1 Fuel vs. Electricity

Tables 9 and 10 shows the results by energy types: fuel vs. electricity. As mentioned in descriptive statistics of the data, fuel and electricity seem to have different demand patterns in the US manufacturing sector. Therefore, this separation of the dependent variable is quite reasonable to examine. The results are remarkable. In the case of fuel, the results strongly support the theoretical prediction. The trade effect on fuel is positive, while the factor substitution effect is negative. This implies that increasing imports from China cause overall fuel consumption by the US manufacturing sector to rise, but labor-intensive industries in this situation use less fuel. Specifically, all results by IV estimation are statistically significant. IV estimates show that the marginal effect of Chinese import penetration ranges from 0.05 to 0.07, and the factor substitution effect is about -0.02. In addition, higher output associated with import penetration from China leads to more fuel use. That is, the industries with comparative advantages against China expand their production more, resulting in more fuel consumption.

In the case of electricity, the result of the trade effect is consistent with the previous results: more imports from China also increase electricity demand by the US manufacturers. However, the

[21] All specifications show similar results. The results are shown in Table B.4.

direction of the factor substitution effect is opposite of the theoretical prediction. These results mean that labor-intensive industries having high Chinese import penetration, causing them to use more electricity. This is the opposite of the result of fuel consumption. The IV estimates are shown in the last three columns in Table 10, in which all results are more significant than the pooled OLS estimates. The coefficient is about 0.03 for all specifications. This suggests that electricity could have the potential to easily replace labor. Therefore, labor-intensive industries use more electricity, thus reducing labor. Further research could investigate the substitutability of non-energy inputs such as labor and capital, with each energy type: fuel and electricity.

4.4.2 Exit and Entry

Increasing imports from China possibly causes domestic firms to face higher competition. It is possible that this causes the domestic firms to exit from the market. Therefore, it is necessary to control for this effect. Because of the limitation of industry level data, how each firm responds to this increase in competition is not observable. Instead, I control for the number of firms in each industry. The IV regression results from adding the number of firms are reported in Table B.6 for fuel and B.8 for electricity. Since the coefficient of the number of firms on fuel is significantly positive, this means that the industries in which entry of firms occurs use energy more. As a result of controlling for the number of firms, the calculated marginal effect of Chinese import penetration is slightly larger. The magnitude of the factor substitution effect of fuel also increases to -0.048. However, for electricity, the number of firms does not significantly affect the electricity demand.

5 Discussion

I investigate the determinants of energy use in the US manufacturing sector in response to increasing imports from China. The modified Heckscher-Ohlin model, by adding energy tax, indicates that energy tax can offset the raised energy use of producers in the North caused by increased imports from the South. The energy tax magnifies the factor substitution effect which has a negative effect on energy use. Therefore, energy use in the North can be reduced while the output is raised.

The simulation results show that increasing imports cause all manufacturing industries to use more energy, proportionally increasing the output of each industry. However, the magnitude of the effect of trade with China is very small. A 10% fall in the price of Chinese imports causes the total energy consumption in US manufacturing to increase by only 0.5%. On the other side, manufacturers respond sensitively to the energy tax such that a 1% rise in energy tax results in a 1% fall in energy consumption and 0.13% decrease in output, with all other prices holding constant. Each industry changes its energy use differently depending on the industry's factor intensity. Higher energy-intensive industries reduce energy use more than other industries. Combining these two scenarios of increasing imports from China and an energy tax can produce an outcome consistent with the data, decreasing energy consumption yet increasing output. Interestingly, total energy use in the manufacturing sector can fall at the same time as US welfare increases due to improved terms of trade.

As reported in the simulation model, my empirical results of IV estimation also show the overall positive trade effect of increasing imports from China on consumption of fuels and electricity. The marginal effect of Chinese import penetration is small, at about 0.08%, but is statistically very significant. However, the direction of factor substitution effects on fuel and electricity are opposite. Increasing imports from China decrease the ratio of labor over fuel, but increase that of labor over electricity.

6 Conclusions

Although imports from China continue to rise, total energy use in US manufacturing continues to decline. This trend is inconsistent with the traditional factor endowment trade theory prediction. To find the determinants of energy consumption in US manufacturing, I modify the Hechscher-Ohline model by adding energy tax in the North as a domestic regulation on energy use. The energy tax reveals the preference of lowering energy use, and causes increasing imports from the South to be different from the traditional H-O model prediction. Without the energy tax, the North has a comparative advantage on energy-intensive industries and increases energy use as imports from the South increase. However, the energy tax can lead the North to use less energy because there will be a substitution both away from energy-intensive industries and from energy use within industries. Increased imports from the South combined with the energy tax can bring the result that the North uses less energy than before and increases welfare due to its improved terms of trade.

I conduct the CGE model of the US economy using the US input-output table for the base year 2005. I simulate several types of scenarios related to a Chinese import shock (due to a price shock) with or without an offsetting energy tax. The numerical results show that increased imports from China cause all manufacturing industries in the US to use more energy even though the magnitude of the effect is very small. However, the energy-decreasing effect of an energy tax dominates the energy-increasing effect of imports from China with a low rate of tax, while the positive welfare effect of trade still holds. However, even without an offsetting energy tax, the effect of an increase in Chinese import penetration on energy use in US manufacturing is estimated to be very small.

Using the US manufacturing industry-level panel data, the effect of increasing imports from China is decomposed into an effect on factor use and an effect on output. Since import penetration is potentially endogenous, I instrument using the Chinese trade share of world trade for Chinese import penetration to US manufacturing. Consistent with the simulation results, the magnitude of the effect is small, but it is positive and statistically significant. The interesting findings from the decomposition of the trade effect is that the factor substitution effect and output scale effect have the opposite effect on consumption of fuels and electricity. In the case of fuel, the factor substitution effect is negative and the output scale effect is positive. This means that increasing imports from China decrease the ratio of labor over fuel within industries, and as output increases due to increased Chinese import penetration, the industries use more fuels. This result is exactly consistent with the prediction of traditional trade theory. However, the opposite results are shown in the case of electricity. The factor substitution effect on electricity is positive which means that electricity is considered to be substitutable with labor rather than fuels. Once the effect of Chinese import penetration is decomposed, I find opposite effects depending on energy types: while the factor substitution effect on fuel is positive, the factor substitution effect on electricity is negative even though the effect of Chinese import penetration on fuel and electricity are both significantly positive.

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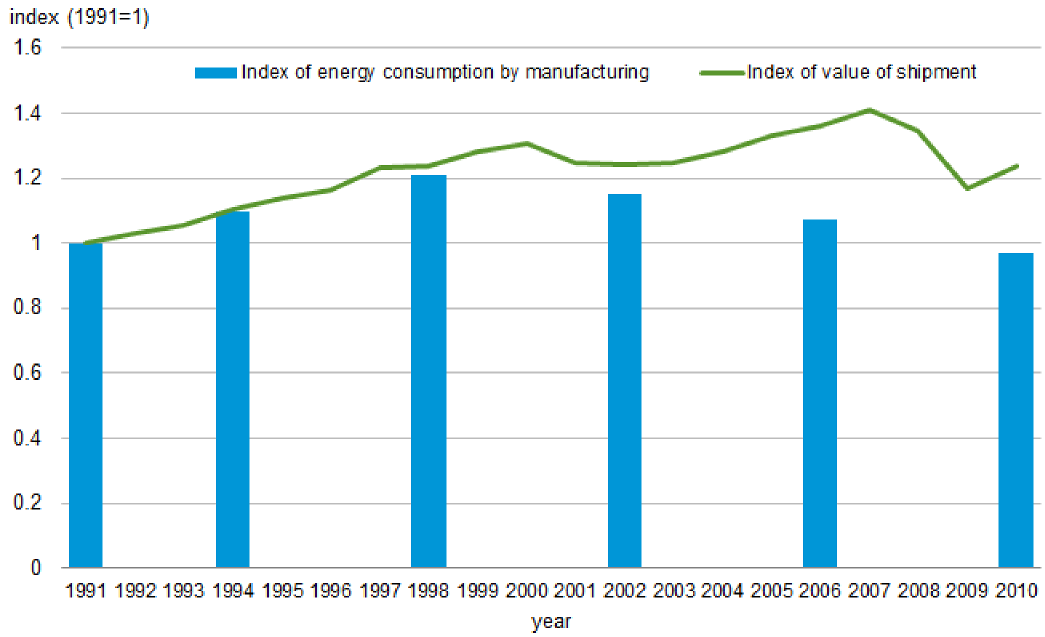
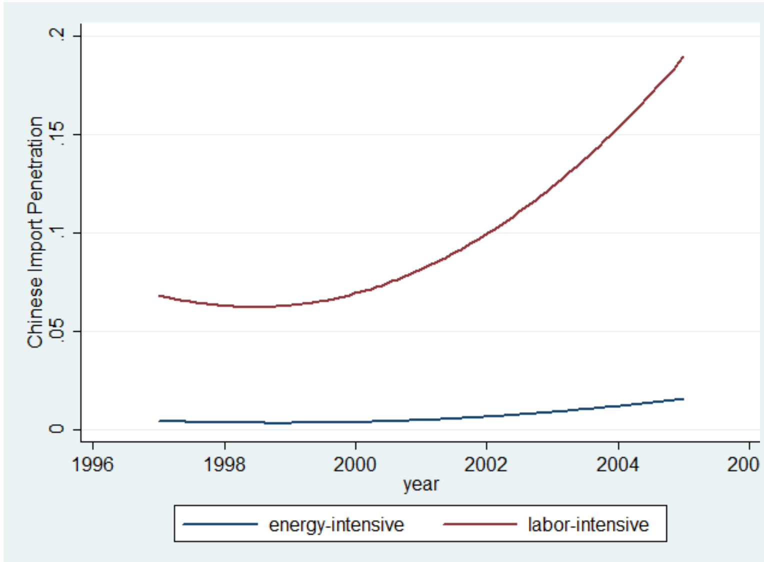
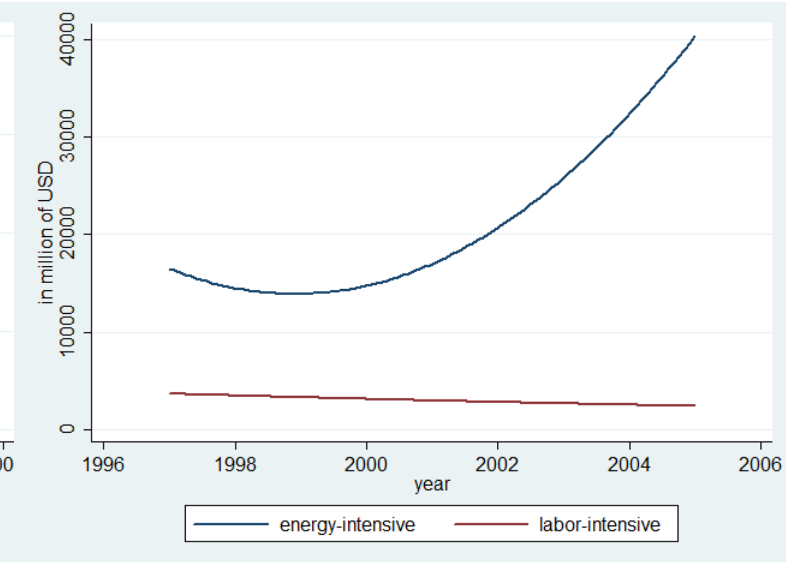


Figure 1: Total energy consumption and value of shipments by U.S. manufacturing

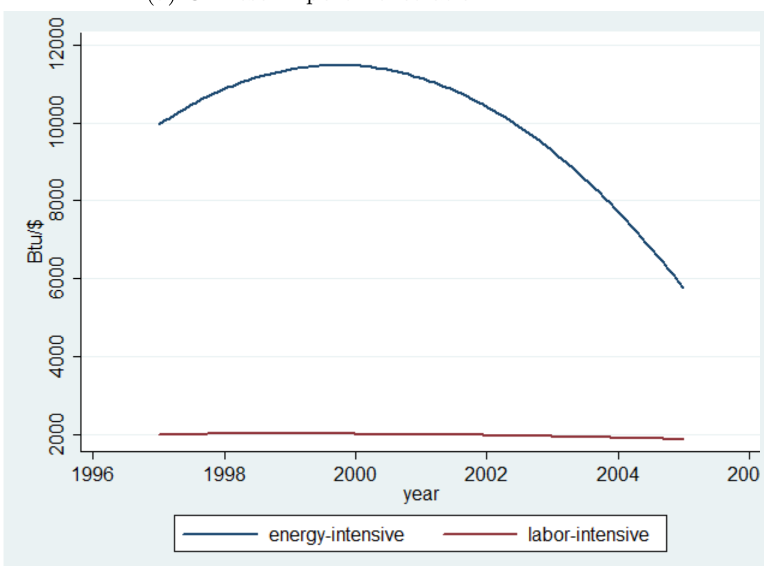
Note: Value of shipment is based on monetary value of shipment collected from the Census Bureau.
Source: US Energy Information Administration



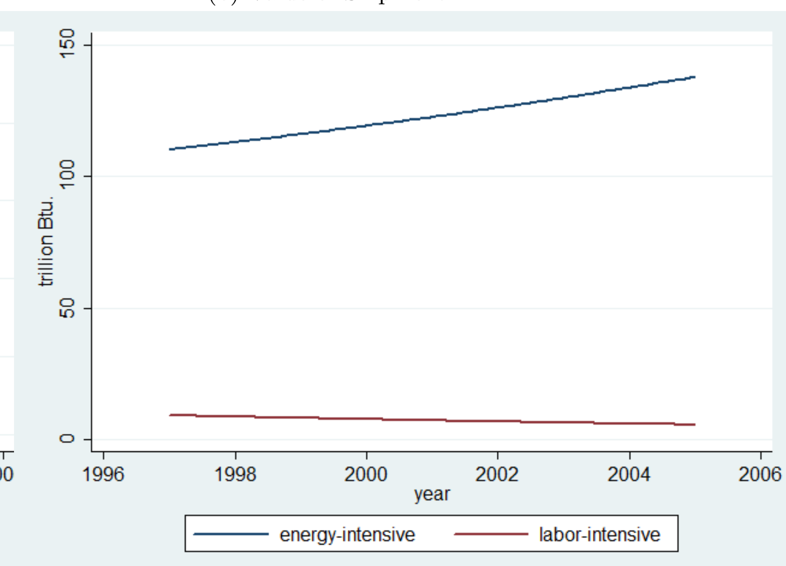
(a) Chinese Import Penetration



(b) Value of Shipment

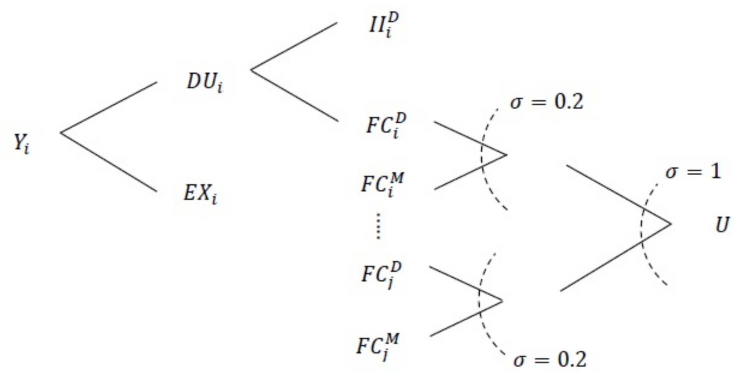


(c) Energy intensity

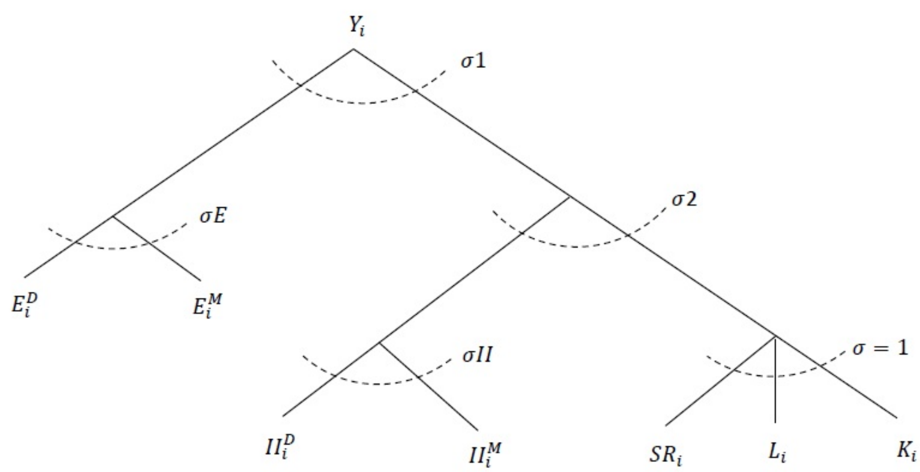


(d) Quantity of Energy Use

Figure 2: US Manufacturing from 1997 to 2005



(a) Overview of CGE Model



(b) Production Structure of CGE Model

Y_i	Domestic output of a sector i
DU_i	Output domestically consumed
EX_i	Exports
FC_i^D	Final consumption of domestic output
FC_i^M	Final consumption of imported goods
E_i^D	Domestic energy intermediate inputs
E_i^M	Imported energy intermediate inputs
II_i^D	Domestic intermediate inputs of manufacturing
II_i^M	Imported intermediate inputs of manufacturing
L_i	Labor
K_i	Capital
SR_i	Service intermediate inputs
σ	Elasticity of substitution

Figure 3: Structure of CGE Model

Table 1: Selected Elasticities

Elasticity of substitution	Meaning	Selected Value
$\sigma 1$	Between composite factor and intermediate inputs	0.5
$\sigma 2$	Between energy and other inputs	0.5
σ_E	Armington elasticities for energy	0.2
σ_{II}	Armington elasticities for intermediate inputs	0.2

Table 2: Fixed Parameters after Calibration

Parameter	Meaning
α	Cost share of composition factor(α_{sr}, α_l and α_k)
β	Distribution between intermediate inputs and composite factor
δ	Distribution between energy and other inputs
γ	Expenditure share of consumption
λ	Distribution between domestic and imported energy inputs
κ	Distribution between domestic and imported intermediate inputs
μ	Distribution between domestic and imported final consumption

Table 3: Production sectors in the US IO table

		Proportion of energy use (%)			cost share(%)		
	Sectors	1	2	7	1	2	7
	Energy						
1	Mining and quarrying	10.5	1.4	3.5	13.64	0.03	2.80
2	Electricity, gas and water supply	23.0	1.7	1.8	28.10	0.00	1.40
	Manufacturing						
3	Food products, beverages and tobacco	0.1	3.7	0.7	0.09	13.40	0.32
4	Textiles, textile products leather and footwear	0.0	0.5	0.2	0.09	0.90	0.70
5	W.ood and products of wood and cork	0.0	0.4	0.2	0.04	0.07	0.49
6	Pulp, paper, paper products, printing and publishing	0.2	2.2	1.1	0.18	0.20	0.68
7	Coke, refined petroleum products and nuclear fuel	51.6	2.9	12.1	58.81	0.08	8.50
8	Chemicals and chemical products	3.0	3.3	8.3	2.59	0.49	4.48
9	Rubber and plastics products	0.1	1.0	1.0	0.14	0.20	1.58
10	Other non-metallic mineral products	1.4	1.3	0.2	6.55	0.08	0.61
11	Basic metals	1.7	1.7	0.9	4.27	0.09	1.42
12	Fabricated metal products except machinery and equipment	0.1	1.3	0.5	0.10	0.05	0.58
13	Machinery and equipment n.e.c	0.0	0.7	0.4	0.07	0.04	0.45
14	Electrical and optical equipment	0.1	1.0	0.3	0.30	0.20	0.73
15	Motor vehicles, trailers and semi-trailers	0.5	0.7	0.4	0.52	0.04	0.24
16	Other transport equipment	0.0	0.3	0.3	0.04	0.05	0.49
17	Manufacturing n.e.c.; recycling	0.1	0.6	0.2	0.13	0.21	0.30
	All other sectors						
18	Other industries	7.7	75.2	67.9	0.23	0.83	1.24
	Total	100	100	100			

Table 4: Scenarios related to increased imports from China and energy tax

	Description
a. Basic Scenario I	Increasing imports from China by price shock (10%)
b. Basic Scenario II	Energy tax in manufacturing (1%)
c. Combined Scenario	Increasing imports from China and energy use tax in manufacturing

Table 5: Changes in intermediate energy input by US manufacturing

		Basic I		Basic II		Combined	
Sectors	Benchmark	△	%	△	%	△	%
3	11447.898	11474.436	(0.232)	11335.586	(-0.981)	11361.842	(-0.752)
4	2134.940	2144.179	(0.433)	2106.009	(-1.355)	2115.150	(-0.927)
5	1471.028	1476.351	(0.362)	1454.615	(-1.116)	1459.886	(-0.757)
6	9709.872	9728.504	(0.192)	9626.411	(-0.860)	9644.856	(-0.670)
8	49800.213	50075.040	(0.552)	49429.389	(-0.745)	49701.310	(-0.199)
9	5840.354	5870.705	(0.520)	5776.091	(-1.100)	5806.114	(-0.586)
10	11145.230	11176.058	(0.277)	11021.067	(-1.114)	11051.481	(-0.841)
11	15472.037	15653.767	(1.175)	15249.678	(-1.437)	15428.744	(-0.280)
12	4929.398	4944.529	(0.307)	4871.063	(-1.183)	4886.053	(-0.879)
13	3305.038	3323.561	(0.560)	3264.258	(-1.234)	3282.587	(-0.679)
14	3615.331	3655.203	(1.103)	3575.238	(-1.109)	3614.691	(-0.018)
15	5513.878	5589.704	(1.375)	5419.935	(-1.704)	5494.610	(-0.349)
16	1814.079	1821.898	(0.431)	1789.766	(-1.340)	1797.510	(-0.913)
17	2318.413	2326.054	(0.330)	2294.107	(-1.048)	2301.678	(-0.722)
Total	128517.708	129259.990	(0.578)	127213.214	(-1.015)	127946.513	(-0.444)

Table 6: Changes in output by US manufacturing

		Basic I		Basic II		Combined	
Sectors	Benchmark	△	%	△	%	△	%
3	662198.908	663734.028	(0.232)	662259.323	(0.009)	663793.286	(0.241)
4	108567.065	109036.886	(0.433)	108166.815	(-0.369)	108636.304	(0.064)
5	111587.472	111991.221	(0.362)	111445.816	(-0.127)	111849.654	(0.235)
6	531117.804	532137.006	(0.192)	531818.168	(0.132)	532837.204	(0.324)
8	593141.040	596414.307	(0.552)	594611.589	(0.248)	597882.665	(0.799)
9	195858.452	196876.303	(0.520)	195640.433	(-0.111)	196657.306	(0.408)
10	113815.360	114130.301	(0.277)	113673.002	(-0.125)	113986.700	(0.151)
11	203253.382	205640.747	(1.175)	202335.621	(-0.452)	204711.511	(0.717)
12	284670.354	285544.164	(0.307)	284114.591	(-0.195)	284988.910	(0.112)
13	315536.828	317305.237	(0.560)	314759.894	(-0.246)	316527.339	(0.314)
14	452781.503	457774.986	(1.103)	452237.787	(-0.120)	457228.303	(0.982)
15	494721.674	501524.959	(1.375)	491155.709	(-0.721)	497922.714	(0.647)
16	189990.403	190809.368	(0.431)	189318.561	(-0.354)	190137.650	(0.078)
17	227122.748	227871.332	(0.330)	226989.025	(-0.059)	227738.187	(0.271)
Total	4484362.993	4510790.846	(0.589)	4478526.335	(-0.130)	4504897.732	(0.458)

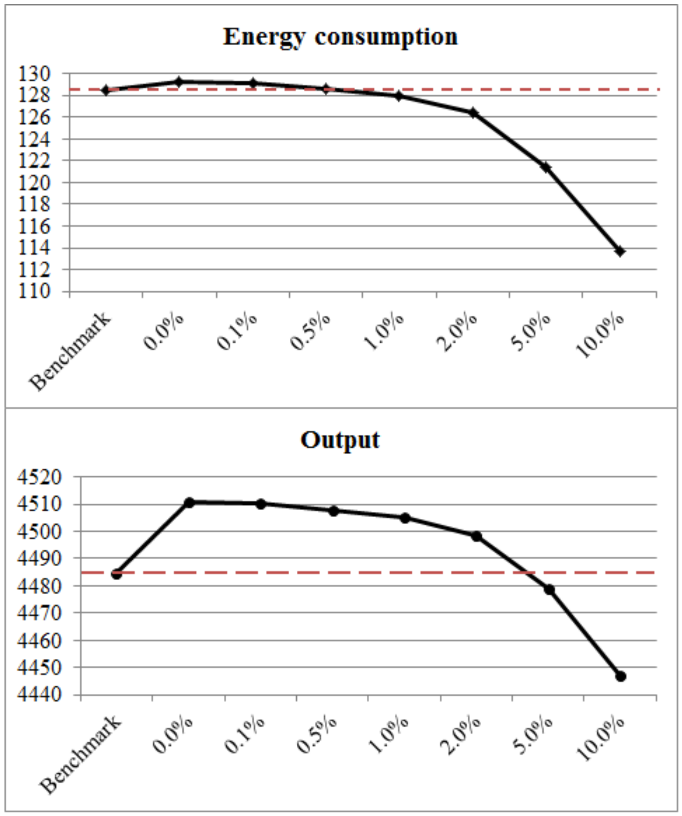


Figure 4: Changes depending on tax rate

Note: Except the benchmark, all results of taxes are based on increasing imports from China.

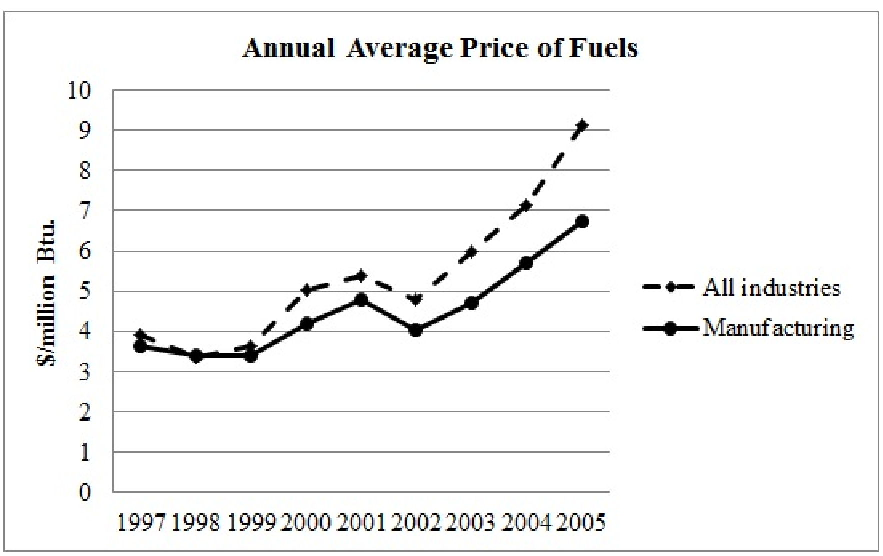


Figure 5: Comparison of energy price for all industries and energy price index for US manufacturing

Note: The dash line shows the annual average price of fuels for all industrial sectors including construction, agriculture as well as manufacturing sector. The solid line is calculated by the constructed energy price.

Table 7: Summary statistics of US manufacturing

Variable	Mean	Std. Dev.	Min.	Max.
Industrial Characteristics (N=4257)				
Value of shipment	8669.4	17143.7	98	445910
Employment	32.4	44.0	0.8	554.9
Payment	1235.0	1741.1	19.9	16162.9
Material Cost	4561.6	11678.0	34.8	345883.1
Value added	4122.4	7072.2	51.7	104711.5
Capital Expenditure	288.8	669.2	1.1	14583.6
Number of firms	670.4	1593.6	3	23787
Industrial Trade (N=3465)				
Imports	2646.9	7145.7	0	126324.8
Exports	1730	4102.0	0	60005.5
Imports from low-wage countries	407.5	1145.0	0	19380.7
Imports from China	320.2	1035.3	0	18961.4
Tariff	0.021	0.034	0	0.517
Variables related to Industrial Energy Use				
Total energy cost	158.9	482.4	0	11246.1
Total electric cost	86.4	188.1	0	2626.8
Total fuels cost	74.0	323.2	0	8619.4
Quantity of electricity (1000 Kwh)	1782.2	4570.6	0	60552.5
Energy Price	8.654	3.1	2.4	16.1
Quantity of energy purchased (million Btu)	28.3	107.1	0.07	1760.7
Quantity of electric purchased (million Btu)	6.1	15.6	0	206.6
Quantity of fuels purchased (million Btu)	22.3	94.6	0.01	1607.4

Table 8: Estimation on the quantity of energy

	Fixed effects			IV Fixed effects		
MODEL VARIABLES	A	B	C	A	B	C
penCHN	0.0234	-0.188***	-0.808***	0.108***	-0.00247	-0.136
	(0.0155)	(0.0512)	(0.210)	(0.0209)	(0.0739)	(0.233)
L/K	-0.107	-0.309	-0.405*	-0.200	-0.296*	-0.317*
	(0.251)	(0.257)	(0.241)	(0.161)	(0.168)	(0.167)
vship	1.456***	1.492***	2.261***	1.469***	1.484***	1.635***
	(0.285)	(0.275)	(0.313)	(0.158)	(0.158)	(0.255)
sqvship	-0.0551***	-0.0495***	-0.0968***	-0.0538***	-0.0511***	-0.0602***
	(0.0157)	(0.0154)	(0.0176)	(0.00859)	(0.00857)	(0.0147)
LKvship	0.0312	0.0512*	0.0623**	0.0427**	0.0522***	0.0547***
	(0.0300)	(0.0309)	(0.0286)	(0.0180)	(0.0189)	(0.0191)
penCHNLK	0.0125	0.00333	0.000784	0.0125	0.00801	0.00760
	(0.00795)	(0.00790)	(0.00787)	(0.00856)	(0.00851)	(0.00834)
penCHNvship		0.0238***	0.173***		0.0117	0.0424
		(0.00591)	(0.0475)		(0.00720)	(0.0496)
penCHNsqvship			-0.00885***			-0.00177
			(0.00264)			(0.00274)
Observations	3,313	3,313	3,313	3,204	3,204	3,204
R-squared	0.405	0.416	0.425	0.353	0.371	0.377
Number of NAICS	380	380	380	363	363	363
Marginal Effects						
penCHN	0.0108	0.0089	0.0055	0.0956***	0.0876***	0.0854***
	(0.0099)	(0.0101)	(0.0010)	(0.0190)	(0.0204)	(0.0211)
penCHNLK	0.0125	0.0033	0.0008	0.0125	0.0080	0.0076
	(0.0076)	(0.0079)	(0.0079)	(0.0086)	(0.0085)	(0.0083)
penCHNvship		0.0238	0.0984		0.0117	0.0275
		(0.0059)	(0.0256)		(0.0072)	(0.0270)

Note: All model specifications use time-fixed effects. Elasticities are evaluated at sample means using the Delta method. *** < 0.01, ** < 0.05, * < 0.1

Table 9: Estimation on the quantity of fuel

	Fixed effects			IV Fixed effects		
MODEL VARIABLES	A	B	C	A	B	C
penCHN	0.00302	-0.226***	-1.054***	0.0571***	-0.0879	-0.478**
	(0.0162)	(0.0553)	(0.2270)	(0.0212)	(0.0754)	(0.2350)
L/K	0.0636	-0.16	-0.292	-0.118	-0.245	-0.308
	(0.3180)	(0.3260)	(0.2980)	(0.1920)	(0.2010)	(0.1990)
vship	1.526***	1.566***	2.594***	1.620***	1.640***	2.081***
	(0.2940)	(0.2890)	(0.3560)	(0.1740)	(0.1760)	(0.2830)
sqvship	-0.0593***	-0.0532***	-0.116***	-0.0621***	-0.0585***	-0.0850***
	(0.0163)	(0.0163)	(0.0213)	(0.0095)	(0.0095)	(0.0162)
LKvship	0.00158	0.0237	0.0392	0.0169	0.0296	0.0372*
	(0.0387)	(0.0398)	(0.0362)	(0.0211)	(0.0220)	(0.0218)
penCHNLK	-0.00408	-0.0140*	-0.0174**	-0.0154	-0.0211**	-0.0222**
	(0.0085)	(0.0082)	(0.0083)	(0.0096)	(0.0096)	(0.0096)
penCHNvship		0.0258***	0.225***		0.0153**	0.105**
		(0.0064)	(0.0522)		(0.0074)	(0.0498)
penCHNsqvship			-0.0118***			-0.00517*
			(0.0030)			(0.0027)
Observations	3,296	3,296	3,296	3,187	3,187	3,187
R-squared	0.425	0.435	0.447	0.396	0.412	0.425
Number of NAICS	380	380	380	363	363	363
Marginal Effects						
penCHN	0.0071	0.0052	0.0006	0.0727***	0.0621***	0.0557**
	(0.0105)	(0.0105)	(0.0104)	(0.0207)	(0.0220)	(0.0222)
penCHNLK	-0.0041	-0.0140*	-0.0174**	-0.0154	-0.0211**	-0.0222**
	(0.0085)	(0.0082)	(0.0083)	(0.0096)	(0.0096)	(0.0096)
penCHNvship		0.0258***	0.1254***		0.0153**	0.0616**
		(0.0064)	(0.0274)		(0.0074)	(0.0273)

Note: All model specifications use time-fixed effects. Elasticities are evaluated at sample means using the Delta method. *** < 0.01, ** < 0.05, * < 0.1

Table 10: Estimation on the quantity of electricity

	Fixed effects			IV Fixed effects		
MODEL VARIABLES	A	B	C	A	B	C
penCHN	0.0360**	-0.0866	-0.296	0.109***	0.121	0.488*
	(0.0167)	(0.0614)	(0.2660)	(0.0243)	(0.0882)	(0.2850)
L/K	-0.348	-0.467*	-0.501*	-0.371**	-0.360*	-0.301
	(0.2480)	(0.2560)	(0.2650)	(0.1820)	(0.1980)	(0.2080)
vship	1.512***	1.533***	1.793***	1.482***	1.480***	1.066***
	(0.2900)	(0.2830)	(0.3750)	(0.1600)	(0.1620)	(0.3260)
sqvship	-0.0590***	-0.0557***	-0.0717***	-0.0560***	-0.0563***	-0.0314*
	(0.0154)	(0.0153)	(0.0204)	(0.0084)	(0.0082)	(0.0185)
LKvship	0.0714***	0.0832***	0.0871***	0.0791***	0.0781***	0.0709***
	(0.0269)	(0.0276)	(0.0286)	(0.0196)	(0.0212)	(0.0226)
penCHNLK	0.0260***	0.0207**	0.0198**	0.0331***	0.0336***	0.0347***
	(0.0092)	(0.0095)	(0.0095)	(0.0097)	(0.0101)	(0.0103)
penCHNvship		0.0138**	0.0642		-0.00131	-0.0857
		(0.0070)	(0.0600)		(0.0082)	(0.0599)
penCHNsqvship			-0.00299			0.00486
			(0.0033)			(0.0033)
Observations	3,296	3,296	3,296	3,187	3,187	3,187
R-squared	0.339	0.342	0.343	0.316	0.314	0.303
Number of NAICS	380	380	380	363	363	363
Marginal Effects						
penCHN	0.0098	0.0088	0.0077	0.0751***	0.0760**	0.0821**
	(0.0111)	(0.0116)	(0.0115)	(0.0224)	(0.0250)	(0.0265)
penCHNLK	0.0260***	0.0207**	0.0198**	0.0331***	0.0336***	0.0347***
	(0.0092)	(0.0095)	(0.0095)	(0.0097)	(0.0101)	(0.0103)
penCHNvship		0.0138**	0.039		-0.0013	-0.0449
		(0.0070)	(0.0323)		(0.0082)	(0.0326)

Note: All model specifications use time-fixed effects. Elasticities are evaluated at sample means using the Delta method. *** < 0.01, ** < 0.05, * < 0.1

Appendix

A Data: the US Input-Output Table

To analyze the model above, I use the US input-output (IO) table for the base year 2005. In this section, I overview the typical structure of IO tables and examine the specific feature of the US economy, especially focusing on the energy use in manufacturing.

A.1 IO tables: An Overview

An IO table describes the flows among the various sectors of the economy to present a static image for a given year. Figure A.1 shows the structure of a typical IO table. Each row of intermediate inputs contains transactions of the output of a sector. These transactions are broadly broken down by intermediate use and final consumption. For example, the value of cell DI_{ij} in the domestic intermediate use matrix shows how much sector j uses the products from sector i as intermediate inputs. The domestic intermediate use matrix (DI) means the intermediate uses which is produced in domestic, while the imported intermediate use matrix (II) contains the imported intermediate uses for each sector. Final consumption is divided into three parts: private consumption (C), government consumption(G), and investment(I). There are also domestic and imported goods and services in final consumption. Finally, trade is also shown in the IO table. Export is captured as part of production through this column and Import with tariff should be subtracted to calculate the transactions of domestic outputs.

The columns of intermediate use shows the cost structure of production activities: intermediate inputs, compensation to labor and capital, taxes on production. If an IO table is balanced, then columns sum of production sectors should be the same as the row sum of domestic production sectors because total input equals total output.

A.2 The US Input-Output Table in 2005

I obtain the US input-output table from OECD website[22]. This IO table's format corresponds exactly to an IO table described in the previous section[23]. For simplicity, I have aggregated sectors

[22] www.oecd.org/sti/inputoutput/

[23] It can be provided on request.

into three parts: energy, manufacturing and aggregated for all other industries. Energy sector includes two industries: 1) mining and quarrying, and 2) utility (electricity, gas and water supply). Manufacturing sector includes 15 detailed industries according to IO classification. Table 3 shows the list of industry classifications used in the numerical analysis. All remaining sectors are aggregated into the sector, 'other industries' which includes agriculture, construction, and services.

I focus on energy use in the manufacturing sector. Among manufacturing industries, the industry, 'coke, refined petroleum products and nuclear fuel' also should be considered as an energy sector. Therefore, I examine how three energy uses including refined petroleum of manufacturing sectors are affected by increasing imports from China with energy tax. Table 3 shows how energy use is distributed across industrial sectors. Mining and quarrying is mostly used by energy sectors. Refined petroleum industry is the biggest consumer for mining and quarrying. About electricity and refined petroleum, manufacturing sector demands relatively about 21.6% and 26.8% of total energy use by the industrial sectors. It shows that energy is one of the important intermediate inputs for producing manufacturing goods. The columns of energy cost share in Table 3 show the ratio of energy cost related to total production cost. These columns are rather interesting in that electricity cost share is quite similar across industries, while fuel cost share of chemical, rubber, plastic products is much higher than other industries. These industries are traditionally considered as energy intensive industries. On the other hand, food and textile industries has high electricity cost share. Through these differences in energy cost share, electricity and fuel are predicted to be differently considered as a product factor even though both are types of energy.

In order to examine how US energy use in manufacturing responds to increased imports from China, the import column in the IO table should be divided into two parts: imports from China and imports from the rest of world. To construct, I use the bilateral trade database from OECD[24]. This data provides bilateral trade value by industry and end-use. I assume the tariff of each sector is consistent regardless trading partners. If examined closely, the imports from China takes a very significant portion in each industry. Specially, the industry of textile and related products are imported from China more than 50% out of total imports in the sector. Interestingly, the industry of machinery and equipment is also imported a lot from China. The pattern of imports from China can be divided into two parts: labor intensive industries which are traditionally predicted by trade

[24]The STAN Bilateral Trade Database from www.oecd.org/sti/btd

theory and which are relatively close to energy intensive industries such as metal and machinery.

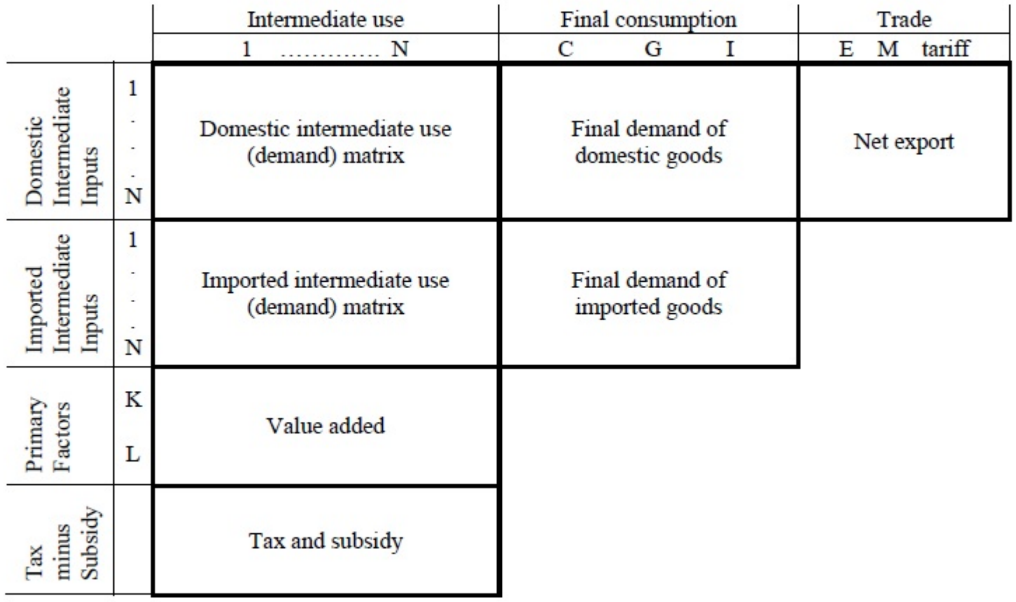


Figure A.1: Structure of IO table

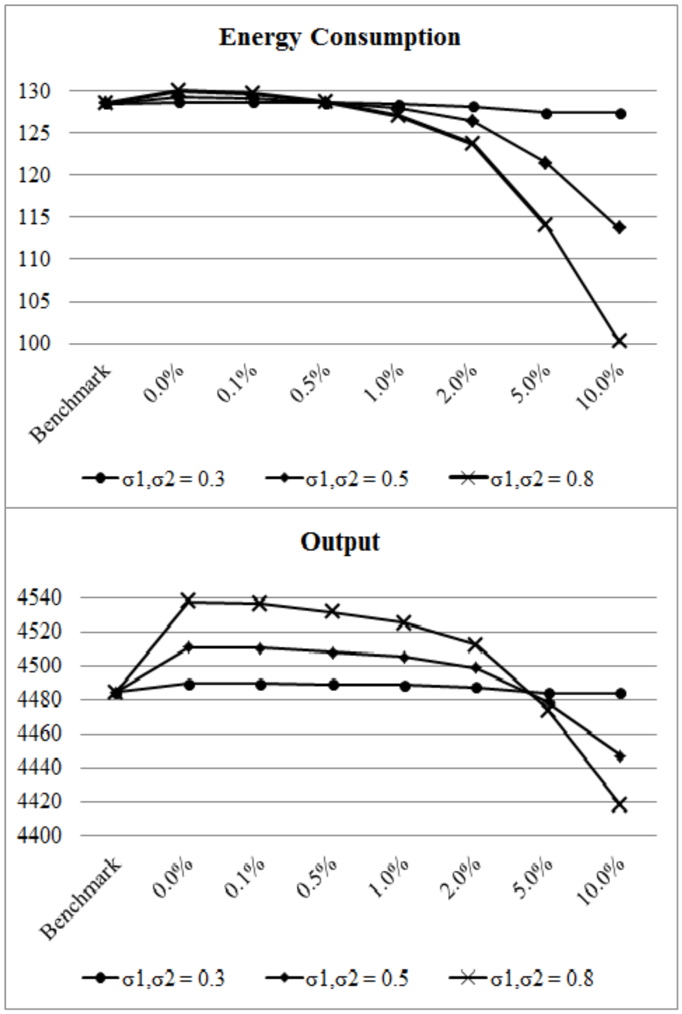


Figure A.2: Sensitivity Checks

B Empirical Analysis

Table B.1: Import Penetration from China into US manufacturing, 1997-2005

Sectoral Description	NAICS code	**Chinese Import Penetration** 1997	2005	Changes 2005-1997	%
Food	311	0.002	0.006	0.004	1.90
Beverage and Tobacco Product	312	0.000	0.000	0.000	0.62
Textile Mills	313	0.006	0.075	0.070	12.11
Textile Product Mills	314	0.027	0.123	0.096	3.61
Apparel	315	0.115	0.286	0.171	1.48
Leather and Allied Product	316	0.306	0.511	0.205	0.67
Wood Product	321	0.007	0.027	0.019	2.68
Paper	322	0.019	0.039	0.020	1.03
Printing and Related Support Activities	323	0.023	0.117	0.094	4.13
Petroleum and Coal Products	324	0.000	0.000	0.000	0.63
Chemical	325	0.004	0.018	0.014	3.54
Plastics and Rubber Products	326	0.006	0.023	0.017	2.98
Nonmetalic Mineral Product	327	0.017	0.048	0.031	1.89
Primary Metal	331	0.006	0.021	0.015	2.37
Fabricated Metal Product	332	0.011	0.051	0.039	3.52
Machinery	333	0.013	0.062	0.049	3.78
Computer and Electronic Product	334	0.029	0.124	0.094	3.25
Electrical Equipment, Appliance, and Component	335	0.048	0.129	0.081	1.67
Transportation Equipment	336	0.004	0.013	0.009	2.33
Furniture and Related Product	337	0.030	0.128	0.097	3.22
Miscellaneous	339	0.100	0.194	0.094	0.94
All sectors		0.030	0.082	0.052	1.70

Table B.2: Changes in Energy Use in US Manufacturing, by sectors 1997-2005

	Quantity of Purchased Fuels				Quantity of Purchased Electricity			
			Changes				Changes	
NAICS	1997	2005	2005-1997	%	1997	2005	2005-1997	%
311	16.581	18.926	2.345	0.14	4.115	5.722	1.607	0.39
312	9.587	9.987	0.400	0.04	2.900	3.550	0.650	0.22
313	14.061	9.144	-4.917	-0.35	8.109	6.172	-1.938	-0.24
314	4.438	3.864	-0.574	-0.13	2.031	2.825	0.794	0.39
315	1.802	0.497	-1.305	-0.72	1.003	0.495	-0.508	-0.51
316	0.694	0.385	-0.309	-0.45	0.320	0.325	0.005	0.01
321	9.748	10.189	0.440	0.05	5.328	6.817	1.489	0.28
322	66.552	62.218	-4.334	-0.07	11.951	12.862	0.911	0.08
323	3.703	3.173	-0.531	-0.14	4.062	5.166	1.103	0.27
324	227.241	350.000	122.759	0.54	27.287	33.552	6.265	0.23
325	70.779	92.387	21.608	0.31	15.764	15.116	-0.648	-0.04
326	8.834	9.206	0.372	0.04	10.010	13.173	3.162	0.32
327	35.806	40.099	4.293	0.12	5.349	6.595	1.246	0.23
331	56.510	79.591	23.081	0.41	17.402	17.923	0.522	0.03
332	5.873	4.871	-1.002	-0.17	3.294	4.201	0.907	0.28
333	2.302	1.782	-0.520	-0.23	1.876	2.115	0.238	0.13
334	2.899	2.206	-0.693	-0.24	4.300	3.936	-0.363	-0.08
335	18.743	16.417	-2.326	-0.12	2.549	2.494	-0.055	-0.02
336	9.380	7.910	-1.470	-0.16	6.050	6.592	0.542	0.09
337	2.528	1.920	-0.608	-0.24	2.207	2.601	0.393	0.18
339	1.762	1.511	-0.251	-0.14	1.401	1.874	0.473	0.34
All	20.936	24.692	3.757	0.18	5.938	6.552	0.614	0.10

Table B.3: Pooled OLS Estimation on the Quantity of Energy

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
lgpenCHN	0.00955	0.00676	0.00705	0.0234	-0.188***	-0.194***	-0.808***	-1.029***	-0.799***	-0.764***
	(0.00962)	(0.00923)	(0.00918)	(0.0155)	(0.0512)	(0.0583)	(0.210)	(0.235)	(0.207)	(0.208)
lgLK	0.0657	0.0826	-0.213	-0.107	-0.309	0.115	-0.405*	-0.0110	-0.299	-0.227
	(0.0849)	(0.0763)	(0.251)	(0.251)	(0.257)	(0.348)	(0.241)	(0.323)	(0.276)	(0.280)
lgvship	0.520***	1.355***	1.525***	1.456***	1.492***	1.286***	2.261***	2.316***	2.147***	1.932***
	(0.0565)	(0.227)	(0.260)	(0.285)	(0.275)	(0.285)	(0.313)	(0.348)	(0.291)	(0.292)
sqlgvship		-0.0508***	-0.0580***	-0.0551***	-0.0495***	-0.0393**	-0.0968***	-0.103***	-0.0922***	-0.0820***
		(0.0131)	(0.0144)	(0.0157)	(0.0154)	(0.0162)	(0.0176)	(0.0209)	(0.0164)	(0.0161)
LKvship			0.0355	0.0312	0.0512*	-0.00807	0.0623**	0.00660	0.0497	0.0448
			(0.0303)	(0.0300)	(0.0309)	(0.0435)	(0.0286)	(0.0401)	(0.0347)	(0.0344)
penCHNLK				0.0125	0.00333	-0.0360**	0.000784	-0.0401**	-0.00242	0.00671
				(0.00795)	(0.00790)	(0.0155)	(0.00787)	(0.0156)	(0.0169)	(0.0154)
penCHNvship					0.0238***	0.0215***	0.173***	0.222***	0.172***	0.167***
					(0.00591)	(0.00691)	(0.0475)	(0.0539)	(0.0472)	(0.0473)
penCHNsqLK						-0.00924*		-0.00953*	-0.00163	0.000120
						(0.00526)		(0.00525)	(0.00553)	(0.00500)
penCHNsqvship							-0.00885***	-0.0119***	-0.00891***	-0.00873***
							(0.00264)	(0.00307)	(0.00264)	(0.00264)
lgNfirm									0.0861	0.0774
									(0.0554)	(0.0550)
lgtfp										0.246***
										(0.0799)
Constant	11.62***	8.254***	7.353***	7.809***	7.082***	7.555***	4.008***	3.447**	4.149***	5.306***
	(0.522)	(1.050)	(1.219)	(1.356)	(1.305)	(1.346)	(1.445)	(1.514)	(1.360)	(1.392)
Observations	3,313	3,313	3,313	3,313	3,313	3,296	3,313	3,296	3,313	3,313
R-squared	0.380	0.401	0.402	0.405	0.416	0.439	0.425	0.451	0.428	0.435
Number of NAICS	380	380	380	380	380	380	380	380	380	380

Table B.4: IV Estimation on the Quantity of Energy

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
lgpenCHN	0.113***	0.0959***	0.0973***	0.108***	-0.00247	0.0517	-0.136	-0.103	-0.0807	-0.0334
	(0.0196)	(0.0194)	(0.0193)	(0.0209)	(0.0739)	(0.0780)	(0.233)	(0.238)	(0.238)	(0.234)
lgLK	0.0684	0.0866**	-0.318**	-0.200	-0.296*	0.0339	-0.317*	0.00334	0.0157	0.146
	(0.0461)	(0.0422)	(0.152)	(0.161)	(0.168)	(0.198)	(0.167)	(0.200)	(0.199)	(0.196)
lgvship	0.542***	1.308***	1.542***	1.469***	1.484***	1.159***	1.635***	1.339***	1.298***	1.080***
	(0.0322)	(0.122)	(0.146)	(0.158)	(0.158)	(0.171)	(0.255)	(0.284)	(0.284)	(0.278)
sqlgvship		-0.0469***	-0.0568***	-0.0538***	-0.0511***	-0.0354***	-0.0602***	-0.0461***	-0.0445***	-0.0353**
		(0.00718)	(0.00814)	(0.00859)	(0.00857)	(0.00906)	(0.0147)	(0.0160)	(0.0160)	(0.0155)
LKvship			0.0488***	0.0427**	0.0522***	0.0145	0.0547***	0.0182	0.0158	0.00689
			(0.0182)	(0.0180)	(0.0189)	(0.0232)	(0.0191)	(0.0238)	(0.0237)	(0.0229)
penCHNLK				0.0125	0.00801	-0.0189	0.00760	-0.0188	-0.0179	-0.00252
				(0.00856)	(0.00851)	(0.0121)	(0.00834)	(0.0121)	(0.0120)	(0.0120)
penCHNvship					0.0117	0.00503	0.0424	0.0405	0.0353	0.0305
					(0.00720)	(0.00773)	(0.0496)	(0.0499)	(0.0499)	(0.0487)
penCHNsqLK						-0.0113***		-0.0110***	-0.0104***	-0.00821**
						(0.00365)		(0.00368)	(0.00368)	(0.00343)
penCHNsqvship							-0.00177	-0.00204	-0.00177	-0.00170
							(0.00274)	(0.00272)	(0.00271)	(0.00262)
lgNfirm									0.0558*	0.0497*
									(0.0292)	(0.0290)
lgtfp										0.233***
										(0.0543)
Observations	3,204	3,204	3,204	3,204	3,204	3,204	3,204	3,204	3,204	3,204
R-squared	0.301	0.343	0.344	0.353	0.371	0.362	0.377	0.369	0.372	0.380
Number of NAICS	363	363	363	363	363	363	363	363	363	363

Table B.5: Pooled OLS Estimation on the Quantity of Fuel

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
lgpenCHN	0.0116	0.00838	0.00838	0.00302	-0.226***	-0.194***	-1.054***	-1.029***	-1.024***	-1.002***
	(0.00975)	(0.00945)	(0.00947)	(0.0162)	(0.0553)	(0.0583)	(0.227)	(0.235)	(0.228)	(0.230)
lgLK	0.0796	0.0996	0.0983	0.0636	-0.160	0.115	-0.292	-0.0110	0.0556	0.102
	(0.0965)	(0.0878)	(0.318)	(0.318)	(0.326)	(0.348)	(0.298)	(0.323)	(0.316)	(0.320)
lgvship	0.545***	1.503***	1.503***	1.526***	1.566***	1.286***	2.594***	2.316***	2.229***	2.086***
	(0.0728)	(0.257)	(0.285)	(0.294)	(0.289)	(0.285)	(0.356)	(0.348)	(0.342)	(0.345)
sqlgvship		-0.0583***	-0.0583***	-0.0593***	-0.0532***	-0.0393**	-0.116***	-0.103***	-0.100***	-0.0934***
		(0.0150)	(0.0159)	(0.0163)	(0.0163)	(0.0162)	(0.0213)	(0.0209)	(0.0205)	(0.0204)
LKvship			0.000163	0.00158	0.0237	-0.00807	0.0392	0.00660	-0.00193	-0.00497
			(0.0389)	(0.0387)	(0.0398)	(0.0435)	(0.0362)	(0.0401)	(0.0394)	(0.0395)
penCHNLK				-0.00408	-0.0140*	-0.0360**	-0.0174**	-0.0401**	-0.0356**	-0.0296*
				(0.00846)	(0.00820)	(0.0155)	(0.00833)	(0.0156)	(0.0157)	(0.0156)
penCHNvship					0.0258***	0.0215***	0.225***	0.222***	0.222***	0.219***
					(0.00638)	(0.00691)	(0.0522)	(0.0539)	(0.0522)	(0.0526)
penCHNsqLK						-0.00924*		-0.00953*	-0.00817	-0.00700
						(0.00526)		(0.00525)	(0.00522)	(0.00507)
penCHNsqvship							-0.0118***	-0.0119***	-0.0120***	-0.0119***
							(0.00298)	(0.00307)	(0.00298)	(0.00300)
lgNfirm									0.165***	0.159**
									(0.0624)	(0.0625)
lgtfp										0.165*
										(0.0949)
Constant	10.99***	7.126***	7.122***	6.973***	6.185***	7.555***	2.073	3.447**	3.060**	3.831**
	(0.668)	(1.192)	(1.349)	(1.410)	(1.387)	(1.346)	(1.570)	(1.514)	(1.522)	(1.574)
Observations	3,296	3,296	3,296	3,296	3,296	3,296	3,296	3,296	3,296	3,296
R-squared	0.403	0.424	0.424	0.425	0.435	0.439	0.447	0.451	0.459	0.462
Number of NAICS	380	380	380	380	380	380	380	380	380	380

Table B.6: IV Estimation on the Quantity of Fuel

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
lgpenCHN	0.0907***	0.0705***	0.0707***	0.0571***	-0.0879	0.00726	-0.478**	-0.419*	-0.366	-0.346
	(0.0203)	(0.0202)	(0.0202)	(0.0212)	(0.0754)	(0.0812)	(0.235)	(0.241)	(0.240)	(0.238)
lgLK	0.0829	0.106**	0.0273	-0.118	-0.245	0.334	-0.308	0.247	0.276	0.336
	(0.0525)	(0.0486)	(0.174)	(0.192)	(0.201)	(0.227)	(0.199)	(0.226)	(0.226)	(0.223)
lgvship	0.561***	1.485***	1.530***	1.620***	1.640***	1.069***	2.081***	1.566***	1.465***	1.363***
	(0.0396)	(0.141)	(0.165)	(0.174)	(0.176)	(0.191)	(0.283)	(0.310)	(0.309)	(0.304)
sqlgvship		-0.0566***	-0.0585***	-0.0621***	-0.0585***	-0.0309***	-0.0850***	-0.0605***	-0.0565***	-0.0523***
		(0.00839)	(0.00920)	(0.00948)	(0.00954)	(0.0100)	(0.0162)	(0.0175)	(0.0173)	(0.0170)
LKvship			0.00943	0.0169	0.0296	-0.0364	0.0372*	-0.0260	-0.0318	-0.0359
			(0.0207)	(0.0211)	(0.0220)	(0.0255)	(0.0218)	(0.0254)	(0.0254)	(0.0250)
penCHNLK				-0.0154	-0.0211**	-0.0684***	-0.0222**	-0.0682***	-0.0659***	-0.0586***
				(0.00959)	(0.00963)	(0.0117)	(0.00957)	(0.0117)	(0.0115)	(0.0120)
penCHNvship					0.0153**	0.00358	0.105**	0.102**	0.0891*	0.0872*
					(0.00735)	(0.00804)	(0.0498)	(0.0502)	(0.0498)	(0.0494)
penCHNsqLK						-0.0198***		-0.0192***	-0.0176***	-0.0165***
						(0.00346)		(0.00350)	(0.00346)	(0.00347)
penCHNsqvship							-0.00517*	-0.00562**	-0.00498*	-0.00497*
							(0.00272)	(0.00270)	(0.00267)	(0.00265)
lgNfirm									0.140***	0.137***
									(0.0336)	(0.0338)
lgtfp										0.111*
										(0.0626)
Observations	3,187	3,187	3,187	3,187	3,187	3,187	3,187	3,187	3,187	3,187
R-squared	0.367	0.402	0.402	0.396	0.412	0.407	0.425	0.422	0.430	0.432
Number of NAICS	363	363	363	363	363	363	363	363	363	363

Table B.7: Pooled OLS Estimation on the Quantity of Electricity

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
lgpenCHN	0.00387	0.00120	0.00187	0.0360**	-0.0866	-0.113*	-0.296	-0.316	-0.316	-0.272
	(0.0106)	(0.0105)	(0.0104)	(0.0167)	(0.0614)	(0.0592)	(0.266)	(0.255)	(0.255)	(0.252)
lgLK	0.0840	0.101	-0.568**	-0.348	-0.467*	-0.694**	-0.501*	-0.724**	-0.717**	-0.623**
	(0.0866)	(0.0798)	(0.242)	(0.248)	(0.256)	(0.306)	(0.265)	(0.310)	(0.309)	(0.303)
lgvship	0.472***	1.272***	1.656***	1.512***	1.533***	1.764***	1.793***	2.014***	2.004***	1.718***
	(0.0601)	(0.223)	(0.259)	(0.290)	(0.283)	(0.290)	(0.375)	(0.360)	(0.359)	(0.348)
sqlgvship		-0.0487***	-0.0650***	-0.0590***	-0.0557***	-0.0671***	-0.0717***	-0.0826***	-0.0823***	-0.0688***
		(0.0126)	(0.0139)	(0.0154)	(0.0153)	(0.0157)	(0.0204)	(0.0197)	(0.0197)	(0.0187)
LKvship			0.0804***	0.0714***	0.0832***	0.109***	0.0871***	0.113***	0.112***	0.106***
			(0.0278)	(0.0269)	(0.0276)	(0.0377)	(0.0286)	(0.0379)	(0.0377)	(0.0361)
penCHNLK				0.0260***	0.0207**	0.0389*	0.0198**	0.0379*	0.0384*	0.0506***
				(0.00920)	(0.00952)	(0.0204)	(0.00948)	(0.0205)	(0.0206)	(0.0180)
penCHNvship					0.0138**	0.0173**	0.0642	0.0662	0.0662	0.0604
					(0.00696)	(0.00699)	(0.0600)	(0.0583)	(0.0582)	(0.0576)
penCHNsqLK						0.00764		0.00757	0.00773	0.0101*
						(0.00646)		(0.00648)	(0.00651)	(0.00567)
penCHNsqvship							-0.00299	-0.00290	-0.00291	-0.00270
							(0.00331)	(0.00327)	(0.00327)	(0.00323)
lgNfirm									0.0192	0.00770
									(0.0664)	(0.0653)
lgtfp										0.330***
										(0.0908)
Constant	10.77***	7.545***	5.514***	6.464***	6.041***	4.909***	5.001***	3.910**	3.865**	5.406***
	(0.555)	(1.058)	(1.265)	(1.445)	(1.410)	(1.407)	(1.768)	(1.674)	(1.696)	(1.671)
Observations	3,296	3,296	3,296	3,296	3,296	3,296	3,296	3,296	3,296	3,296
R-squared	0.304	0.323	0.329	0.339	0.342	0.346	0.343	0.347	0.347	0.359
Number of NAICS	380	380	380	380	380	380	380	380	380	380

Table B.8: IV Estimation on the Quantity of Electricity

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
lgpenCHN	0.0928***	0.0769***	0.0793***	0.109***	0.121	0.109	0.488*	0.481*	0.479*	0.545*
	(0.0230)	(0.0230)	(0.0229)	(0.0243)	(0.0882)	(0.0897)	(0.285)	(0.288)	(0.288)	(0.282)
lgLK	0.0878*	0.106**	-0.685***	-0.371**	-0.360*	-0.437*	-0.301	-0.361	-0.362	-0.165
	(0.0474)	(0.0443)	(0.171)	(0.182)	(0.198)	(0.228)	(0.208)	(0.244)	(0.245)	(0.236)
lgvship	0.494***	1.222***	1.677***	1.482***	1.480***	1.556***	1.066***	1.121***	1.126***	0.795**
	(0.0342)	(0.128)	(0.147)	(0.160)	(0.162)	(0.186)	(0.326)	(0.359)	(0.361)	(0.348)
sqlgvship		-0.0446***	-0.0638***	-0.0560***	-0.0563***	-0.0599***	-0.0314*	-0.0340*	-0.0342*	-0.0203
		(0.00743)	(0.00803)	(0.00844)	(0.00818)	(0.00924)	(0.0185)	(0.0200)	(0.0201)	(0.0191)
LKvship			0.0953***	0.0791***	0.0781***	0.0868***	0.0709***	0.0777***	0.0779***	0.0647**
			(0.0200)	(0.0196)	(0.0212)	(0.0258)	(0.0226)	(0.0281)	(0.0281)	(0.0267)
penCHNLK				0.0331***	0.0336***	0.0398***	0.0347***	0.0396***	0.0395***	0.0632***
				(0.00971)	(0.0101)	(0.0148)	(0.0103)	(0.0150)	(0.0151)	(0.0140)
penCHNvship					-0.00131	0.000230	-0.0857	-0.0854	-0.0847	-0.0910
					(0.00818)	(0.00849)	(0.0599)	(0.0600)	(0.0602)	(0.0581)
penCHNsqLK						0.00261		0.00206	0.00198	0.00533
						(0.00442)		(0.00449)	(0.00451)	(0.00399)
penCHNsqvship							0.00486	0.00491	0.00488	0.00492
							(0.00330)	(0.00328)	(0.00329)	(0.00314)
lgNfirm									-0.00689	-0.0162
									(0.0340)	(0.0337)
lgtfp										0.359***
										(0.0604)
Observations	3,187	3,187	3,187	3,187	3,187	3,187	3,187	3,187	3,187	3,187
R-squared	0.252	0.286	0.292	0.316	0.314	0.317	0.303	0.305	0.305	0.316
Number of naics	363	363	363	363	363	363	363	363	363	363