The International Location of Pork Production

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Efficient hog production technologies which have cost advantages for international competition also have environmental disadvantages which may effect the location of facilities using this technology. This paper presents an econometric analysis of the impact of country characteristics on the growth of pork production in major producing countries over the period 1985-2003.

keywords: pork production, location analysis

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Developments in production, breeding, and management techniques in pork production have produced scale economies and enabled considerable increases in productivity for larger operations. Improved farming techniques, improvements in management practices, and advances in genetics have resulted in significant productivity advances in terms of increased weight, decreased feed requirements, and the number of pigs farrowed per sow per year (OECD, 2003).

Efficient production practices are essential for success in the globalized economy, and pork producers have strong incentives to pursue economies of size with large production units employing the latest technologies (Beghin and Metcalfe). Large-scale concentrated pork production, however, has much more significant impacts on the local environment than older small-scale dispersed production. The environmental impacts of the larger, more efficient technologies create a potential barrier to the adoption of these technologies and have significant potential to impact location decisions for production facilities (Sullivan, Vasavada, and Smith).

This paper considers the effects of large scale pork production technologies on local environments and identifies production location characteristics which may lower the costs of these effects. We present an econometric model to test for the hypothesized impacts of these location characteristics on changes in pork production for 17 major pork producing countries in recent years. A brief review of recent international pork production, consumption, and trade characteristics is presented first as background for the location analysis.

International Pork Production, Consumption, and Trade

World pork production increased 56.2 percent (average annual growth rate of 2.4 percent) between 1980 and 2003 to 88 million metric tons. The volume of pork exports increased approximately 9.3 percent annually for this period of time and expanded to 4.3 million metric tons (Figure 1).

The shares of the top five producing countries in the world market accounted for, on average, 86.4 percent of production during the period of 2000-2003 (Figure 2). Pork production in the U.S. increased about 2 percent per year and expanded to 9.1 million metric tons in 2003 (Figure 3). According to OECD (2003), production in the EU as a whole grew at a slower annual rate of about 1 percent during the 1990s and early 2000s but there was variation between EU countries: production declined in Germany, the Netherlands, and the United Kingdom, but increased in Belgium, Denmark, and Spain.

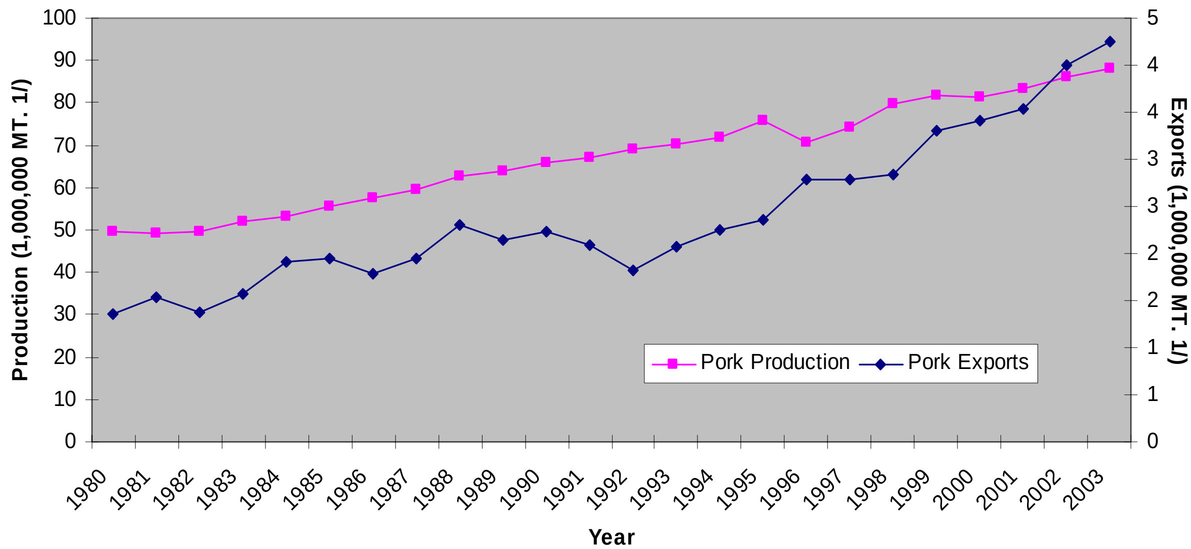

Figure 1. World Production and Exports of Pork (1980-2003)
1/ Carcass weight equivalent

Source: USDA, Foreign Agricultural Service (FAS). Production, Supply and Distribution Online. Webpage: http://www.fas.usda.gov/psd/Psdselection.asp (Accessed August, 2004).

Market shares of the top five pork exporting countries accounted for, on average, 88.6 percent of the global export market during the period of 2000-2003 (Figure 4). The EU was the largest exporter in this period of time. The EU's share in the global pork export market declined from 43 percent in 2000 to 27 percent in 2003, while export market shares for Canada, Brazil, and China gradually increased. The U.S. export share remained roughly stable.

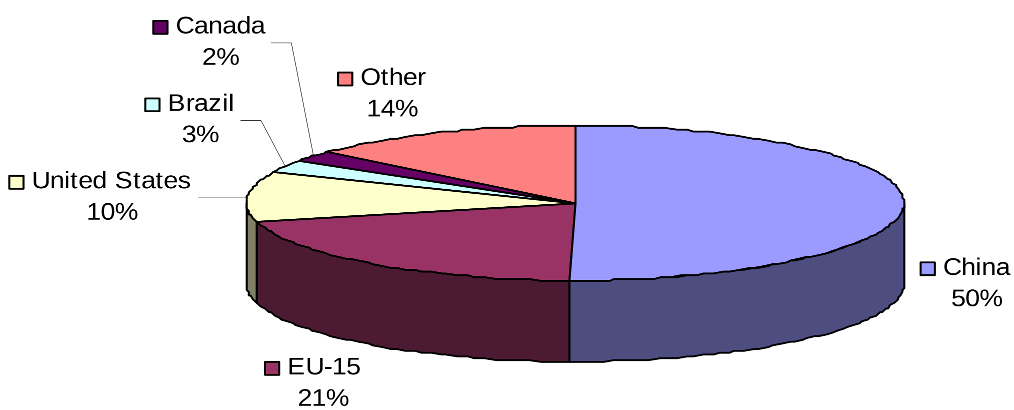

Figure 2. Country Shares of World Pork Production (2000-2003 Average)

Source: USDA, Foreign Agricultural Service (FAS). Production, Supply and Distribution Online. Webpage: http://www.fas.usda.gov/psd/Psdselection.asp (Accessed August, 2004).

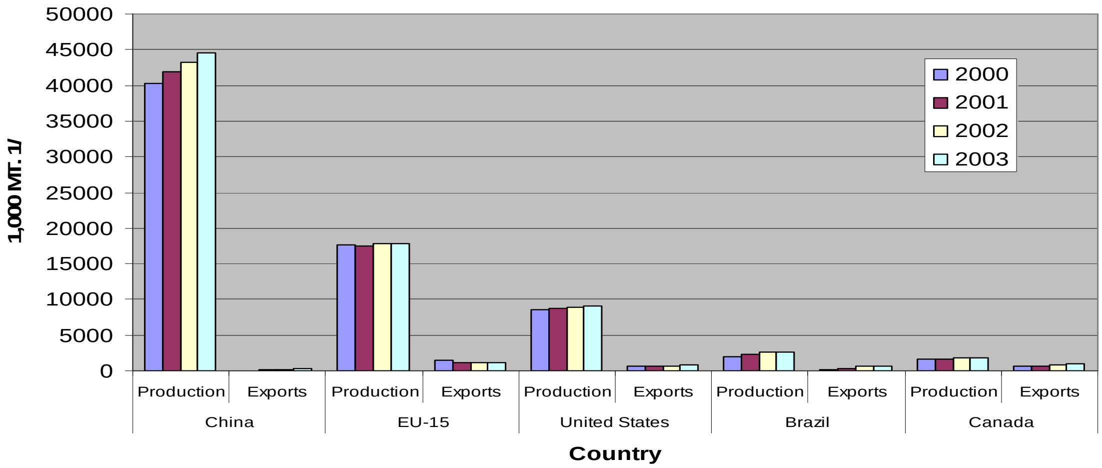

Figure 3. Major Countries Pork Production and Exports (2000-2003)
1/ Carcass weight equivalent

Source: USDA, Foreign Agricultural Service (FAS). Production, Supply and Distribution Online. Webpage: http://www.fas.usda.gov/psd/Psdselection.asp (Accessed August, 2004).

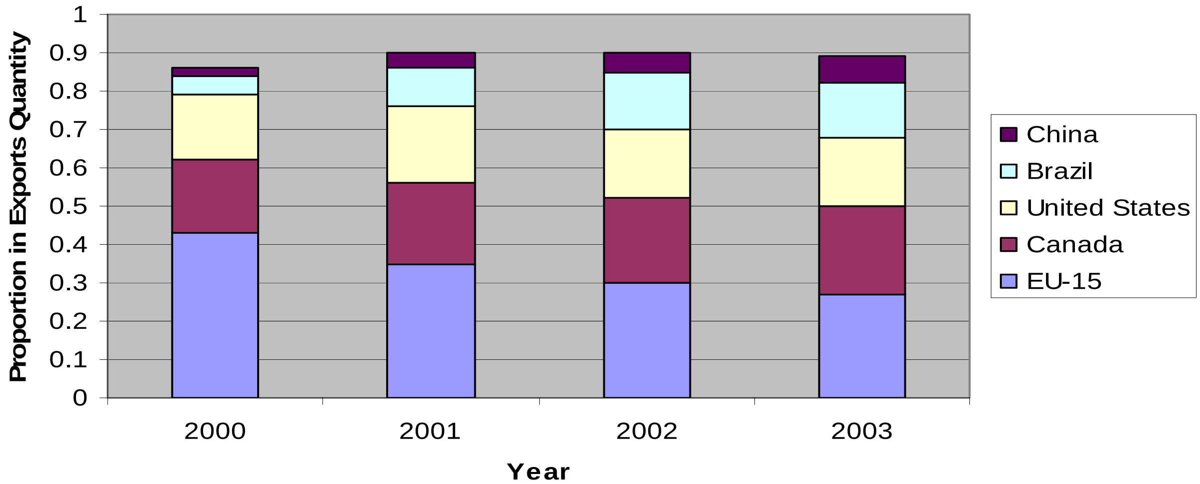

Figure 4. Market Share of Top Five Pork Exporting Countries (2000-2003)

Source: USDA, Foreign Agricultural Service (FAS). Production, Supply and Distribution Online. Webpage: http://www.fas.usda.gov/psd/Psdselection.asp (Accessed August, 2004).

World Pork Consumption

Pork accounted for the largest share of world meat consumption. Production has increased to meet increasing consumer demand. World pork consumption increased more that 78 percent between 1980 and 2003, when it reached 87.5 million metric tons (Figure 5). Poultry consumption increased by 219 percent during this period and continues to show a higher rate of growth than pork, while beef consumption has been stagnant in general. Table 1 shows that China, the EU, the U.S., and Japan account for three-quarters of the total world pork consumption during the early 2000s.

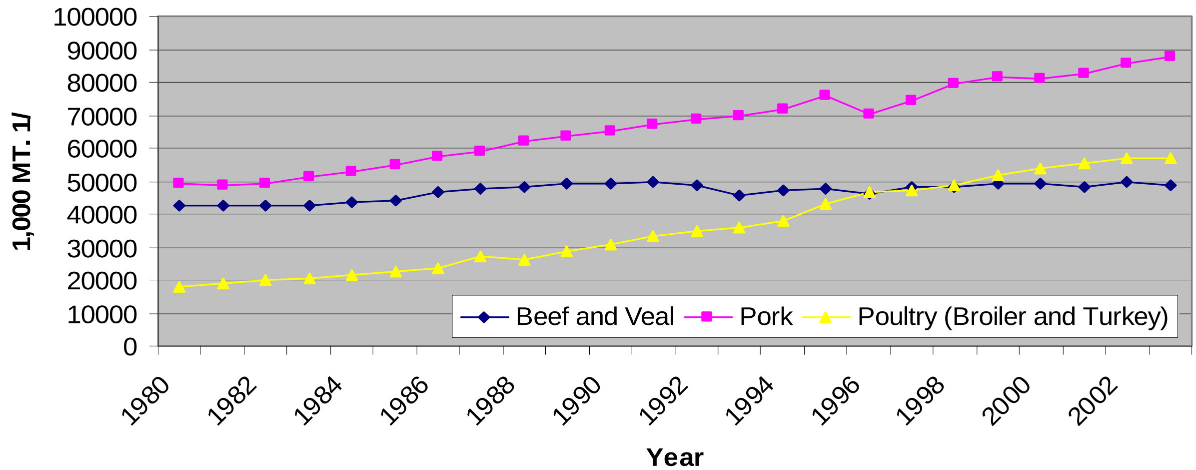

Figure 5. World Meat Consumption (1980-2003)
1/ Carcass weight equivalent

Source: USDA, Foreign Agricultural Service (FAS). Production, Supply and Distribution Online. Webpage: http://www.fas.usda.gov/psd/Psdselection.asp (Accessed October, 2004).

Table 1. Pork Consumption by Countries

Country	Average Per Capita Consumption (Kg)				Annual Average Consumption (1000 MT)	Annual Growth Rate (%)	
	1980-84	1985-89	1990-94	1997-2003	2000-2003	1980-89	1990-2003
Australia	15	17	19	19	373.5	2.2	0.4
Canada	32	31	29	29	1051.25	-1.9	0.6
China	13	18	23	31	42606.5	5.4	4.3
EU	38	40	40	43	16444.75	0.9	0.8
Japan	13	15	15	17	2311.25	1.8	1.5
Korea	8	9	15	20	1177.25	4.1	5.4
Mexico	19	13	11	11	1330.5	-6.8	2.4
Poland	39	43	49	47	1575.25	0.5	0.2
Russia	NA	NA	18	15	2224	NA	-3.4
U.S.	30	29	30	29	8586	-1.2	0.4
World	12	13	13	14	103998.25	1.2	1.0

NA: not available

Source: USDA, Foreign Agricultural Service (FAS). Production, Supply and Distribution Online. Webpage: http://www.fas.usda.gov/psd/Psdselection.asp (Accessed October, 2004).
United Nations (UN), Food and Agriculture Organization (FAO). FAOSTAT (database). Webpage: http://faostat.fao.org/?language=EN (Accessed October, 2004).

Pork Production Technology and Location

According to Haley, Jones, and Southard (1998), expansion of a country's hog production capacity is limited by its resource base. Of the three key hog production resources – land, labor, and capital - land is most likely to constrain growth in pork production. Land is a key factor in pork production. First, land is necessary to house the animals. Although the land requirement for an animal housing facility is minimal, large production facilities may require an extensive low population buffer zone around the housing unit due to odors and other localized environmental impacts. Second, as in the U.S. and Canada, hog feed supplies are frequently drawn from the domestic land base. The absence of a land base adequate to supply feed can be mitigated, however, by importing feed, as is done by Denmark. Third, land is a non-substitutable input into the hog production process for manure utilization. An adequate land base for spreading manure residues is essential, simply because no other economically viable means of manure disposal currently exits. Recent expansion of large, intensive pork production facilities has made manure utilization a topic of public debate in the major pork production countries.

As technological advances in pork production have favored large increases in the size of production units, the importance of lightly inhabited land, to buffer production facilities, and arable land, to produce feed and accommodate manure disposal, is enhanced. The inter-country transferability of production technology and the non-transferability of land with desirable characteristics for large-scale pork production fit well with the Heckscher-Ohlin framework (Appleyard and Field) focusing on factor endowments as a key determinant of trade. Nations with a large land endowment, accompanied by good feed supplies and low levels of environmental regulation may have an advantage in expansion of pork production.

The relative abundance of open land in a country tends to make the land factor less costly relative to the cost of that same factor in another country. Given the intensive use of open land in modern pork production, countries with abundant open land may have a comparative advantage in expanding pork production in the future.

A theoretical framework to test the impact of land availability on the international location of pork production can be developed by considering the responsiveness of production in country *i* in period *t* to changes in demand:

$$\text{chgprod}_{it} = f\,(\text{chgdemand}_{it})$$

if the ability of a country to change production in response to a change in demand is affected by land characteristics of the country, then:

$chgprod_{it} = f_i(chgdemand_{it})$, and

$f_i = g(landchar_i)$

Econometric Model

Our location model maintains that production responds to changes in pork demand and, that the response to pork demand is affected by land availability. World pork consumption and per capita real GDP of each country were used as exogenous pork demand shifters for each country. Increasing world pork consumption increases the demand for total pork production, and increased world demand has the potential to stimulate production increases in any pork-producing country. Also, an increase in per capita real GDP is assumed here to result in growth of households' purchasing power and, since pork is a normal good, this is hypothesized to increase domestic demand for pork.

Assuming that "open land" is a limiting resource for pork production, the responsiveness of pork production in any country to an increase in demand will be affected by the availability of open land. We employed population density and arable land per unit of pork production as measures of land availability. If a country is densely populated, increases in pork production can be restricted because of difficulty in finding locations for new or expanded production facilities away from populated areas. Higher arable land per unit of pork production may enhance the ability of countries to increase pork production since the greater availability of arable land facilitates increases in both feed production and manure spreading.

We use percentage change in pork production as a dependant variable due to differences in size of countries. Percentage change in pork production is modeled as a function of world consumption and per capita real GDP. The general reduced form of supply response model is represented as:

$$PCP_{it} = \alpha + \beta_{1it} Con_t + \beta_{2it} PCGDP_{it} + \mu_i + \varepsilon_{it} \qquad (1)$$

where PCP_{it} is percentage change in pork production in country *i* and year *t*; Con_t is world pork consumption in year *t*; $PCGDP_{it}$ is percentage change in per capita real GDP in country *i* and year *t*. Utilizing a one-way error component model for the disturbance, the random disturbance μ_i is constant through years and it accounts for any country specific effect that is not included in the regression. The remainder disturbance ε_{it} varies with individual countries and years and can be thought of as the usual disturbance in the regression.

The responses of pork production to change in world pork consumption (β_{1it}) and to change in per capita real GDP (β_{2it}) are affected by the land constraints and specified as:

$$\beta_{1it} = \gamma_1 + \gamma_2 Popden_i + \gamma_3 Araland_{it}$$
$$\beta_{2it} = \gamma_4 + \gamma_5 Popden_i + \gamma_6 Araland_{it} \qquad (2)$$

where $Popden_i$ is population density in country *i* and $Araland_{it}$ is arable land per unit of pork production in country *i* and year *t*; $Popden_i$ is calculated by dividing population by total area. $Araland_{it}$ is measured by dividing arable land by one year-lagged pork production. Incorporating land availability measures (2) into equation (1) results in the following:

$$PCP_{it} = \alpha + \gamma_1 Con_t + \gamma_2 Popden_i * Con_t + \gamma_3 Arland_{it} * Con_t$$
$$+ \gamma_4 PCGDP_{it} + \gamma_5 Popden_i * PCGDP_{it} + \gamma_6 Arland_{it} * PCGDP_{it}$$
$$+ \mu_i + \varepsilon_{it} \quad (3)$$

Finally, we include population density and arable land per unit of production in the estimating equation to allow for direct effects on percentage change in pork production:

$$PCP_{it} = \alpha + \gamma_1 Con_t + \gamma_2 Popden_i * Con_t + \gamma_3 Arland_{it} * Con_t$$
$$+ \gamma_4 PCGDP_{it} + \gamma_5 Popden_i * PCGDP_{it} + \gamma_6 Arland_{it} * PCGDP_{it}$$
$$+ \beta_3 Popden_i + \beta_4 Arland_{it} + \mu_i + \varepsilon_{it} \quad (4)$$

Data

This study considers pork production across 17 major pork-producing countries, including EU as a country. We employed annual data from 1985 through 2003. The choice of the period was based on data availability. Pork production data were extracted from the raw data file of Production, Supply and Distribution (PS&D) of the Foreign Agricultural Service, USDA. Pork consumption data were from Custom Query of PS&D of Foreign Agricultural Service. Arable land and population data were obtained from FAOSTAT, Food and Agriculture Organization of the United Nations. Finally GDP data were acquired from statistical databases of the Statistics Division, United Nations.

The EU has grown in size with successive waves of accessions over the time of this analysis. PS&D pork production data are reported for individual EU countries through 1992 and as an aggregate EU total from 1993 on. In the study, we summed production in the following 13 major production countries into a EU aggregate value for the years prior to 1993: Austria, Belgium-Luxembourg, Denmark, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, and the United Kingdom. Data for Switzerland are available from 1985 only to 1999. Among former Soviet Union countries, only the Russian Federation and the Ukraine are included as pork producers. Yearly data from 1988 to 2003 are employed for these two countries because separate data are not available before Soviet Union disintegration.

Hypotheses

We tested the following hypotheses related to the response of pork production to changes in demand:

(1) $\beta_{1it} > 0$: Pork production responds positively to increase in world pork consumption across countries.

(2) $\gamma_2 < 0$: Responsiveness to world pork consumption is lower (higher) in countries with higher (lower) population density.

(3) $\gamma_3 > 0$: Responsiveness to world pork consumption is higher (lower) in countries with more (less) arable land per unit of pork production.

(4) $\beta_{2it} > 0$: Pork production responds positively to increase in per capita real GDP across countries.

(5) $\gamma_5 < 0$: Responsiveness to per capita real GDP is lower (higher) in countries with higher (lower) population density.

(6) $\gamma_6 > 0$: Responsiveness to per capita real GDP is higher (lower) in countries with more (less) arable land per unit of pork production.

Model Estimation Statistics and Results

As seen in Table 2, R^2 for the model was 0.2034, indicating that independent variables in the model explain about 20 percent of the variation in pork production. Adjusted R-squared ($\overline{R}^2$), mean square error (MSE), and standard error (SE) of the estimating equation are 0.1831, 0.0019 and 0.0566, respectively.

The F-test is a test of the hypothesis that the true coefficients of all regressors in the estimating equation (4) are 0. This is not exactly F-distributed but asymptotically F-distributed in finite samples. The F-value was 9.99, leading to the rejection of the joint null hypothesis that all non-intercept parameters are 0 at the 0.01 level.

The t ratios for the parameter estimates and their significance levels are presented in Table 2. We also performed one-tailed t-tests at the 5 percent significance level for the hypotheses that γ_2 and γ_5 are less than zero, and γ_3 and γ_6 are greater than zero. Test results are also presented in Table 2.

World consumption and per capita real GDP are both included in the estimating equation three times: as stand-alone variables and as interaction terms with population density and arable land per unit of pork production. To test if world consumption and per capita real GDP impacted pork production, we specified joint hypotheses tests for three variables. The following null hypotheses were tested using the partial F-test:

$$H_0\text{: } \gamma_1 = \gamma_2 = \gamma_3 = 0 \text{, and}$$

$$H_0\text{: } \gamma_4 = \gamma_5 = \gamma_6 = 0 \qquad (5)$$

Table 2. Parameter Estimates of the Estimating Equation

Estimated model

$$PCP_{it} = -0.07989 + 0.00042\,Con_t - 0.26442\,Popden_i * Con_t + 0.00778\,Arland_{it} * Con_t$$
$$(-3.447)^a \quad (1.896)^c \quad (-2.157)^b \quad (2.307)^b$$

$$+ 0.00180\,PCGDP_{it} - 1.72375\,Popden_i * PCGDP_{it} - 0.02187\,Arland_{it} * PCGDP_{it}$$
$$(1.133) \quad (-2.176)^b \quad (-0.906)$$

$$+ 57.37993\,Popden_i + 0.18152\,Arland_{it}$$
$$(5.079)^a \quad (0.647)$$

One-tailed t-test at $\alpha = 0.05$ (with $t_{crit} = 1.645$)

Hypotheses	Result
$H_0: \gamma_2 = 0$ $H_1: \gamma_2 < 0$	Reject H_0
$H_0: \gamma_3 = 0$ $H_1: \gamma_3 > 0$	Reject H_0
$H_0: \gamma_5 = 0$ $H_1: \gamma_5 < 0$	Reject H_0
$H_0: \gamma_6 = 0$ $H_1: \gamma_6 > 0$	Do not reject H_0

R^2	$\overline{R}^2$	MSE	SE (reg)	df	obs.
0.2034	0.1831	0.0019	0.0566	313	322

Note: Numbers in parentheses below each estimated parameter represent asymptotic *t* ratios. [a], [b] and [c] represent statistical significance at 1%, 5% and 10%, respectively. $\overline{R}^2$ is the adjusted R-squared; MSE is the mean square error; SE is the standard error of regression; and df is the degree of freedom.

where γ_1, γ_2, and γ_3 are parameter estimates related to world consumption and γ_4, γ_5 and γ_6 are parameter estimates related to per capita real GDP in the estimating equation. The partial F-test can be expressed in terms of R^2 obtained from the restricted model which exclude explanatory variables related to per capita real GDP (R_R^2) and the unrestricted model which include every explanatory variable (R_{UR}^2) (Jung and Koo, 2000).

We rejected the null hypothesis for the world consumption parameters, H_0: $\gamma_1 = \gamma_2 = \gamma_3 = 0$ at the 1 percent significance level because the calculated F-value is 14.69 and the critical F-statistic is 3.78. The calculated F-value of 19.52 also led to the rejection of the second null hypothesis for the per capita income parameters.

We expected a negative effect of population density ($Popden_i$) and a positive effect of arable land per unit of pork production ($Arland_{it}$) on the response of pork production to changes in both world consumption and per capita real GDP.

The estimation generally yielded significant coefficient estimates with the expected signs. The estimated impacts of both population density (γ_2) and arable land per unit of pork production (γ_3) on the responsiveness of pork production to world pork consumption were significant at α=0.05 level with estimates of -0.2644 and 0.0078, respectively. The estimated impact of population density (γ_5) on the responsiveness of production to changes in per capita income was significant at α=0.05 with a coefficient estimate of -1.7237, while the coefficient of arable land per unit of production (γ_6) is not statistically different from zero.

Our findings thus suggest that the responsiveness of production to increases in world pork consumption is lower (higher) in countries with a higher (lower) population density, and greater (smaller) in countries with more (less) arable land per unit of pork production. The responsiveness of pork production to changes in per capita real GDP is lower (higher) in countries with higher (lower) population density, but not significantly affected by arable land availability. For example, an increase (decrease) of 1 person per hectare in population density causes about 0.026 percent decrease (increase) in the response of pork production to change in world consumption (β_{1it}). An increase (decrease) of 10 hectares of arable land per unit of pork production leads to about 0.008 percent increase (decrease) in the response to change in world consumption. Additionally, an increase (decrease) of 1 person per hectare in population density results in approximately 1.72 percent decrease (increase) in the response of pork production to a change in per capita real GDP (β_{2it}).

Table 3 depicts the response of pork production to change in demand across countries. The response to both world pork consumption (β_{1it}) and per capita real GDP (β_{2it}) are evaluated at year 2003. As for the response of pork production to world pork consumption, 13 out of 17 countries have expected positive signs for β_{1it}. The response of pork production to change in per capita real GDP does not yield expected signs across countries, with only 5 countries with positive estimates for 2003. Of the three variables including per capita real GDP in the estimation, only the coefficient estimate of the interaction of population density and per capita real GDP was individually statistically significant. Although we expected per capita real GDP to have a demand-related positive effect on pork production, the negative effect in our results in Table 3 may be due to increased objections to hog production facilities as income in a country increases. This effect would likely be even greater in countries with higher population densities, as shown by the negative and significant coefficient of the interaction variable between population density and per capita real GDP.

Table 3. Response of Pork Production to Pork Demand across Countries

Country	Response to World Consumption (β_{1it})[1]	Response to Per Capita Income (β_{2it})[2]
Australia	0.001377801	-0.000946914
Russian Federation	0.00099376	-0.000016809
Ukraine	0.000627947	-0.000808689
Canada	0.000605622	0.001208393
Brazil	0.000544052	0.000959844
United States	0.000498375	0.000855788
Mexico	0.000466808	0.000428317
Bulgaria	0.000382869	0.00011046
Romania	0.000349514	-0.00032196
Hungary	0.000214641	-0.000271515
Poland	0.000160874	-0.000516361
European Union[3]	0.000114699	-0.000498389
China	0.000093877	-0.000573415
Switzerland[4]	-0.000022355	-0.001236083
Philippines	-0.000204641	-0.002663938
Japan	-0.000438415	-0.004076075
Korea; Republic of	-0.000813532	-0.006366808

Note: Both β_{1it} and β_{2it} are evaluated at year 2003 as a critical year. Countries are sorted in a descending order by the response to world consumption, β_{1it}.

1. $\beta_{1it} = \gamma_1 + \gamma_2 Popden_i + \gamma_3 Araland_{it}$, where $Popden_i$ is population density in country i; $Araland_{it}$ is arable land per unit of pork production in country i and year t; $Araland_{it}$ is calculated by dividing arable land by one-year-lagged production.
2. $\beta_{2it} = \gamma_4 + \gamma_5 Popden_i + \gamma_6 Araland_{it}$, where $Popden_i$ and $Araland_{it}$ are previously stated.
3. We consider the following 13 major production countries as EU: Austria, Belgium-Luxembourg, Denmark, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.
4. The response of Switzerland to both world consumption and per capita income is evaluated at year 1999 due to data availability.

Summary And Conclusion

Technological changes in pork production practices have resulted in increased economies of size. Since low cost production is a key factor in the ability of firms to compete successfully in international markets, firms that adopt the new technologies will have an advantage in the world market. The new large-scale production technologies, however, have greater negative impacts on local production areas than old small-scale technologies, and the location of new pork production facilities is likely to be impacted by differences in environmental costs in different locations. Environmental regulations, and the added costs generally associated with compliance, are considerations often factored into the choice of a business location, such as manure disposal. Previous research has suggested that geographic variations in environmental regulations and enforcement can induce a migration of industries across state or country boundaries to "pollution havens" where compliance costs associated with environmental regulation are lower. Given the apparent importance of "open" land to expansion of large-scale hog production, we attempted to develop an empirical model to examine the relationship between measures of land availability and changes in pork production.

This study examined the response of pork production to pork demand across countries. We maintained that pork production responds to change in pork demand and, that the response to pork demand is affected by land availability.

Population density and the availability of arable land per unit of pork production were found to have significant impacts on the responsiveness of pork production to changes in world pork consumption. Higher population density decreased production responsiveness to increased world consumption and greater amounts of arable land relative to pork production increased responsiveness. Population density was found to have a negative impact on the responsiveness of pork production to per capita real GDP, while the amount of arable land per unit of pork production appeared to have no impact on production response to changes in income.

The observed negative effect of per capita real GDP on pork production may be due to increased objections to hog production facilities with higher income levels, and this effect is greater in countries with higher population densities. Compared with the densely populated countries of the Philippines, Japan and Korea with virtually insurmountable land constraints, countries with relatively large land endowments and much less dense population such as Australia, the Russian Federation, Canada, Brazil, and the U.S. seem to have the potential to expand production in the future and meet expected increases in world demand for pork.

Future Research

Regional trade agreements have become a fixture in the global pork trade, and their role in pork production is increasing. We did not evaluate the effect of bilateral and multilateral trade agreements on pork production and trade policy of individual countries. An outbreak of foot-and-mouth disease (FMD) and classical swine fever (CSF) contributed to a slowdown in the growth of global pork consumption and trade. A more comprehensive study would include the impacts of these and other factors affecting pork production. These issues are left for future research.

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