



# Key Performance Indicators in Pork Production: An International Comparison Using 2019 Data

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This document updates a 2020 report that benchmarked international pork production using 2018 data. That report showed that China and Japan had the highest profits, Denmark and the Netherlands had the highest animal productivity and that the United States and Matto Grosso in Brazil had the lowest costs. As was true for the 2020 report, this report also estimates the value of improving key performance indicators in each country, and describes the key indicators that drive financial performance. Because this is the second in a series, we are now able to compare changes in key indicators between the 2018 data used in the first report and the 2019 data used to generate this report. The raw data in both reports comes primarily from an international benchmarking network known under the acronym InterPIG. The representatives of the seventeen participating countries, listed in List 1, come from scientific institutions and extension services of producer organizations and have built the database over several years. Members meet once per year to update and actualize the dataset and ensure that the cross-country comparisons are as accurate as possible. They use production and financial data from farm records to measure the countrywide average performance of representative pork farms. Definitions have been standardized across countries using a glossary of terms so, for instance, a “gilt” is defined in the same way in every data set, and carcass weights are adjusted to reflect whether the head is left on or removed. The InterPIG group also functions as a forum for information exchange.

Several key importing countries do not participate in InterPIG. Merck Animal Health technical, marketing, and sales staff helped collect representative data for two of them, China and Japan. The intention is to add additional countries in future years. The data for Japan is from the Agriculture and Livestock Industries Corporation, Japanese Ministry for Agriculture Fisheries and Forestry, and other sources, and the data for China is from producers and veterinarians in China. We also used information from discussions with veterinarians and producers based in the USA, who either have ownership of pigs in China or who have consulted there extensively, to make adjustments to the data for China. The data for China is for a modern, large-scale, single-story, non-filtered pig farm that is free of African swine fever virus (ASFV) and does not necessarily represent averages for all farms in that country.

This report begins with a look at the raw data. All comparisons are for 2019 and results are presented in U.S. dollars. Much of the information is available from reports written by InterPIG members, so the value-added here is the inclusion of China and Japan and the novel approach of comparing pig production across

countries. Namely, we conduct an analysis to determine which factors give each country a competitive advantage or disadvantage. These calculations, which provide a novel approach to evaluating competitiveness, help us isolate how much of an advantage or disadvantage each factor conveys to each country. Year-over-year comparisons are then made to compare changes in key indicators between 2018 and 2019. We then calculate the marginal value of changes in key performance indicators, such as pigs born alive per litter farrowed. There is no consensus on how performance should be measured. Breeding companies are interested in performance per breeding female, pig farmers evaluate performance per pig produced, and those who are interested in international trade measure performance based on kilograms of meat. We, therefore, present results using all three measures. Values are presented based on a breed-to-market system, where breeding, nursery (rearing) and finishing (fattening) phases are combined.

## List 1. InterPig Membership

InterPIG is a collaborative network involving the following organizations and countries:

1	Great Britain	Agriculture and Horticulture Development Board (AHDB)
2	Austria	VLV Upper Austria
3	Belgium	Flemish Government and Boerenbond Belgie
4	Brazil	Embrapa Swine and Poultry
5	Brazil	Submits data for two regions: Mato Grosso (MT) and Santa Catarina (SC)
6	Canada	Canadian Pork Council
7	Czech Republic	Institute of Agricultural Economics and Information (UZEI)
8	Denmark	SEGES
9	Finland	Atria
10	France	IFIP
11	Germany	Thuenen Institute and Interessengemeinschaft der Schweinehalter (ISN)
12	Hungary	AKI Research Institute of Agricultural Economics
13	Ireland	Teagasc
14	Italy	Research Centre for Animal Production (CRPA)
15	Netherlands	Wageningen Economic Research
16	Spain	SIP Consultors
17	Sweden	Svenska Pig
18	USA	Iowa State University

## Part 1: The Raw Data

Figure 1 shows the total carcass weight produced per breeding female, the average carcass weight, and the number of pigs marketed per year. As was true in our previous report Italy has by far the heaviest carcasses and also leads in terms of carcass weight produced per breeding female. Denmark and the Netherlands produce the next highest carcass weight per breeding female because they sell the largest number of pigs per breeding female at 31.29 and 28.68, respectively. The USA and Brazil are in the middle of the pack and China lags in this measure with only 16.63 pigs marketed per female. China experienced widespread mortality in 2019 due to an outbreak of African Swine Fever (ASF) that began in August of 2018. This is not reflected in our data because the farm we used, as our basis for comparison, did not experience an outbreak. This outbreak did, however, influence the financial performance of our representative farm because it led to higher prices for live pigs.

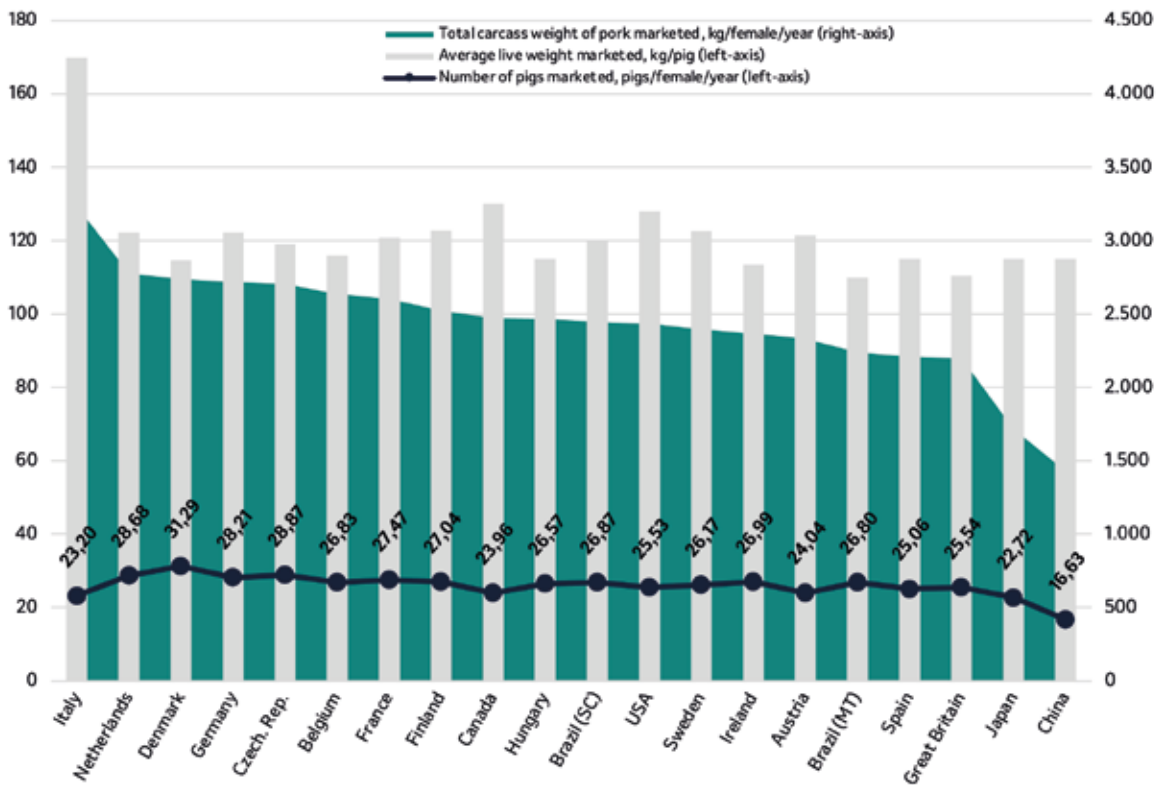


Fig. 1 Total carcass weight produced per breeding female, average live weight, and number of pigs marketed—2019

Figures 2, 3 and 4 show the revenue, cost, and profit for each country. The results are presented on a per kilogram of carcass weight sold, per pig sold, and per breeding female basis in Figures 2, 3, and 4, respectively. Figure 2 (bars) shows, that Japan and China have by far the highest production costs per kilogram of pork sold. Italy comes in third in part because Italian pig farmers raise very large Italian White pigs for a premium branded ham market. The state of Mato Grosso in Brazil and the USA have the lowest overall costs. Brazil has two data points because of the huge differences that exist between the traditional pig farming state of Santa Catarina (SC) and the new frontier in Brazilian pork production, Mato Grosso (MT). Santa Catarina is free of foot and mouth disease virus (FMDV) and is eligible to export to a wide range of countries. Mato Grosso has FMDV and can only export to a very narrow range of importers.

Figure 2 also shows the market price received (line) and net profit (shaded area). Market pig prices are highest in China, Japan and Italy. Net profit is greatest in China then Japan. The ASF outbreak in China resulted in large losses in domestic production and increases in Chinese pork imports which led to strong prices in almost every country. Only three countries (Italy, Ireland, and the Czech Republic) experienced losses. This was a turnaround from 2018 when many of the European countries showed negative net profits. The straight line shows the average net profit across all countries is US\$0.19 per kg of carcass weight. This average in 2018 was only \$0.01.

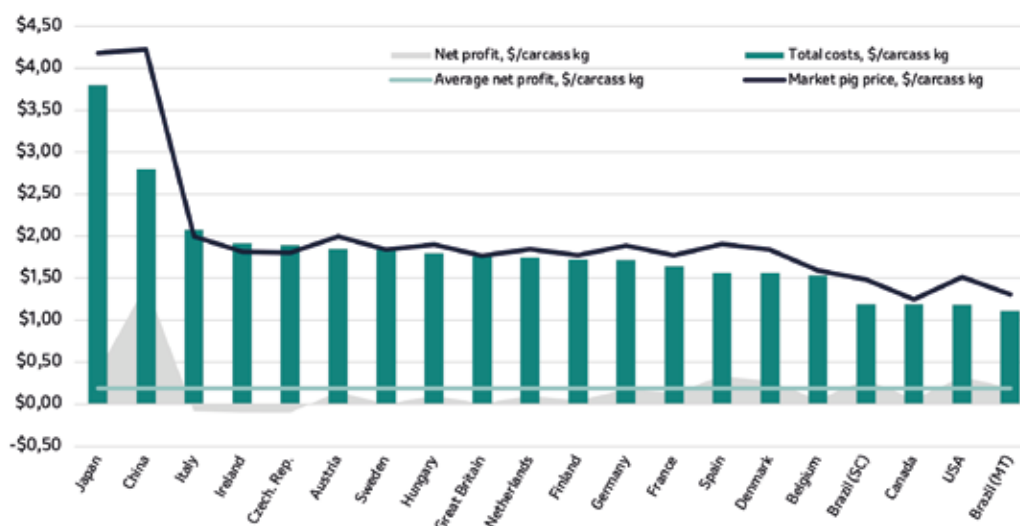


Fig. 2 Revenue, cost, and profit per carcass kg sold—2019

Figure 3 shows that Italy has the highest costs when measured on a per pig sold basis. This reflects the high carcass weights, low productivity, and high feed costs in Italy. Results for other countries are similar to those in Figure 2. Figure 4 shows the same data but on a per breeding female basis. Italy and Japan have the highest cost values. China is much more competitive in this measure. As could be seen in Figure 1, Chinese breeding females are much less productive than in other countries, which explains why China is ranked so poorly in terms of the cost of producing pigs or carcass weight and yet is more competitive when cost is expressed on a per breeding female basis.

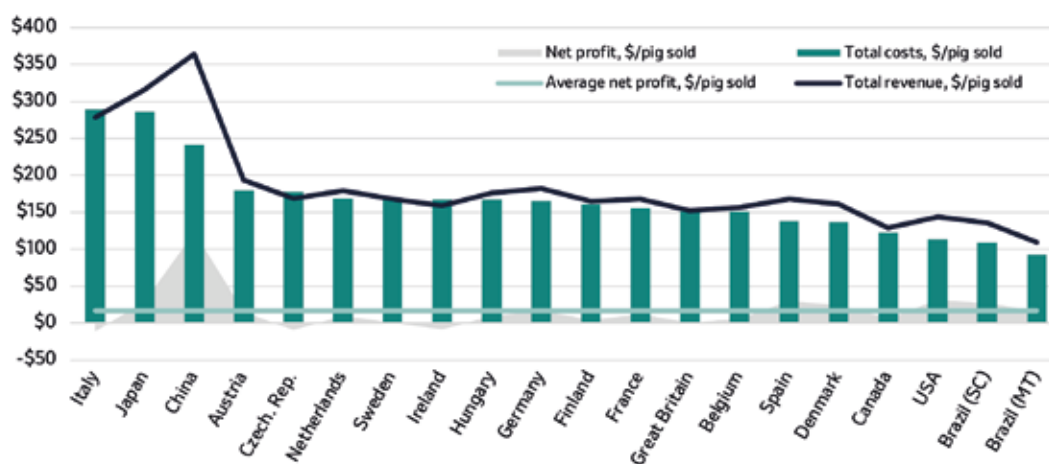


Fig. 3 Revenue, cost, and profit per pig sold—2019

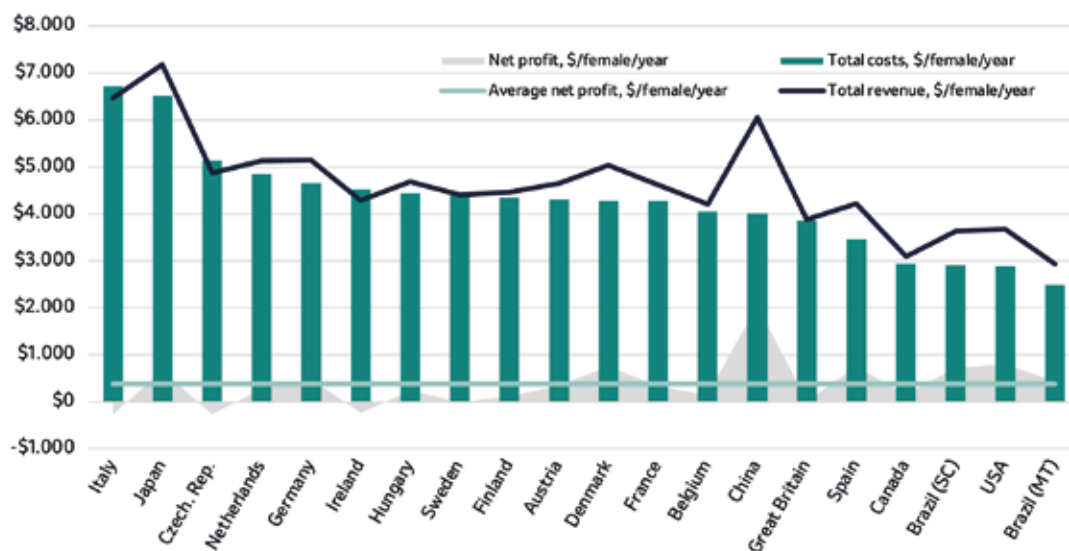


Fig. 4 Revenue, cost, and profit per breeding female—2019

Figures 5, 6 and 7 (bars) provide additional detail on the breakdown of costs. Feed makes up a large portion of costs in all countries, particularly in Japan, China, and Italy. These high feed costs are compensated for by high market pig values and revenue, as shown by the line. Low feed costs in the USA and Brazil provide these two countries with a significant advantage in cost of production. This advantage is offset, to a certain degree, by relatively low market pig prices. The information in Figures 5, 6 and 7 can also be expressed in percentage terms and this information is available in Appendix 1. Each cost component as a percentage of the total cost does not vary when the results are reported on a per kg of carcass weight, per pig sold, or per breeding female basis. Therefore a single table with the breakdown of costs by component as a percentage of the total cost is provided.

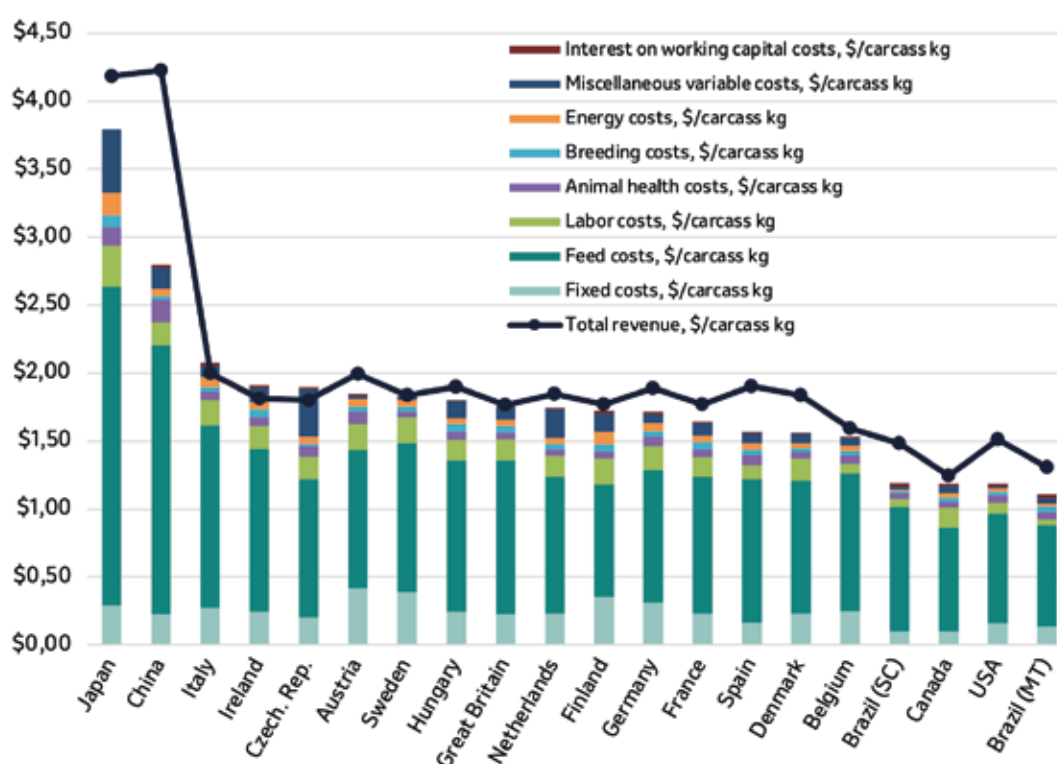


Fig. 5 Detailed costs per carcass kg sold—2



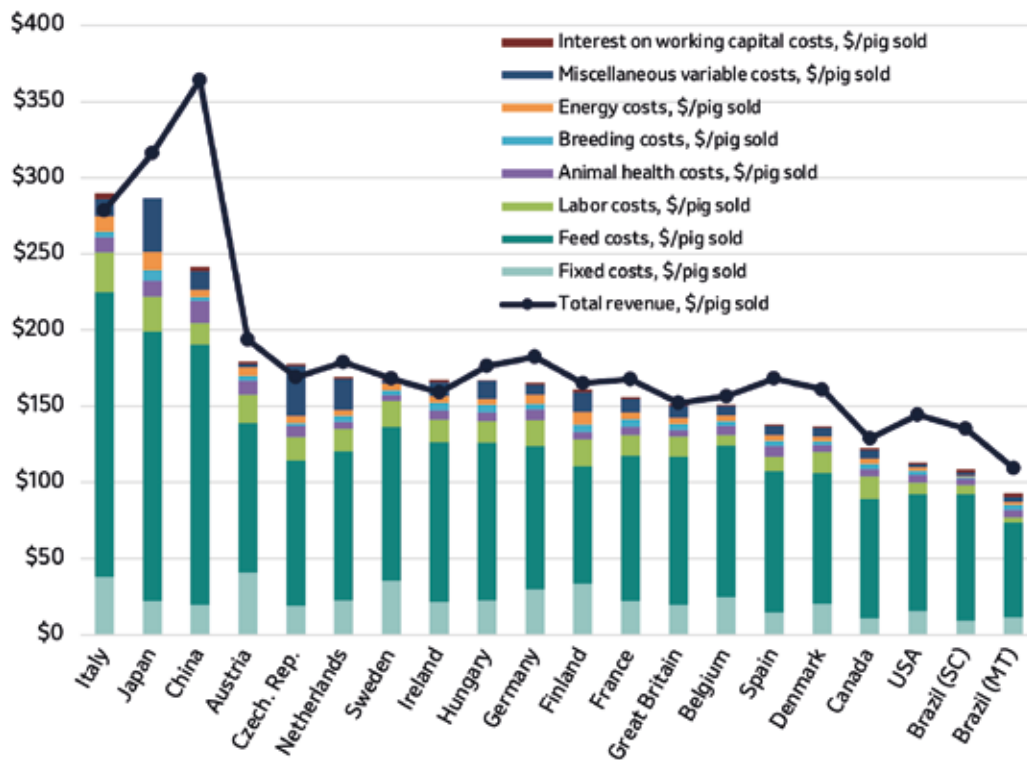


Fig. 6 Detailed costs per pig kg sold—2019

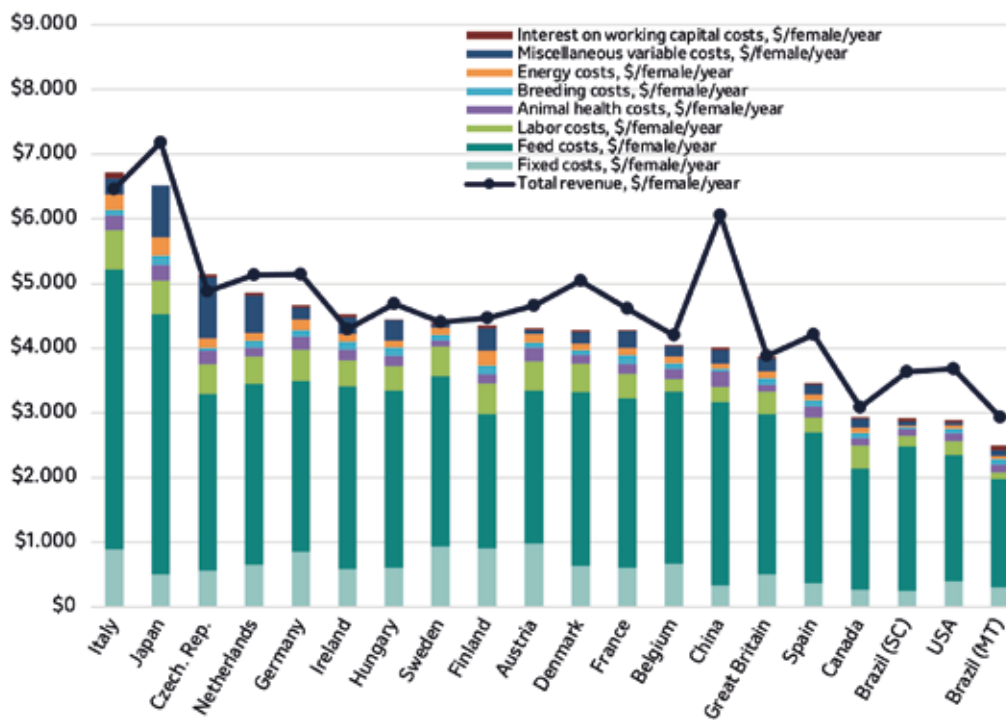


Fig. 7 Detailed costs per breeding female—2019



Figure 8 compares feed prices on a dollars per metric tonne basis for feed in the breed-to-wean and wean-to-market phases of production. The wean-to-market feed price is typically higher than the breeding female feed price. Feed prices are highest in Japan and China and lowest in countries in North and South America, with the exception of the state of Santa Catarina in Brazil. Feed prices for countries in Europe fall in the middle. Countries with lower feed prices also have lower market pig prices. This is because low feed prices stimulates production in these countries until live pig prices fall to equal the cost of production. It is also true that countries with high feed prices erect trade barriers to protect domestic producers.

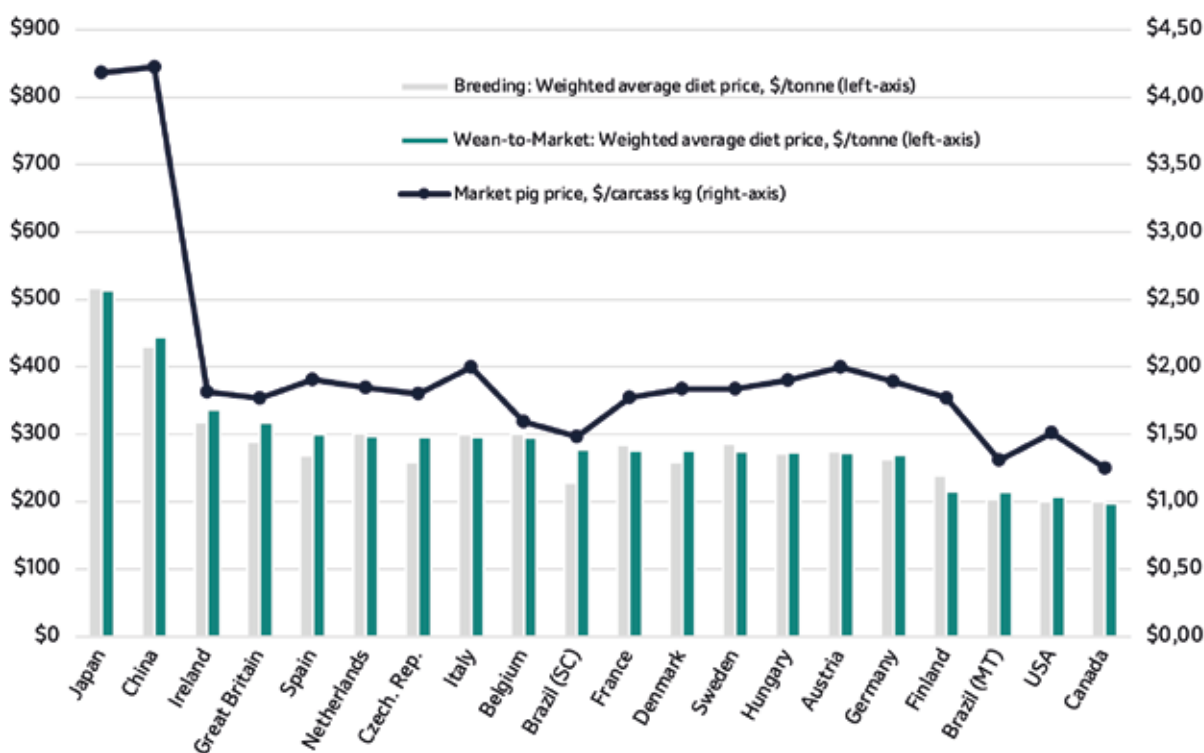


Fig. 8 Feed costs by phase of production and market pig prices—2019

Figure 9 compares labor cost per hour, or wage rate, against labor productivity, measured as the hours of labor used per breeding female for all phases of production (breed-to-market). The Netherlands, Denmark and Sweden have the highest labor cost per hour, and Belgium, USA and Spain have the highest labor productivity (lowest labor usage). The USA has modest labor costs per hour and comes in second in terms of labor productivity. The Czech Republic, Hungary, Brazil (SC), and China have very low labor productivity (high labor usage) but also have low hourly labor costs. Generally, the higher the cost of labor per hour in a country, the higher the labor productivity (low labor usage). Belgium, USA, and Spain are exceptions in that they have relatively high labor productivity and modest cost of labor per hour. Japan and Italy have relatively low labor productivity despite higher labor costs per hour.

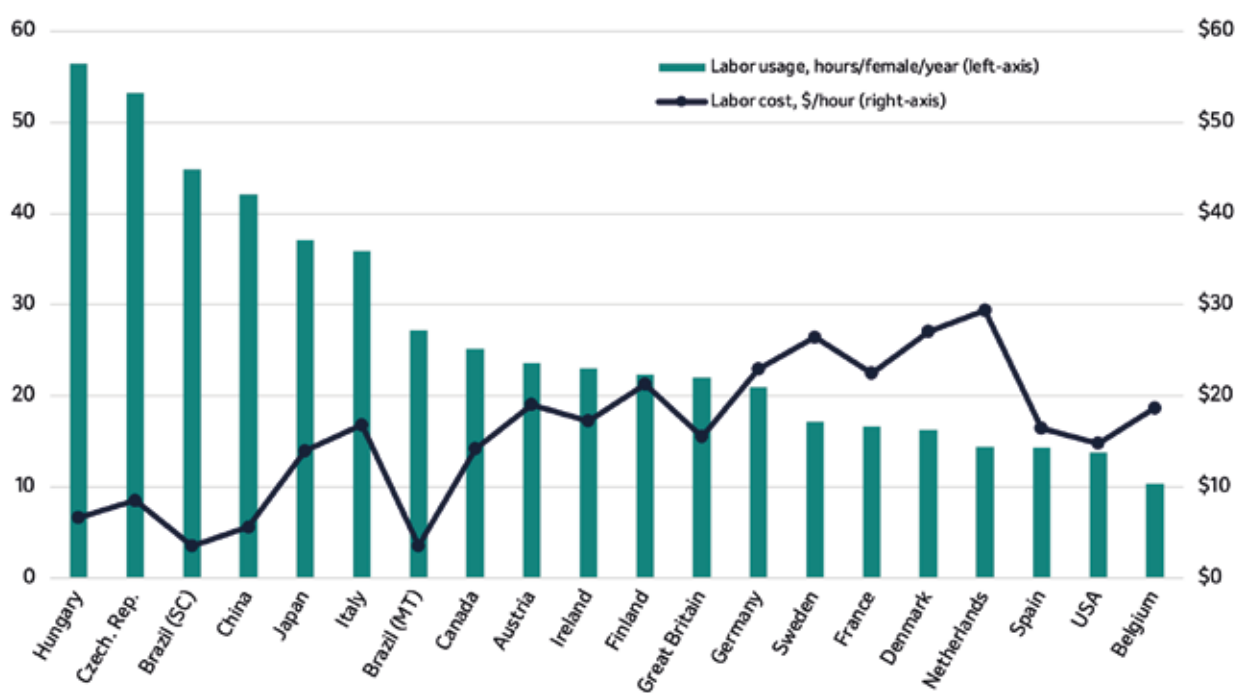


Fig. 9 Labor usage and cost—2019

## Part 2. Sources of Competitive Advantage

Here we explore the factors that give producers a leg up, measured by profit, over producers in other countries. We do this by setting the costs, prices, and productivity for each country to the same value, the average for all countries. The only values that varied for each country are those for the factor evaluated. Each factor is evaluated alone, one-at-a-time. Any differences in profitability, therefore, are due strictly to the country differences in the values for that factor. As an example, one of the factors evaluated was feed prices. For that factor, feed prices in the breeding, nursery (rearing) and finishing (fattening) phases of production were set to the values reported for each country. All other values were the same for every country, set to the average value of all countries. For each factor, the relative advantage or disadvantage is measured as the difference in profitability relative to a hypothetical country with average values for the factor evaluated. An advantage (disadvantage) is reported as a positive (negative) contribution to profitability above (below) the hypothetical average country. In order to reduce the number of figures to evaluate, we present results on a dollars per kilogram sold basis (Table 1). The set of countries are listed in the first column and the table is sorted according to the second column which is the profit advantage of each country compared to the average of all the countries. The results expressed based on a per pig sold or per breeding female basis are in Appendix 2.

The factors that contributed to the highest relative advantage or disadvantage were market pig prices, feed prices, and productivity. The relative advantage or disadvantage for the other factors evaluated, wage rates, labor productivity, and fixed costs are lower but still important.

The third column in Table 1 evaluates the contribution of market pig prices to profitability in 2019. Japan and China benefit from high market pig prices. Brazil, Canada, and the USA lose out in this regard. High market pig prices in China and Japan give producers there a respective US\$2.24 and US\$2.20 per kg of carcass weight advantage over a country with average market pig prices, such as Austria. China's advantage over USA is actually US\$2.71 since USA has a US\$0.47 disadvantage to the average. This means that, if somehow China and USA are made equal by every measure except market pig prices, with the same costs, same productivity, etc., producers in China would earn US\$2.71 per kg of carcass weight more than those in the USA because of the higher market pig prices they receive. Producers in Canada received the lowest market pig prices,

giving them a US\$0.74 per kg of carcass weight disadvantage to a country with average market pig prices and a US\$2.98 disadvantage to producers in China.

The fourth column in Table 1 provides the same comparison for feed prices. The USA, Brazil and Canada in the Americas, as well as Finland in Europe, benefit from low feed prices while Italy, Ireland, China, and Japan fare poorly on this measure. Low feed prices in Canada give producers there a US\$0.35 per kg of carcass weight advantage over a country with average feed prices. Producers in Japan have the highest feed prices giving them a US\$0.78 per kg of carcass weight disadvantage to a country with average feed prices and a US\$1.13 disadvantage to producers in Canada with the lowest feed prices.

The fifth column in Table 1 evaluates the importance of genetics, health, nutrition, and animal husbandry, i.e. productivity in breeding, nursery (rearing), and finishing (fattening). Here Denmark, the Czech Republic, the Netherlands, and Ireland lead while China, Japan, and Italy lag. Producers in Denmark have the highest productivity giving them a US\$0.23 per kg of carcass weight advantage to a country with average productivity. Producers in Japan are at a \$0.53 per kg of carcass weight disadvantage to a country with average productivity and a \$0.76 disadvantage to producers in Denmark.

The sixth column in Table 1 evaluates the impact of fixed costs, which are determined primarily by building costs, on relative profitability. Low fixed costs provide the greatest competitive advantage to producers in Brazil (SC and MT), Canada, Spain, China and the USA. Higher fixed costs provide the largest competitive disadvantage to producers in Sweden, Italy, Austria and Finland. Producers in the state of Santa Catarina in Brazil have the lowest fixed costs giving them a US\$0.14 per kg of carcass weight advantage to a country with average fixed costs and a US\$0.32 advantage to producers in Austria with the highest fixed costs.

The seventh column in Table 1 evaluates labor productivity, measured as the hours of labor used per breeding female for all phases of production (breed-to-market). Belgium, The Netherlands, USA, Spain and Denmark perform well under this measure while China, Brazil (SC), the Czech Republic and Hungary lag. The eighth column in Table 1 shows the other part of the labor equation by comparing the cost of labor per hour or wage rate. The countries that have low labor productivity, including Brazil (SC and MT), the Czech Republic, China, and Hungary, all have low wage rates. The Netherlands,

the highest wage rates. To evaluate labor costs, both labor productivity and wage rate are evaluated together (ninth column). Brazil (MT and SC), Spain, Belgium and the USA fare well, and Japan, and Italy do poorly. Producers in the state of Mato Grosso in Brazil have the lowest labor costs giving them a US\$0.12 per kg of carcass weight advantage to a country with average labor costs and a US\$0.23 per kg advantage over Italy with the highest labor costs.

**Table 1.** Profit Advantage of Select Factors, All Other Variables Held Constant, US\$ Per Carcass kg Sold Basis, 2019

Country	Profit advantage over average	Market pig prices	Feed prices	Productivity	Fixed costs	Labor usage	Wage rates	Labor Usage & Wage Rates
China	\$1.24	\$2.24	-\$0.56	-\$0.52	\$0.06	-\$0.16	\$0.12	\$0.03
Japan	\$0.20	\$2.20	-\$0.78	-\$0.53	\$0.02	-\$0.08	\$0.02	-\$0.07
Spain	\$0.15	-\$0.08	-\$0.04	-\$0.09	\$0.09	\$0.08	\$0.00	\$0.05
USA	\$0.14	-\$0.47	\$0.28	-\$0.06	\$0.08	\$0.09	\$0.02	\$0.07
Brazil (SC)	\$0.10	-\$0.50	\$0.04	\$0.09	\$0.14	-\$0.11	\$0.14	\$0.09
Denmark	\$0.09	-\$0.15	\$0.08	\$0.23	\$0.01	\$0.08	-\$0.12	-\$0.02
Brazil (MT)	\$0.01	-\$0.68	\$0.30	\$0.10	\$0.12	\$0.00	\$0.14	\$0.11
Germany	-\$0.01	-\$0.09	\$0.09	\$0.12	-\$0.09	\$0.05	-\$0.08	-\$0.04
Austria	-\$0.04	\$0.01	\$0.08	\$0.02	-\$0.18	\$0.02	-\$0.03	-\$0.04
France	-\$0.06	-\$0.21	\$0.06	\$0.08	\$0.00	\$0.07	-\$0.07	\$0.00
Netherlands	-\$0.09	-\$0.14	-\$0.04	\$0.18	-\$0.01	\$0.09	-\$0.15	-\$0.02
Hungary	-\$0.09	-\$0.08	\$0.05	-\$0.15	\$0.00	-\$0.19	\$0.11	\$0.00
Canada	-\$0.13	-\$0.74	\$0.35	\$0.02	\$0.13	\$0.01	\$0.02	\$0.00
Belgium	-\$0.13	-\$0.39	-\$0.03	\$0.07	-\$0.03	\$0.11	-\$0.03	\$0.07
Finland	-\$0.14	-\$0.21	\$0.28	\$0.13	-\$0.12	\$0.04	-\$0.06	-\$0.04
Great Britain	-\$0.18	-\$0.22	-\$0.06	\$0.12	\$0.03	\$0.03	\$0.01	\$0.01
Sweden	-\$0.19	-\$0.15	\$0.06	\$0.04	-\$0.14	\$0.07	-\$0.11	-\$0.04
Italy	-\$0.27	\$0.01	-\$0.04	-\$0.26	-\$0.15	-\$0.07	-\$0.01	-\$0.11
Czech. Rep.	-\$0.29	-\$0.18	\$0.01	\$0.22	\$0.03	-\$0.16	\$0.09	-\$0.03
Ireland	-\$0.29	-\$0.17	-\$0.12	\$0.17	\$0.01	\$0.03	-\$0.01	-\$0.01

## Part 3. Year over Year Comparisons

Table 2 compares several key productivity and financial measures between 2018 and 2019. Hungary, Finland and the USA saw the largest increase in total carcass weight per female and in the number of pigs marketed. The rapid increase in productivity in Hungary may be due to the ongoing transition from small pig farms to more modern commercial large-scale farms. China and Japan went backward due to disease outbreaks (ASF in China and Classical Swine Fever in Japan). In China, the productivity estimates are for a farm that is free of ASFV. The productivity impacts there, however, are related to the ASFV as producers responded to the outbreak by, for example, reducing the use of injectable vaccines and other animal health products due to perceived fears that injections may transmit the virus. Producers in China also compensated for reduced female productivity by increasing the market weight of pigs.

**Table 2. Year-Over-Year Comparisons of Key Indicators, 2019 vs. 2018**

Country	Total carcass weight of pork marketed (kg/female/year)	Average live weight marketed (kg/pig)	Number of pigs marketed (pigs/female/year)	\$/kg carcass weight				
				Country	Net profit	Market pig price	Total cost	Total feed cost
Hungary	330.56	6.21	2.24	China	0.68	1.08	0.40	0.32
Finland	110.30	-1.20	0.96	Germany	0.41	0.26	-0.15	-0.08
USA	109.48	0.90	0.99	Denmark	0.40	0.36	-0.04	0.01
France	91.74	0.52	0.85	Brazil (MT)	0.33	0.33	0.00	-0.03
Spain	45.85	2.64	-0.12	Spain	0.31	0.24	-0.08	-0.05
Ireland	42.92	0.90	0.01	Austria	0.30	0.21	-0.09	-0.08
Great Britain	30.03	0.93	0.14	Netherlands	0.28	0.24	-0.03	0.00
Czech. Rep.	26.79	0.00	0.29	Finland	0.26	0.01	-0.25	-0.18
Austria	26.78	-0.27	0.32	Brazil (SC)	0.26	0.16	-0.10	-0.08
Canada	23.96	2.23	0.00	Czech. Rep.	0.26	0.21	-0.05	-0.02
Sweden	11.27	-1.10	0.35	Hungary	0.26	0.22	-0.04	0.02
Denmark	7.30	1.83	-0.13	France	0.25	0.20	-0.05	0.00
Netherlands	-0.78	1.40	-0.34	Belgium	0.23	0.06	-0.18	-0.10
Brazil (SC)	-1.67	-1.03	0.21	Canada	0.18	0.02	-0.16	-0.15
Italy	-17.69	0.00	-0.13	Ireland	0.16	0.11	-0.05	-0.06
Brazil (MT)	-29.59	0.00	-0.35	Great Britain	0.07	-0.06	-0.13	-0.08
Belgium	-30.31	0.36	-0.48	USA	0.06	0.08	0.02	0.02
Germany	-30.34	0.00	-0.29	Italy	0.03	-0.12	-0.15	-0.13
Japan	-69.76	0.00	-0.86	Sweden	0.00	-0.08	-0.07	-0.02
China	-101.89	5.00	-1.98	Japan	-0.25	0.22	0.47	0.01
<b>Average</b>	<b>28.75</b>	<b>0.97</b>	<b>0.08</b>		<b>0.22</b>	<b>0.19</b>	<b>-0.04</b>	<b>-0.04</b>



The financial measures on the right side of Table 3 show that almost all countries benefited from higher market pig prices and lower feed costs leading to notable increases in profits. Japan is the only country where producers made less in 2019 than in 2018. However, this was from a very high profit base in 2018.

**Table 3.** Change in Profit Per Incremental Change in KPI, 2019

	US\$/breeding female/year			US\$/pig sold		
	Litters farrowed / female / year	Pigs born alive / litter farrowed	Prewean mortality (% of pigs born alive)	Wean-to-market Mortality (% of pigs placed)	Wean-to-market Average daily gain (kg / day)	Wean-to-market Feed-to-gain ratio (kg feed / kg gain)
<b>Increment</b>	<b>0.05</b>	<b>0.25</b>	<b>-1.0%</b>	<b>-1.0%</b>	<b>0.01</b>	<b>-0.025</b>
China	\$78.15	\$70.14	\$32.82	\$1.17	\$3.05	\$1.26
Japan	\$45.45	\$44.22	\$24.18	\$1.36	\$2.29	\$1.47
Denmark	\$41.16	\$26.66	\$21.84	\$0.65	\$0.99	\$0.77
Germany	\$35.98	\$26.70	\$19.70	\$0.73	\$1.27	\$0.80
Spain	\$34.22	\$28.13	\$18.25	\$0.67	\$1.25	\$0.85
Austria	\$33.88	\$30.30	\$18.00	\$0.82	\$1.40	\$0.79
France	\$31.77	\$25.48	\$17.49	\$0.75	\$1.10	\$0.81
Finland	\$31.49	\$23.94	\$16.57	\$0.73	\$0.62	\$0.73
Netherlands	\$30.13	\$23.72	\$16.08	\$0.71	\$1.17	\$0.87
USA	\$30.05	\$28.16	\$17.40	\$0.55	\$0.94	\$0.66
Hungary	\$29.19	\$26.87	\$15.01	\$0.76	\$1.25	\$0.75
Sweden	\$27.79	\$20.93	\$15.06	\$0.78	\$0.88	\$0.79
Brazil (SC)	\$26.54	\$23.43	\$13.36	\$0.46	\$0.73	\$0.81
Belgium	\$26.52	\$20.95	\$13.56	\$0.74	\$1.01	\$0.83
Czech. Rep.	\$25.02	\$19.11	\$12.82	\$0.82	\$0.99	\$0.85
Great Britain	\$24.08	\$19.80	\$12.47	\$0.75	\$0.85	\$0.84
Brazil (MT)	\$22.42	\$20.55	\$12.09	\$0.45	\$0.69	\$0.58
Italy	\$22.03	\$19.18	\$11.14	\$1.20	\$1.49	\$1.26
Ireland	\$21.68	\$17.50	\$11.15	\$0.80	\$0.82	\$0.92
Canada	\$19.37	\$17.13	\$10.51	\$0.57	\$0.73	\$0.63
<b>Average</b>	<b>\$31.85</b>	<b>\$26.64</b>	<b>\$16.48</b>	<b>\$0.77</b>	<b>\$1.18</b>	<b>\$0.86</b>



## Part 4. Marginal Values of Key Performance Indicators

When producers in any country consider changes in such things as diets, genetics, or animal health interventions to improve productivity, they are making some sort of cost-benefit analysis, whether formal or informal. This is not easy because the value of productivity improvements depends on market pig prices, feed prices, fixed costs, and other factors and, therefore, will vary over time and from one country to another. For example, what is the value of reducing mortality from wean-to-market by one percent? The answer is different for each country depending on the market pig prices, feed prices, fixed costs, and other factors for that country in 2019. The results reported in this section are intended to help producers make better cost-benefit calculations for decision-making, such as whether to use a vaccine or antimicrobial to reduce disease and improve productivity.

The model used for this analysis links all phases of production from breeding to market. We can, therefore, change any productivity measure and calculate the impact on profits from breed-to-market. To operationalize this, we changed litters farrowed per female per year by 0.05, pigs born alive per litter farrowed by 0.25, pre-wean mortality and wean-to-market mortality by a negative one-percentage point, average daily gain by 0.01 kg per day and feed conversion by a negative 0.025 kg of feed per kg of gain. In order to isolate the impact of each, these marginal changes in productivity measures were each done individually, with all other factors remaining at their original values for each country. The outcome is the benefit, measured as the increase in profitability, given the incremental change in the productivity measure for each country. The results are summarized in Table 3.

The differences between countries are substantial. A 0.25 pig increase in the number of pigs born alive per litter farrowed in China, for example, yields a marginal increase in profit of US\$70.14 per breeding female per year. In Canada, the same incremental improvement in pigs born alive per litter farrowed yields a marginal increase in profit of only US\$17.13 per breeding female per year. This has significant implications for resource allocation and investment decisions made by producers. A producer in China could spend US\$23.38 on an intervention to get a 0.25 pig increase in the number of pigs born alive per litter farrowed and get a 3:1 benefit:cost ratio ( $\text{US\$70.14} \div \text{US\$23.38} = 3:1$ ). To get the same 3:1 benefit:cost ratio, producers in Canada, could only spend US\$5.71 to get a 0.25 pig increase in

the number of pigs born alive per litter farrowed ( $\text{US\$}17.13 \div \text{US\$}5.71 = 3:1$ ).

Japan and China would benefit the most by increasing productivity in the breed-to-wean and wean-to-market phases of production. Italy would also benefit relatively more by increasing productivity in the wean-to-market phase. The degree to which an increase in all of the productivity measures, except the wean-to-market feed-to-gain ratio, will increase profit is a function primarily of 1) fixed costs, 2) market pig prices and 3) feed prices (the main variable cost). When market pig prices are high relative to feed prices, the profit earned on each pig or kg of pork sold is relatively high. The value of weaning extra pigs, lowering mortality, or increasing average daily gain to increase the kg of pork sold is greater when raising pigs is already profitable. As the number of pigs weaned and kg of pork sold goes up, the incremental increase in profitability will be greater in countries with higher fixed costs since those higher fixed costs are spread over more pigs, i.e., economies of scale. The extent to which an increase in the wean-to-market feed-to-gain ratio will increase profit on a per pig sold basis depends on feed prices and the weight of pigs at market. The value of improving the feed-to-gain ratio is highest when feed prices are high, and when pigs are marketed at heavier weights.

In 2019, pig production was most profitable in China, Japan, Spain, Denmark and the USA (Figures 2, 3, and 4). This is driven mainly by high market pig prices in Japan and China. In the USA, Spain and Denmark, it is the combination of low costs and higher market pig prices. Producers in Italy lost money in 2019, but fixed costs are relatively high in Italy (Figures 5, 6 and 7). Producers in every country, except Japan, were more profitable in 2019 (Table 2) than in 2018 and the value of improving productivity increased as well. The value of improving the wean-to-market feed-to-gain ratio is highest in Japan and China, both with relatively high feed prices (Figure 8), and Italy with high feed prices and pigs marketed at very heavy weights (Figures 1 and 8).

## Conclusions

The questions that continue to motivate this work are, who are the world's best pork producers and why? How can competitiveness best be measured? What is the value of improving key performance indicators in each country, and what are the key indicators that drive financial performance? The answers to these questions is that it depends. If we compare pork producers based on profitability as we do when we evaluate companies, then Japan and China come out on top. If we use animal husbandry as a performance measure, then Denmark and the Netherlands rank at the top. If we use production costs as a metric, then the USA and the state of Mato Grosso in Brazil are most competitive. This latter measure makes most sense if we are interested in trade in pork meat, and in this regard, Mato Grosso can be ruled out because they are prohibited from exporting to most lucrative import markets. The source of the competitiveness of producers in the USA is not just cheap feed. The USA has high feed and labor productivity even though the cost of these inputs is below that in many other countries. The USA also has low fixed costs. Understanding the competitive advantages and disadvantages of countries is an ongoing pursuit. Changes occur annually, as country-specific situations change (e.g., policy directives, disease outbreaks), and global market conditions evolve.

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## Appendix 1. Breakdown of Total Costs by Component, 2019

Country	Fixed costs	Feed cost	Labor costs	Animal health costs	Breeding costs	Energy costs	Miscellaneous variable costs	Interest on working capital costs
Japan	7.8%	61.7%	7.9%	3.7%	2.3%	4.3%	12.3%	0.0%
China	8.1%	70.8%	5.9%	5.9%	1.1%	1.9%	5.3%	0.9%
Italy	13.2%	64.5%	9.0%	3.3%	1.3%	3.5%	3.8%	1.3%
Ireland	12.9%	62.5%	8.8%	3.6%	3.0%	2.6%	5.5%	1.1%
Czech. Rep.	10.8%	53.3%	8.8%	4.1%	0.9%	2.8%	18.4%	0.8%
Austria	22.7%	54.9%	10.4%	4.9%	2.0%	3.0%	1.3%	0.8%
Sweden	21.2%	59.8%	10.3%	2.1%	2.2%	2.5%	1.1%	0.8%
Hungary	13.6%	61.8%	8.4%	3.3%	3.1%	2.5%	7.0%	0.3%
Great Britain	12.9%	64.2%	8.9%	2.7%	2.8%	2.6%	5.2%	0.7%
Netherlands	13.3%	57.7%	8.7%	2.7%	2.3%	2.4%	12.1%	0.7%
Finland	20.8%	47.8%	11.0%	3.1%	3.1%	5.2%	8.1%	0.9%
Germany	18.2%	56.7%	10.3%	4.4%	2.1%	3.6%	4.0%	0.7%
France	14.2%	61.2%	8.8%	3.3%	3.4%	2.7%	5.9%	0.5%
Spain	10.5%	67.2%	6.8%	4.9%	2.6%	2.9%	4.4%	0.7%
Denmark	14.8%	62.7%	10.3%	3.2%	1.6%	2.5%	4.2%	0.7%
Belgium	16.4%	65.8%	4.8%	3.8%	2.2%	2.5%	4.0%	0.6%
Brazil (SC)	8.6%	76.5%	5.4%	3.6%	1.1%	0.7%	2.1%	1.9%
Canada	8.9%	63.8%	12.1%	3.7%	2.8%	2.8%	4.5%	1.2%
USA	13.7%	67.7%	7.1%	4.2%	2.6%	2.0%	1.3%	1.4%
Brazil (MT)	12.2%	67.0%	3.9%	4.9%	3.8%	1.7%	3.9%	2.6%

## Appendix 2. Sources of Competitive Advantage on a Per Pig Sold and Per Female Basis

Country	Profit advantage over average (\$/pig sold)	Market pig prices	Feed prices	Productivity	Fixed costs	Labor usage	Wage rates	Labor Usage and Wage Rates
China	\$106.45	\$206.23	-\$51.88	-\$45.28	\$5.92	-\$15.16	\$10.87	\$2.74
USA	\$14.55	-\$43.51	\$25.70	-\$7.10	\$7.07	\$8.15	\$1.45	\$5.99
Spain	\$13.31	-\$7.34	-\$4.02	-\$10.72	\$8.05	\$7.75	-\$0.26	\$4.71
Japan	\$12.81	\$202.20	-\$71.57	-\$42.95	\$1.50	-\$7.21	\$2.29	-\$6.82
Brazil (SC)	\$10.22	-\$46.01	\$3.93	\$5.57	\$12.78	-\$10.20	\$12.98	\$7.86
Denmark	\$7.62	-\$13.46	\$7.11	\$24.15	\$0.94	\$7.50	-\$11.12	-\$1.49
Germany	\$0.50	-\$8.62	\$7.97	\$10.87	-\$8.04	\$4.40	-\$6.92	-\$3.59
Brazil (MT)	-\$0.15	-\$62.25	\$27.51	\$8.12	\$10.77	\$0.27	\$12.97	\$10.13
Austria	-\$2.12	\$1.12	\$7.73	\$1.39	-\$16.45	\$1.65	-\$2.90	-\$3.86
France	-\$4.52	-\$19.61	\$5.31	\$6.02	\$0.12	\$6.68	-\$6.41	-\$0.05
Netherlands	-\$6.77	-\$12.60	-\$3.35	\$15.81	-\$0.47	\$8.27	-\$13.52	-\$1.41
Hungary	-\$7.38	-\$7.81	\$4.77	-\$15.35	-\$0.33	-\$17.40	\$9.81	-\$0.20
Canada	-\$10.27	-\$67.74	\$31.93	\$1.60	\$11.78	\$0.68	\$2.06	-\$0.25
Belgium	-\$10.98	-\$35.97	-\$3.18	\$3.11	-\$2.42	\$10.42	-\$2.52	\$6.58
Finland	-\$12.20	-\$19.69	\$26.09	\$13.56	-\$10.94	\$3.25	-\$5.19	-\$3.82
Great Britain	-\$15.84	-\$19.96	-\$5.95	\$11.21	\$3.17	\$3.07	\$0.70	\$0.75
Sweden	-\$16.42	-\$13.59	\$5.47	\$4.52	-\$12.81	\$6.16	-\$10.47	-\$3.32
Ireland	-\$25.29	-\$15.82	-\$10.86	\$17.06	\$0.65	\$2.85	-\$1.06	-\$0.93
Czech. Rep.	-\$25.67	-\$16.79	\$0.97	\$22.93	\$2.60	-\$14.44	\$7.87	-\$2.63
Italy	-\$27.82	\$1.21	-\$3.69	-\$24.53	-\$13.88	-\$6.66	-\$0.62	-\$10.42

**Table A2.1. Profit Advantage of Select Factors, All Other Variables Held Constant, Per Pig Sold Basis, 2019**

Country	Profit advantage over average (\$/pig sold)	Market pig prices	Feed prices	Productivity	Fixed costs	Labor usage	Wage rates	Labor Usage and Wage Rates
China	\$106.45	\$206.23	-\$51.88	-\$45.28	\$5.92	-\$15.16	\$10.87	\$2.74
USA	\$14.55	-\$43.51	\$25.70	-\$7.10	\$7.07	\$8.15	\$1.45	\$5.99
Spain	\$13.31	-\$7.34	-\$4.02	-\$10.72	\$8.05	\$7.75	-\$0.26	\$4.71
Japan	\$12.81	\$202.20	-\$71.57	-\$42.95	\$1.50	-\$7.21	\$2.29	-\$6.82
Brazil (SC)	\$10.22	-\$46.01	\$3.93	\$5.57	\$12.78	-\$10.20	\$12.98	\$7.86
Denmark	\$7.62	-\$13.46	\$7.11	\$24.15	\$0.94	\$7.50	-\$11.12	-\$1.49
Germany	\$0.50	-\$8.62	\$7.97	\$10.87	-\$8.04	\$4.40	-\$6.92	-\$3.59
Brazil (MT)	-\$0.15	-\$62.25	\$27.51	\$8.12	\$10.77	\$0.27	\$12.97	\$10.13
Austria	-\$2.12	\$1.12	\$7.73	\$1.39	-\$16.45	\$1.65	-\$2.90	-\$3.86
France	-\$4.52	-\$19.61	\$5.31	\$6.02	\$0.12	\$6.68	-\$6.41	-\$0.05
Netherlands	-\$6.77	-\$12.60	-\$3.35	\$15.81	-\$0.47	\$8.27	-\$13.52	-\$1.41
Hungary	-\$7.38	-\$7.81	\$4.77	-\$15.35	-\$0.33	-\$17.40	\$9.81	-\$0.20
Canada	-\$10.27	-\$67.74	\$31.93	\$1.60	\$11.78	\$0.68	\$2.06	-\$0.25
Belgium	-\$10.98	-\$35.97	-\$3.18	\$3.11	-\$2.42	\$10.42	-\$2.52	\$6.58
Finland	-\$12.20	-\$19.69	\$26.09	\$13.56	-\$10.94	\$3.25	-\$5.19	-\$3.82
Great Britain	-\$15.84	-\$19.96	-\$5.95	\$11.21	\$3.17	\$3.07	\$0.70	\$0.75
Sweden	-\$16.42	-\$13.59	\$5.47	\$4.52	-\$12.81	\$6.16	-\$10.47	-\$3.32
Ireland	-\$25.29	-\$15.82	-\$10.86	\$17.06	\$0.65	\$2.85	-\$1.06	-\$0.93
Czech. Rep.	-\$25.67	-\$16.79	\$0.97	\$22.93	\$2.60	-\$14.44	\$7.87	-\$2.63
Italy	-\$27.82	\$1.21	-\$3.69	-\$24.53	-\$13.88	-\$6.66	-\$0.62	-\$10.42

**Table A2.2. Profit Advantage of Select Factors, All Other Variables Held Constant, Per Breeding Female Basis, 2019**

Country	Profit advantage over average (\$/female/year)	Market pig prices	Feed prices	Productivity	Fixed costs	Labor usage	Wage rates	Labor Usage and Wage Rates
China	\$1,668.65	\$5,514.03	-\$1,387.26	-\$997.02	\$158.38	-\$405.37	\$290.61	\$73.18
USA	\$417.41	-\$1,163.35	\$687.28	-\$235.73	\$188.96	\$217.83	\$38.73	\$160.18
Denmark	\$379.72	-\$359.84	\$190.22	\$834.02	\$25.05	\$200.61	-\$297.24	-\$39.72
Spain	\$371.85	-\$196.20	-\$107.50	-\$336.74	\$215.22	\$207.09	-\$6.98	\$125.98
Brazil (SC)	\$342.78	-\$1,230.19	\$105.01	\$119.68	\$341.63	-\$272.82	\$347.06	\$210.11
Japan	\$290.45	\$5,406.31	-\$1,913.58	-\$1,122.53	\$40.01	-\$192.91	\$61.36	-\$182.27
Germany	\$104.39	-\$230.56	\$213.11	\$307.91	-\$215.10	\$117.52	-\$184.94	-\$95.86
Brazil (MT)	\$62.97	-\$1,664.43	\$735.47	\$189.97	\$287.92	\$7.11	\$346.75	\$270.93
Austria	-\$29.65	\$29.86	\$206.71	-\$50.83	-\$439.72	\$44.03	-\$77.54	-\$103.20
France	-\$46.07	-\$524.40	\$141.90	\$157.08	\$3.09	\$178.51	-\$171.42	-\$1.37
Netherlands	-\$95.93	-\$336.86	-\$89.60	\$464.21	-\$12.59	\$221.14	-\$361.42	-\$37.65
Hungary	-\$132.77	-\$208.75	\$127.64	-\$455.80	-\$8.74	-\$465.29	\$262.38	-\$5.33
Canada	-\$225.94	-\$1,811.18	\$853.67	-\$39.71	\$315.03	\$18.07	\$54.99	-\$6.56
Belgium	-\$227.01	-\$961.76	-\$84.93	\$56.87	-\$64.77	\$278.56	-\$67.42	\$176.06
Finland	-\$258.81	-\$526.35	\$697.65	\$348.78	-\$292.62	\$86.93	-\$138.90	-\$102.16
Great Britain	-\$358.47	-\$533.57	-\$158.97	\$243.07	\$84.73	\$82.21	\$18.64	\$20.02
Sweden	-\$373.21	-\$363.32	\$146.37	\$72.04	-\$342.46	\$164.78	-\$280.02	-\$88.71
Ireland	-\$612.47	-\$423.04	-\$290.44	\$444.03	\$17.45	\$76.14	-\$28.46	-\$24.82
Italy	-\$638.00	\$32.39	-\$98.70	-\$681.06	-\$371.07	-\$178.07	-\$16.49	-\$278.55
Czech. Rep.	-\$639.87	-\$448.80	\$25.98	\$681.76	\$69.58	-\$386.05	\$210.31	-\$70.26