US Pork and China Trade in a Specific Factors Model

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Abstract

Trade with China affects US outputs and factor prices, gauged in the present paper with an applied specific factors model of production focused on pork production. Capital returns closely mirror price changes in the comparative static adjustments. Pork output increases slightly but much more in the long run as investment pursues higher return. Wages of agricultural workers rise while production wages fall in the general equilibrium adjustment.

Keywords: *Pork exports, China, specific factors model*

Introduction

The US pork industry will benefit from rising exports to China, gauged in the present paper with a specific factors model. The present simulation gauges the effects of changing prices due to free trade with China on US wages, capital returns, and outputs. China has agreed to import US pork products under the US China Relations Act and accession to the World Trade Organization. China consumes over half the pork in the world as well as by-products unpopular in the US. Chinese tariff rates on US pork have fallen from over 30% to half that level. Hayes (2001, 2005) estimates Chinese demand could boost the US price of hogs by almost one quarter.

Pork is the most widely consumed form of animal protein, about 40% globally. Growth in pork production and consumption is due to substitution as well as rising incomes. The main growth in pork production is occurring in China, Brazil, the US, and Canada. Major importers are Russia, Japan, the US, Mexico, and Hong Kong. Major exporters are the EU, Canada, the US, China, and Brazil. The US pork industry has recently developed into a major exporter. Although traditional US pork producers were mainly smaller diversified farms, there has been consolidation with the largest pork producers are in the Southeast and Midwest.

Japan is the world's largest pork importer and largest customer of US pork exports. Demand for US pork products in China is strong. Despite official restrictions prior to WTO ascension, large quantities were smuggled. Pork export purchases by China increased 38% in 2011 making China the third largest importer of US pork with a market share of 13%.

The present specific factors model projects adjustments in US agriculture to increased pork exports by separating inputs into six labor skill groups along with energy and industrial capital. Outputs are pork, the rest of agriculture, manufactures, and services. Wages, capital returns, the price of energy, and outputs adjust to changing trade prices. Sensitivity to a range of constant elasticity substitution is addressed.

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Trade with China promises to raise US pork and agricultural prices. Manufacturing prices will fall with increased import competition while business services can expect rising prices. Factor intensity is critical to the comparative static adjustments. Factor payment shares and industry employment shares anticipate the directions and strengths of adjustments. Contrary to partial equilibrium analysis, input substitution plays only a minor role due to the flexibility of output and factor price adjustments. The model provides perspective by focusing on an industry with quite a bit at stake as the US moves to free trade with China.

The Specific Factors Model

The specific factors model is a fundamental model of production and trade that assumes constant returns, competitive pricing, cost minimization, and full employment as developed by Jones and Scheinkman (1977), Chang (1979), and Thompson (1995). Full employment of labor, capital, and energy is described by $v = Ax$ where v is the input vector, A the matrix of cost minimizing unit inputs, and x the output vector. Capital is industry specific. Competitive pricing in each industry is stated $p = A^T w$ where p is the vector of product prices and w factor prices.

Differentiate the full employment and competitive pricing conditions to derive the model in elasticity form,

$$(1) \quad \begin{pmatrix} \sigma & \lambda \\ \theta^T & 0 \end{pmatrix} \begin{pmatrix} w' \\ x' \end{pmatrix} = \begin{pmatrix} v' \\ p' \end{pmatrix} = \begin{pmatrix} 0 \\ p' \end{pmatrix}$$

where $'$ represents percentage change, σ is the matrix of substitution elasticities, λ the matrix of industry employment shares, and θ^T the transposed matrix of factor payment shares. The model solves for the effects of exogenous changes in p' on w' and x' for given factor endowments assuming $v' = 0$.

Factor shares θ and industry shares λ are from the data for the six labor skill groups,

G	Managers	N	Professionals
W	Service Workers	C	Clerks
A	Agricultural Workers	D	Production Workers

as in Thompson (1996). Two other inputs in each sector are energy E and sector specific capital input K_j. The four outputs in the present model are

M	Manufacturing	S	Services
P	Pork	O	Other Agriculture

Labor payments in manufacturing, services, and agriculture, and data on skilled labor groups are from the NAICS industry estimates of the Bureau of Labor Statistics (2007). Energy data is from the US Department of Energy (2007). For Agriculture and Pork, value added, labor, and energy input data are from the Census of Agriculture (2007). Value added in manufacturing is from the US Economic Census (2007) with value added in services derived as the residual of gross output. Industrial capital receives the residual after subtracting labor and energy bills.

Table 1 is the matrix of total payments leading to the factor shares in Table 2 and industry shares in Table 3. Summing down a column in Table 1 gives total sector revenue. For instance, value added in pork P is \$18 billion and the factor share of agricultural workers A in Table 2 is \$0.3/18 = 1.7%. Capital has the largest factor shares. Agricultural workers A have the largest labor share in pork P followed closely by service workers W at 1.4%. The energy E share in pork P is 5%. Other agriculture O has the highest energy share at 16.5%.

Table 1. Factor Payments (\$billion)

	M	S	O	P	Total
G	74	352	3	0.1	429
N	120	1,517	0.4	0.1	1,637
W	95	901	4	0.3	1,000
C	46	480	1	0.1	528
A	1	1	12	0.3	14
D	246	64	1	0.0	310
K_j	4,502	6,737	212	16	11,467
E	236	760	46	1	1,043
Total	5,319	10,811	279	18	16,428

Table 2. Factor Shares θ_{ij}

	M	S	O	P
G	.014	.033	.010	.007
N	.023	.140	.001	.003
W	.018	.083	.013	.014
C	.009	.044	.005	.004
A	.0002	.0001	.044	.016
D	.046	.006	.002	.003
K_j	.846	.623	.759	.903
E	.044	.070	.165	.050

Industry shares of factor employment are in Table 3. Summing across rows in Table 1 gives total factor incomes. Derivation of industry shares assumes wages are equal across industries for each type of labor. Total income of service workers W in all sectors is \$1,000 billion and \$4.0/\$1,000 = 0.4% are employed in other agriculture O. Capital K_j is sector specific with all industry shares equal to one. There are very large shares of service workers W, clerks C, professionals N, and managers G in services S, and a very large share of agricultural workers A in other agriculture O. The pork industry P employs 2.0% of agricultural workers and less than 1% of other labor types.

Table 3. Industry Shares λ_{ij}

	M	S	O	P
G	.172	.822	.007	.0003
N	.074	.926	.0002	.00003
W	.095	.901	.004	.0003
C	.087	.910	.003	.0001
A	.061	.068	.851	.020
D	.793	.205	.002	.0002
E	.393	.588	.018	.001

Substitution elasticities summarize adjustments in cost minimizing inputs when factor prices change as developed by Jones (1965) and Takayama (1982). The Allen (1938) partial elasticity of substitution between factor *i* and the price of factor *k* in sector *j* is S_{ij}^{k}. Cobb-Douglas production implies $S_{ij}^{k} = 1$ scaled by constant elasticity of substitution CES. The cross price elasticity is derived from the Allen elasticity as $E_{ij}^{k} = \theta_{kj}S_{ij}^{k}$. With CES production $E_{ij}^{k} = \theta_{kj}$. Linear homogeneity implies $\Sigma_k E_{ij}^{k} = 0$. Own price elasticities E_{ij}^{i} are the negative of the sum of cross price elasticities. Aggregate substitution elasticities $\sigma_{ik} = \sum_j \lambda_{ij} E_{ij}^{k}$ are the industry share weighted average of cross price elasticities with linear homogeneity implying $\sum_k \sigma_{ik} = 0$.

Cobb-Douglas substitution elasticities are in Table 4. With CES = 0.5 these substitution elasticities would be half as large, perhaps more appropriate as the applied production literature generally finds inelastic substitutes. The following discussion considers sensitivity of the specific factors model to CES substitution.

Table 4. Substitution Elasticities σ_{ik}

	w_G	w_N	w_W	w_C	w_A	w_D	e	r_M	r_S	r_O	r_P
a_G	-.646	.119	.072	.038	.000	.013	.066	.026	.310	.002	.00003
a_N	.031	-.589	.078	.042	.000	.009	.068	.011	.349	.0001	.000003
a_W	.031	.129	-.633	.041	.000	.010	.068	.015	.340	.001	.00002
a_C	.031	.130	.077	-.673	.000	.009	.068	.013	.343	.001	.00001
a_A	.012	.012	.018	.008	-.446	.005	.149	.009	.026	.205	.002
a_D	.018	.047	.031	.016	.0002	-.362	.050	.122	.077	.001	.00002
a_E	.027	.107	.065	.035	.0003	.015	-.570	.035	.274	.011	.0001
a_M	.014	.023	.018	.009	.0002	.046	.044	-.154	.000	.000	.000
a_S	.033	.140	.083	.044	.0001	.006	.070	.000	-.377	.000	.000
a_O	.010	.001	.013	.005	.044	.002	.165	.000	.000	-.241	.000
a_P	.007	.003	.014	.004	.016	.003	.050	.000	.000	.000	-.097

The largest own substitution is for clerks C and the smallest for pork capital K_P. Every 1% increase in the clerk wage leads to a 0.67% decline in its input, and every 1% increase in the price of pork capital r_P decreases its input 0.09%. An increase of 1% in the agricultural wage w_A lowers the input of agricultural workers 0.45%.

Own labor substitution is larger than own capital substitution, with more substitution between labor types than between labor and capital. Energy is sensitive to its own price. The highest sensitivities to the energy price are for agricultural labor and capital inputs.

Comparative Static Elasticities of Price Changes

Inverting the system matrix (1) yields the comparative static elasticities of interest. Table 5 reports elasticities of factor prices with respect to output prices. Every 1% increase in the price of other agriculture p_O raises the wage of agricultural workers w_A by 1.06% with very small changes in other wages and an increase of 1.25% in its capital return r_O. The increase in p_O attracts managers G, agricultural workers A, production workers D, and energy E from other industries, raising its capital productivity. Other capital returns diminish due to their reduced labor and energy inputs.

Table 5. Factor Price and Output Price Elasticities

	p_M	p_S	p_O	p_P
w_G	.064	.934	.002	.00006
w_N	.009	.994	-.003	-.00002
w_W	.021	.979	-.0004	.00004
w_C	.016	.985	-.001	.00001
w_A	.019	-.084	1.06	.008
w_D	.683	.316	.001	.0001
e	.100	.864	.036	.0002
r_M	1.14	-.135	-.002	-.00002
r_S	-.027	1.03	-.003	-.00003
r_O	-.026	-.221	1.248	-.001
r_P	-.009	-.078	-.021	1.107

The price of pork p_P has small effects in Table 5 except for its own capital. The only sizeable effect of a 10% increase in the price of pork is an increased return to pork capital r_P of 11.1%.

Every 1% increase in the price of manufactures p_M would raise production wages w_D 0.68%, manager wages w_G by 0.06%, and return to manufacturing capital r_M by 1.14%. Wages depend heavily on the price of services p_S with near unit elasticities for managers w_G, professionals w_N, service w_W, and clerks w_C. The price of energy e is sensitive to the price of the large services sector.

Some factors will benefit and others will lose for any vector of price changes. Thompson and Toledo (2000) show comparative static effects of price changes on factor prices are identical for all CES production functions implying the same comparative static elasticities in Table 5 hold for any degree of CES substitution.

Table 6 reports price elasticities of outputs along the production frontier. A higher price raises output and draws labor and energy from other industries. The largest own output effect occurs for other agriculture where every 1% increase in p_O raises output x_O by 0.25%. A 10% increase in the price of pork p_P causes a 1.1% increase in pork output x_P. The price of pork price has trivial effects on other outputs. The smallest own price effect is in the large service sector that is unable to attract input from the rest of the economy.

Table 6. Production Frontier Elasticities

	p_M	p_S	p_O	p_P
x_M	.137	-.135	-.002	-.00002
x_S	-.027	.031	-.003	-.00003
x_O	-.026	-.221	.248	-.001
x_P	-.009	-.078	-.021	.107

Adjustments to Trade with China

Trade with China will raise prices of agriculture and but lower prices in manufactures. For the model simulation, price changes are set at 20% for pork p_P, 5%

for other agriculture p_O, 5% for services p_S, and -10% for manufactures p_M. Multiply this vector of predicted price changes by the matrix of factor price elasticities in Table 5 to find the projected vector of factor price adjustments in Table 7.

Table 7. US Free Trade with China

	Price Change		Factor Prices		Outputs	Long Run Outputs
		w_G	4.04			
		w_N	4.86			
		w_W	4.69			
		w_C	4.76			
		w_A	4.84			
		w_D	-5.25			
		w_E	3.51			
p_M	-10%	r_M	-12.1	x_M	-2.06	-12.1
p_S	5%	r_S	5.41	x_S	0.41	5.41
p_O	5%	r_O	5.39	x_O	0.39	5.39
p_P	20%	r_P	21.7	x_P	1.74	21.7

With this vector of price changes, wages rise almost 10% except for the -5% decline for production workers. Capital returns in pork rise about 21%. Capital returns in other agriculture and services rise about 5% but the capital return in manufacturing falls over 12%. The price of energy increases about 3%.

Output effects in Tables 7 are found multiplying model elasticities in Table 6 by the vector of price changes. With Cobb-Douglas production, pork output x_P increases 1.74% . Manufacturing output x_M declines 2.06%. Increases in other agriculture x_O and services x_S are negligible.

Factor price adjustments are proportional to price changes and identical for any degree of CES substitution. Output adjustments scale according to CES and would be half as large as Table 7 with CES of 0.5.

In the long run, the changing capital returns in Table 7 will alter investment and capital stocks leading to larger output adjustments. Assuming the capital stock ultimately changes in proportion to the change in its return, capital in pork production would increase 22%. Capital in other agriculture and services would increase over 5% while manufacturing capital would fall 12%. Outputs would adjust to the same degree as these capital changes given constant returns. The last column in Table 7 reports these predicted long run output changes. Pork output x_P increases over 17% while output in the rest of agriculture x_O increases over 3% with long run investment.

Conclusion

The present specific factors model gauges the potential income redistribution and output adjustments in the US pork industry due to free trade with China. US agriculture will enjoy higher prices as will business services, while manufacturing faces import competition and falling prices. Agricultural and other labor types gain except for the falling wages of production labor. Capital returns rise in pork and the rest of agriculture. Output adjustments are moderate in the short run but substantial in the long run as investment seeks higher returns. Pork output increases almost 2% due to price changes in the short run but over 20% in the long run as investment is attracted to the higher return.

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