WTO Accession and Performance of Chinese Manufacturing Firms

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Online Appendix

A. TFP estimation

We next describe how we estimate the sector-specific production functions (at the 2-digit level), which allow us to calculate firm-level TFP and markups. The estimation closely follows De Loecker and Warzynski (2012) and Ackerberg et al. (2016). We start from a Cobb-Douglas production function that describes gross output as a function of labor, capital and intermediate input:

$$q_{it} = \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \omega_{it} + \epsilon_{it}. \tag{2}$$

In the absence of firm-level output and input prices, we rewrite it using nominal variables:

$$\tilde{r}_{it} = \beta_k \tilde{k}_{it} + \beta_l l_{it} + \beta_m \tilde{m}_{it} + \widetilde{\omega}_{it} + \epsilon_{it} \tag{A. 1}$$

where $\tilde{r}_{it} = q_{it} + p_{it}^{Q} - \overline{p_t^{Q}}$ is deflated revenue, $\tilde{k}$ is fixed assets deflated by a capital deflator, l is labor input and $\tilde{m}$ is deflated intermediate input use defined similarly as $\tilde{r}_{it}$. $\widetilde{\omega}_{it}$ represents the sum of productivity and the deviations between the firm-level prices and industry price deflators, $\widetilde{\omega}_{it} = \omega_{it} + \left(p_{it}^{Q} - \overline{p_t^{Q}}\right) - \beta_m \left(p_{it}^{M} - \overline{p_t^{M}}\right)$. The firm-specific prices are assumed to be monotonic functions of the state variable in the production function ω_{it}, such that $\widetilde{\omega}_{it} = f(\omega_{it})$ is a monotonic function as well.

As in Levinsohn and Petrin (2003), our control function is based on the use of intermediate inputs. Firm i's intermediate input demand is

$$m_{it} = m\left(\tilde{k}_{it}, l_{it}, e_{it}, \tau_{st-1}^{O}, \tau_{st-1}^{I}, \omega_{it}\right) \tag{A.2}$$

Where e_{it} is a dummy indicating firm i's exporting status; τ_{st}^{O} is the output tariff of the 4-digit industry and τ_{st}^{I} is the input tariff of the 2-digit sector that firm i belongs to. Under the assumption that ω_{it} is the only unobserved firm-specific factor and that there is a conditionally

monotonic relationship between m_{it} and ω_{it}, we invert this function to get the following function *h(.)* as a proxy for productivity

$$\omega_{it} = h\left(m_{it}, \tilde{k}_{it}, l_{it}, e_{it}, \tau^{O}_{st-1}, \tau^{I}_{st-1}\right) \tag{A.3}$$

We allow the law of motion of productivity to depend on lagged output and input tariffs, as well as firms' export status, as described by the following $g(.)$ function

$$\omega_{it} = g(\omega_{it-1}, e_{it}, \tau^{O}_{st-1}, \tau^{I}_{st-1}) + \xi_{it} \tag{A.4}$$

where ξ_{it} is the innovative part of the productivity evolution process. Assuming that the stock of working capital is predetermined one period earlier and that lagged variable inputs, labor and materials, are orthogonal to contemporary productivity shocks, we use $\left(\tilde{k}_{it}, l_{it-1}, m_{it-1}\right)$ as instrumental variables and set up moment conditions to identify the coefficients in the production function.

The estimation procedure takes two steps. In a first stage, we run the following regression

$$\tilde{r}_{it} = \varphi\left(\tilde{k}_{it}, l_{it}, \tilde{m}_{it}, e_{it}, \tau^{O}_{st-1}, \tau^{I}_{st-1}, Z_i\right) \tag{A.5}$$

where $\tilde{r}_{it}$ is firm *i*'s deflated revenue in year *t*. Function $\varphi(.)$ is proxied by a 3rd order polynomial of capital, labor and intermediate inputs, as well as the interactions of the terms in the polynomial with industry-level input and output tariffs and the export status dummy. Meanwhile, we also control for ownership, year, province and 4-digit industry fixed effects that are combined in the vector Z_i.

After this first stage estimation, we use the predicted value of φ_{it} to construct a productivity estimate for each value of $(\beta_k, \beta_l, \beta_m)$ as follows:

$$\widehat{\omega}_{it} = \varphi_{it} - \beta_k \tilde{k}_{it} - \beta_l l_{it} - \beta_m \tilde{m}_{it}. \tag{A.6}$$

In the second stage, we proxy the law of motion of productivity ω_{it} with a linear function

$$\omega_{it} = \alpha_0 + \alpha_1 \omega_{it-1} + \alpha_O \tau^{O}_{st-1} + \alpha_I \tau^{I}_{st-1} + \alpha_e e_{it} + \xi_{it} \tag{A.7}$$

We estimate this linear function with $\widehat{\omega}_{it}$ and $\widehat{\omega}_{it-1}$ as constructed in (A.6) to obtain an estimate of the residual $\hat{\xi}_{it}$. Given our identifying assumptions on the timing of input choices, ξ_{it} should be independent of the predetermined stock of capital, as well as the lagged variable

inputs. We thus use the following moment condition to estimate parameters in the production function.

$$E\left[\xi_{it}(\boldsymbol{\beta}).\begin{bmatrix}\tilde{k}_{it}\\ l_{it-1}\\ \tilde{m}_{it-1}\end{bmatrix}\right]=0 \tag{A.8}$$

We use the same GMM algorithm as De Loecker and Warzynski (2012) and use the OLS estimates as starting values. The parameter estimates and standard errors are shown in Table A.2.

Once we obtain the estimates for the production function parameters, we calculate TFP estimates as

$$TFP_{it}=\tilde{r}_{it}-\hat{\beta}_k\tilde{k}_{it}-\hat{\beta}_l l_{it}-\hat{\beta}_m\tilde{m}_{it} \tag{A.9}$$

B. Markup estimation

As detailed in De Loecker and Warzynski (2012), one can obtain the firm-level price-cost markup by dividing the output elasticity with respect to a variable input with the corresponding revenue share. In principle, one can also use labor input and the output elasticity of labor to estimate markup. We choose to use intermediate input because labor is unlikely to be as easily adjustable as material inputs. If an input is quasi-fixed, the first order condition will not always hold and the input demand equation needs to condition on firm-specific information. Moreover, there is also a concern that labor input is under-estimated (See the discussion in Hsieh and Klenow (2009)).

From the production function estimates, we can calculate the output elasticity in the numerator of equation (6). The firm-level data directly provides an estimate on the revenue share of intermediates, but we adjust this in the denominator of (6) by stripping out the idiosyncratic error ϵ in the production function and using the intermediate estimate $\hat{\varphi}_{it}$ instead of deflated revenue directly. The ratio of these two quantities provides then an estimate for the markup.

Column (1) of Table A.3 shows the annual average median TFP growth for the period 1998-2007 by industry. Note that weighting TFP growth by firm size, as in Brandt et al. (2012), raises the sectoral averages substantially and leads to an overall average growth of 1.95% per year. A second difference with Brandt et al. (2012) is that the current estimates impose the same technology on all firms in a sector, due to the parametric production function framework.

At the same time, it avoids the assumption of perfect competition that the index number framework requires, and markup increases do not end up in TFP growth estimates anymore, depressing the average relative to Brandt et al. (2012). The median markup across firms are shown in column (2) to (5) for years 1998, 2001, 2004 and 2007 respectively.

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Table A.1 Comparing alternative price deflators over the 1998-2003 period (1998=100)

	Preferred series Firm-level price changes, aggregated to 4-digit industry dropping many outliers	**Alternative series (1)** Firm-level price changes, aggregated to 4-digit industry dropping fewer outliers	**Alternative series (2)** China's Statistial Yearbook, 2-digit industry series
China's Industrial Classification (2-digit)	(1)	(2)	(3)
13. Agriculture Food Processing	96.7	96.0	96.6
14. Other Food Production	98.7	97.9	97.2
15. Beverages	99.4	97.7	97.3
16. Tobacco Products	143.1	148.6	125.2
17. Textiles	100.8	100.0	97.8
18. Textile Wearing Apparel, Footwear, Caps	101.0	100.9	99.1
19. Leather, Fur, Feather & Related Products	102.5	102.8	100.5
20. Processing of Timber, Articles of Wood, etc.	98.5	97.9	95.0
21. Furniture	100.6	101.0	98.9
22. Paper and Paper Products	99.9	100.9	96.0
23. Printing, Reproduction of Recording Media	98.5	98.4	94.1
24. Cultural, Educational, Arts and Crafts, Sports and Entertainment Products	99.0	99.0	97.6
25. Processing of Petroleum, Coke, Nuclear Fuel	121.3	122.8	119.9
26. Chemicals and Chemical Products	98.8	98.8	100.5
27. Pharmaceutical Products	94.3	91.3	93.9
28. Man-made Fibres	104.1	104.4	100.1
29. Rubber Products	95.7	95.9	93.4
30. Plactics Products	98.9	98.3	96.0
31. Non-metallic Mineral Products	98.2	97.3	95.0
32. Smelting & Processing of Ferrous Metals	102.7	103.8	107.4
33. Smelting & Proc. of Non-ferrous Metals	102.6	101.0	101.1
34. Metal Products	98.8	98.6	97.3
35. General-purpose Machinery	98.5	97.7	97.0
36. Special-purpose Machinery	98.9	98.2	97.9
37. Transport Equipment	96.1	95.5	93.1
39. Electrical Machinery and Equipment	98.3	97.2	93.6
40. Comm. Eq., Computer & Other Electronic Eq.	96.6	94.4	89.8
41. Measuring Instruments and Machinery for Cultural Activity and Office Work	96.2	96.2	88.2
42. Artwork and Other Manufacturing	100.0	100.1	97.3
Weighted average	100.6	100.2	98.2

Note: This table shows the 2003 value of three alternative price deflators (1998=100). The preferred series is created from the firm-level information on current and constant price output. The 4-digit industry-year aggregate is constructed as an output-weighted average, omitting outliers more than 0.5 standard deviation different from the average change (15-25% per year). For the alternative series (1), we omit outliers outside a 1 standard deviation (7-10% per year). The table shows the output-weighted deflators at the 2-digit level.

		Alternative series (1)	Alternative series (2)
parial / spearman rank correlation:	Preferred series	0.997 / 0.957	0.923 / 0.898
	Alternative series (1)		0.920 / 0.871

Table A.2 Estimates of Cobb-Douglas production function coefficients

China's Industrial Classification	material	labor	capital	Obs.
13. Agriculture Food Processing	0.933	0.027	0.021	82,823
	(0.066)	(0.113)	(0.014)	
14. Other Food Production	0.934	0.047	0.017	29,890
	(0.013)	(0.024)	(0.005)	
15. Beverages	0.926	0.043	0.032	24,222
	(0.006)	(0.005)	(0.004)	
16. Tobacco Products	0.788	0.061	0.291	1,853
	(0.135)	(0.177)	(0.197)	
17. Textiles	0.956	0.012	0.007	113,468
	(0.006)	(0.004)	(0.002)	
18. Textile Wearing Apparel, Footwear and Caps	0.872	0.104	0.026	61,769
	(0.007)	(0.013)	(0.004)	
19. Leather, Fur, Feather and Related Products	0.911	0.063	0.025	30,060
	(0.008)	(0.006)	(0.005)	
20. Processing of Timber, Articles of Wood, Bamboo, Rattan, Palm and Straw	0.921	0.048	0.014	26,579
	(0.006)	(0.007)	(0.003)	
21. Furniture	0.922	0.051	0.018	14,157
	(0.010)	(0.012)	(0.005)	
22. Paper and Paper Products	0.930	0.052	0.012	41,525
	(0.034)	(0.051)	(0.005)	
23. Printing and Reproduction of Recording Media	0.895	0.059	0.052	28,523
	(0.010)	(0.017)	(0.004)	
24. Cultural, Educational, Arts and Crafts, Sports and Entertainment Products	0.888	0.083	0.028	16,589
	(0.013)	(0.020)	(0.005)	
25. Processing of Petroleum, Coking and Nuclear Fuel	0.881	0.049	0.044	3,961
	(0.164)	(0.220)	(0.073)	
26. Chemicals and Chemical Products	0.939	0.011	0.026	86,155
	(0.018)	(0.031)	(0.005)	
27. Pharmaceutical Products	0.918	0.037	0.037	29,187
	(0.007)	(0.008)	(0.010)	
28. Man-made Fibres	0.957	0.002	0.025	4,230
	(0.071)	(0.074)	(0.016)	
29. Rubber Products	0.930	0.032	0.023	13,862
	(0.264)	(0.484)	(0.116)	
30. Plactics Products	0.918	0.047	0.026	54,939
	(0.003)	(0.003)	(0.002)	
31. Non-metallic Mineral Products	0.981	0.016	0.005	123,687
	(0.088)	(0.073)	(0.043)	
32. Smelting and Processing of Ferrous Metals	0.923	0.091	-0.002	21,197
	(0.048)	(0.073)	(0.029)	
33. Smelting and Processing of Non-ferrous Metals	0.931	0.070	-0.008	9,759
	(0.122)	(0.094)	(0.067)	
34. Metal Products	0.919	0.035	0.029	47,438
	(0.117)	(0.167)	(0.039)	
35. General-purpose Machinery	0.937	0.013	0.028	77,313
	(0.045)	(0.041)	(0.021)	
36. Special-purpose Machinery	0.935	0.016	0.023	44,044
	(0.021)	(0.024)	(0.006)	
37. Transport Equipment	0.907	0.033	0.042	55,616
	(0.056)	(0.090)	(0.008)	
39. Electrical Machinery and Equipment	0.922	0.039	0.025	50,400
	(0.051)	(0.075)	(0.004)	
40. Communication Equipment, Computer and Other Electronic Equipment	0.884	0.058	0.047	37,249
	(0.026)	(0.027)	(0.012)	
41. Measuring Instruments and Machinery for Cultural Activity and Office Work	0.915	0.052	0.026	15,584
	(0.160)	(0.243)	(0.031)	
42. Artwork and Other Manufacturing	0.807	0.230	0.004	22,225
	(0.079)	(0.147)	(0.022)	

Note: Cobb-Douglas production function coefficients estimated using the methology of De Loecker and Warzynski (2012), estimated separately by 2-digit sector. Block-bootstrapped standard errors in brackets.

Table A.3 Summary statistics by sector for TFP growth and markup estimates

	Median Annual TFP growth		Median markup (P/MC - 1)		
China's Industrial Classification	1998-2007	2001-2007	2001	2004	2007
13. Agriculture Food Processing	0.01	0.01	0.22	0.23	0.23
14. Other Food Production	0.00	0.00	0.30	0.32	0.36
15. Beverages	0.01	0.01	0.29	0.30	0.36
16. Tobacco Products	-0.02	0.01	0.38	0.63	0.62
17. Textiles	0.02	0.02	0.28	0.26	0.30
18. Textile Wearing Apparel, Footwear and Caps	0.02	0.02	0.15	0.17	0.18
19. Leather, Fur, Feather and Related Products	0.01	0.01	0.17	0.19	0.22
20. Processing of Timber, Articles of Wood, etc.	0.07	0.08	0.23	0.22	0.25
21. Furniture	0.09	0.12	0.23	0.21	0.23
22. Paper and Paper Products	0.03	0.04	0.20	0.20	0.22
23. Printing and Reproduction of Recording Media	0.03	0.05	0.24	0.23	0.25
24. Cultural, Educational, Arts and Crafts, Sports goods, etc.	0.03	0.04	0.16	0.15	0.18
25. Processing of Petroleum, Coking and Nuclear Fuel	-0.05	-0.06	0.01	0.14	0.17
26. Chemicals and Chemical Products	0.00	0.00	0.23	0.26	0.30
27. Pharmaceutical Products	0.02	0.02	0.29	0.31	0.35
28. Man-made Fibres	0.00	0.00	0.20	0.20	0.23
29. Rubber Products	0.00	0.00	0.23	0.23	0.27
30. Plactics Products	0.02	0.03	0.20	0.17	0.20
31. Non-metallic Mineral Products	0.04	0.05	0.31	0.32	0.36
32. Smelting and Processing of Ferrous Metals	0.00	-0.01	0.15	0.10	0.14
33. Smelting and Processing of Non-ferrous Metals	-0.05	-0.07	0.15	0.19	0.24
34. Metal Products	-0.02	-0.02	0.20	0.19	0.22
35. General-purpose Machinery	0.00	0.01	0.25	0.23	0.27
36. Special-purpose Machinery	0.02	0.03	0.24	0.23	0.26
37. Transport Equipment	0.01	0.01	0.20	0.21	0.25
39. Electrical Machinery and Equipment	-0.02	-0.03	0.17	0.18	0.20
40. Communication Eq., Computer & Other Electronic Eq.	0.04	0.05	0.17	0.19	0.19
41. Measuring Instr & Machinery for Cultural, Office Work	0.07	0.06	0.25	0.27	0.29
42. Artwork and Other Manufacturing	0.05	0.05	0.08	0.08	0.09

Note: All firms with non-missing information are included for calculating the summary statistics. TFP growth measures are based on production function parameter estimates in Table A.2. Markups are measured as the ratio of the output elasticity of materials over its revenue share minus 1, where the revenue has been adjusted to remove the impact of idiosyncratic ex-post shocks.

Table A.4 Robustness checks for the effect of tariffs on imports and domestic prices

(a) Imports (2000-2007)

	Dependent variable is ordinary trade imports into China (in logs) at the product level (6-digit HS)				
	All goods	Materials	Intermediate inputs	Capital goods	Consumer goods
	(1a)	(2a)	(3a)	(4a)	(5a)
(i) OLS estimates					
Import tariff (lagged)	-2.769	-1.558	-3.736	-2.099	-1.844
	(0.304)	(0.813)	(0.613)	(0.665)	(0.565)
Year FE	yes	yes	yes	yes	yes
Product FE	yes	yes	yes	yes	yes
Observations	127,049	8,458	73,351	19,013	26,061

Note: All coefficients are estimated using separate regressions. We exclude duty-free imports and aggregate firm-level trade flows to the product level. The regressions allow for a different elasticity for imports entering through trade intermediaries (not reported). Standard errors in parentheses are clustered at the product level; ***, **, and * indicate significance at the 1%, 5%, and 10% level.

(b) Domestic price level

	Dependent variable is an index of the Chinese domestic price level at the sector (2-digit) or industry (4-digit) level				
	All goods	Materials	Intermediate inputs	Capital goods	Consumer goods
	(1b)	(2b)	(3b)	(4b)	(5b)
(i) Preferred series: OLS estimates (1998-2007)					
Import tariff (lagged)	0.245	0.446	0.396	0.145	0.000
	(0.032)	(0.175)	(0.064)	(0.045)	(0.029)
Year FE	yes	yes	yes	yes	yes
Industry or sector FE	yes	yes	yes	yes	yes
Observations	4,240	70	1,950	1,180	980
(ii) 4-digit deflator without extrapolation: IV estimates (1998-2003)					
Import tariff (lagged)	0.147	0.138	0.246	0.052	-0.027
	(0.075)	(0.136)	(0.147)	(0.078)	(0.123)
Year FE	yes	yes	yes	yes	yes
Industry or sector FE	yes	yes	yes	yes	yes
Observations	2,544	49	1,170	708	588

Note: All coefficients are estimated using separate regressions for 4-digit industries. The instrument in panel (ii), from 2001 onwards, is the maximum allowable tariff under the WTO agreement. In panel (i), the price index from 1998 to 2003 is calculated by aggregating firm-level price changes to the 4-digit industry level as described in Section 4; we extrapolate the index to the end of the sample period using a sectoral price index taken from China's statistical yearbook and observed at the 2-digit sector level. In panel (ii), the sample is limited to the 1998-2003 period where the detailed index is defined. Standard errors in parentheses are clustered at the industry level.

Table A.5 Robustness check on the effect of tariffs on firm-level markup & productivity

(a) OLS estimates (1998-2007)

Dependent variable:	Markup		Productivity	
	Within-industry output share weights		Within-industry output share weights	
	(1a)	(2a)	(3a)	(4a)
Output tariff (lagged)	0.061	0.09	-0.194	-0.124
	(0.037)	(0.047)	(0.086)	(0.065)
Input tariff (lagged)	0.164	0.686	-1.455	-1.532
	(0.144)	(0.091)	(0.286)	(0.136)
Firm FE	yes	yes	yes	yes
Year FE	yes		yes	
Sector-year FE		yes		yes
Observations	1,211,861	1,213,586	1,194,720	1,196,451

Note: Sample only includes firms that did not switch industry. Standard errors in parentheses are clustered two-ways at the industry-year and at the firm level.

(b) Alternative TFP measures (1998-2007)

	Dependent variables are alternative TFP measures using …			
	wage bill as labor input	alternative price index	produduction fct. at 4-digit level	includinge 4-digit industry switchers
	(1b)	(2b)	(3b)	(4b)
Output tariff (lagged)	-0.143	-0.113	0.170	-0.097
	(0.068)	(0.064)	(0.134)	(0.058)
Input tariff (lagged)	-1.044	-2.307	-2.369	-1.745
	(0.136)	(0.133)	(0.252)	(0.265)
Firm FE	yes	yes	yes	yes
Sector-year FE	yes	yes	yes	yes
Observations	1,196,391	1,196,467	1,196,814	1,424,428

Note: All regressions use as instrument for tariffs from 2001 onwards the maximum allowable tariff under the WTO agreement. Sample in columns (1b)-(3b) only includes firms that did not switch industry. Standard errors in parentheses are clustered two-ways, at the industry-year and at the firm level.

Table A.6 Effect of tariffs on entry, exit, and industry transitions

Dependent variable:	No. of active firms (log)	Entry rate	Exit rate	Switch-in rate	Switch-out rate	Restructuring rate
	(1)	(2)	(3)	(4)	(5)	(6)
(a) benchmark						
Output tariff (lagged)	0.001	-0.052	0.046	0.037	0.063	-0.011
	(0.018)	(0.036)	(0.029)	(0.033)	(0.038)	(0.013)
Input tariff (lagged)	0.330	0.402	-0.091	0.009	-0.098	0.031
	(0.059)	(0.115)	(0.093)	(0.107)	(0.124)	(0.040)
Industry FE & Year FE	yes	yes	yes	yes	yes	yes
Observations	4,238	4,237	4,237	4,237	4,237	4,238
(b) normalized by incumbents or survivors						
Output tariff (lagged)	0.001	-0.074	0.051	0.031	0.098	-0.005
	(0.018)	(0.073)	(0.059)	(0.071)	(0.070)	(0.024)
Input tariff (lagged)	0.330	0.891	-0.134	0.088	-0.126	0.020
	(0.059)	(0.236)	(0.189)	(0.227)	(0.222)	(0.078)
Industry FE & Year FE	yes	yes	yes	yes	yes	yes
Observations	4,238	3,558	3,781	3,699	3,695	3,810
(c) current tariff rates						
Output tariff	0.004	-0.051	0.067	0.082	0.042	-0.016
	(0.019)	(0.036)	(0.029)	(0.034)	(0.039)	(0.013)
Input tariff	0.342	0.213	-0.104	-0.020	-0.116	0.040
	(0.059)	(0.114)	(0.092)	(0.106)	(0.123)	(0.040)
Industry FE & Year FE	yes	yes	yes	yes	yes	yes
Observations	4,228	4,227	4,227	4,227	4,227	4,228
(d) estimation with OLS						
Output tariff (lagged)	-0.006	0.000	0.054	0.040	0.076	-0.013
	(0.017)	(0.033)	(0.027)	(0.030)	(0.035)	(0.012)
Input tariff (lagged)	0.342	0.311	-0.105	0.003	-0.120	0.033
	(0.058)	(0.112)	(0.091)	(0.105)	(0.121)	(0.039)
Industry FE & Year FE	yes	yes	yes	yes	yes	yes
Observations	4,238	4,237	4,237	4,237	4,237	4,238
(e) Post-WTO period						
Output tariff (lagged)	-0.019	-0.101	0.065	0.03	0.092	-0.039
	(0.023)	(0.054)	(0.037)	(0.053)	(0.063)	(0.019)
Input tariff (lagged)	0.493	0.506	0.146	0.072	-0.247	0.076
	(0.070)	(0.163)	(0.113)	(0.160)	(0.190)	(0.058)
Industry FE & Year FE	yes	yes	yes	yes	yes	yes
Observations	2,967	2,967	2,967	2,966	2,967	2,967

Note: Estimation is with IV (except panel (d)) over the 1998-2007 period (except panel (e)). Number of firms entering, exiting, or switching industries are normalized by total number of active firms (except panel (b)); ratios above 1 are excluded. The log of number of firms in (1) is divided by 10 to normalize coefficient estimates to be of similar magnitude. Standard errors in parentheses.