Who Will Pay for Improved Health Standards in U.S. Meat-processing Plants?
Simulation Results from the USAGE Model

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Abstract

It is possible that Covid will produce permanent changes in work practices that increase costs in U.S. meat-processing plants. These changes may be beneficial for the safety of meat-processing workers and the health of the community more generally. However, they will have economic costs. In this paper we use USAGE-Food, a detailed computable general equilibrium (CGE) model of the U.S., to work out how those costs would be distributed between farmers and consumers of meat products. We also calculate industry and macroeconomic effects. Despite modelling the farmers as owning fixed factors, principally their own labour, we find that the farmer share in extra processing costs is likely to be quite moderate. Throughout the paper, we support simulation results by back-of-the-envelope calculations, diagrams and sensitivity analysis. These devices identify the mechanisms in the model and key data points that are responsible for the main results. In this way, we avoid the black-box criticism that is sometimes levelled at CGE modelling.

JEL codes: D58; Q12; Q13; Q17; and Q18

Key words: split of meat-processing costs between farmers and consumers; computable general equilibrium simulations; back-of-the-envelope explanations; diagrammatic analysis

1. Introduction

Meat-processing plants are particularly dangerous workplaces for the spread of the Covid virus.[1] This has led to changes in the way these plants are organized, including the requirement for greater distances between workers, improved hygiene measures and the installation of separation barriers. These changes increase costs per unit of meat processed.

In this paper we use the USAGE model to examine the effects on the U.S. economy of increased costs in meat processing. USAGE is a detailed computable general equilibrium (CGE) model.[2] We refer to the version applied here as USAGE-Food.[3] This version distinguishes 392 industries. These include 13 agricultural industries and 24 industries producing manufactured food products. Among these industries are: three meat-animal producers, Cattle ranching, Other-animal farms and Poultry& egg farms; and three meat-processing industries, Beef processing, Other-animal processing (mainly pigs) and Poultry processing.

There is no clear information on the extent to which Covid-related changes have increased the costs of meat processing, or on the permanency of these increases. In the scenarios we examine, the cost increases are maintained post-Covid and add 10 per cent to primary factor requirements (capital and labour) per unit of output in each of the three meat-processing industries. Our results are close to linear with respect to the 10-per-cent assumption. Readers can deduce the effects of a 5 per cent increase in primary-factor requirements simply by halving the results presented here for a 10 per cent increase.

USAGE-Food is set up with a database for 2015 and produces results for effects after 5 years. Literally, we model the cost increases in meat processing as occurring in 2015 and we look at how these cost increases affect the economy of 2020. Almost all our results are percentage deviations. For example, we will find that the assumed cost increases in the three meat-processing industries in 2015 would reduce GDP in 2020 by 0.031 per cent below what it would have been without the cost increases. To a close approximation, this can be thought of as the percentage effect on GDP in 2025 of cost increases occurring in 2020.

Why 5 years? This simplifies the analysis by allowing us to adopt long-run assumptions at the macro level for labour and capital. A period such as 5 years means that we abstract from short-run adjustment effects. We assume that 5 years is sufficient for wage rates throughout the economy to adjust to bring aggregate employment back to its baseline level. For capital, we assume that 5 years is sufficient for capital stocks to adjust to bring expected rates of return approximately back to baseline levels (levels that would apply without the assumed cost increases). By showing 5-year effects of Covid-related increases in the cost of meat processing, our results complement those of Lusk *et al.* (2021) for short-run effects.

Models such as USAGE-Food contain many thousands of equations. These equations describe optimizing behaviour by U. S. households, investors, exporters and importers, and equilibration between demands and supplies and between prices and costs. The central database for setting the coefficients in the equations is an updated version of the BEA's Benchmark input-output tables, see Dixon *et al.* (2017). It is not practical to set out the

[1] See, for example, Weiner-Bronner (2020), Waltenburg *et al.* (2020) and Sents (2020),

[2] USAGE (U.S. Applied General Equilibrium) has been continuously developed at the Centre of Policy Studies (CoPS) over the last 15 years. For an overview of USAGE and its applications see Dixon *et al.* (2013).

[3] USAGE-Food is described in Dixon *et al.* (2020).

model in a short paper, and even if it were possible to provide full technical detail, it is not clear that this would help readers with limited time budgets to assess the results. So how do we avoid the “black-box” criticism?

Our method is to provide back-of-the-envelope (BOTE) explanations. While in theory each result from a CGE model depends on thousands of parameters, data points and every detail of the equation system, in practice any particular set of CGE results depends on a small subset of these items. For each application, the challenge for CGE modellers is to identify the relevant items and to use them in a convincing BOTE explanation of the principal results.

The parameters identified for the application in this paper are mainly substitution elasticities in the household utility function and in production functions for farm and associated processing industries. The key data points identified are mainly cost and sales shares: the shares of meat-processing costs in household purchases of different meat products; the shares of exports in sales from different agricultural industries; the shares of imports in the domestic markets for different agricultural products; the shares of fixed factors in the costs of meat-farming industries; and the share of agricultural value-added in U.S. GDP.

On assumptions, our BOTE explanations of the macro results show the roles of those for employment, wages, capital and rates of return. In addition to these macro assumptions, the BOTE explanations highlight competition in meat processing. We assume that the sector is competitive with factors of production that are mobile within our 5-year period. This means that cost increases in meat processing are passed forward to consumers and back to farmers.

We conduct sensitivity simulations targeting the substitution elasticities identified by the BOTE explanations as being important determinants of the split of extra processing costs between farmers and consumers.

The paper is organized as follows. Sections 2 to 5 present results covering consumer prices, real farm incomes, industry outputs and employment, and the macro economy. Section 6 contains sensitivity analysis. Concluding remarks are in section 7.

2. Effects on prices to households

Table 1 shows percentage effects on consumer prices (prices paid at the supermarket) of 10 per cent increases in primary-factor requirements per unit of output in each of the meat-processing industries. In our simulations we assume that cost increases in meat processing have no effect on aggregate consumer prices (cpi). Thus, the results in Table 1 indicate relative price movements. For example, a 10 per cent increase in primary-factor requirements per unit of output in Beef processing raises the price of beef products in supermarkets by 1.488 per cent relative to the general consumer price level. Similarly, 10 per cent increases in primary-factor requirements per unit of output in Other-animal processing and Poultry processing raise the prices of these products sold to households by 1.444 per cent and 1.673 per cent relative to consumer prices in general.

The first step in understanding these results is to look at meat-processing primary-factor costs incurred in delivering meat products to households. In the USAGE-Food database, these costs per dollar of household spending on Beef, Other-animal products and Poultry are: 19.6 cents, 17.8 cents and 19.1 cents. On this basis, we calculate the impact effects on supermarket prices of 10 per cent increases in primary-factor requirements in meat processing

Table 1. Percentage effects on prices to households of increased costs in meat processing
(effects after 5 years of 10% increases in primary-factor input per unit output in meat processing industries)

	Beef processing	Other-animal processing	Poultry processing	Total meat processing
Food	0.172	0.059	0.123	0.356
Meat-processing products	0.760	0.255	0.573	1.596
Beef	1.488	0.004	0.037	1.529
Other animals (mainly pork)	0.003	1.444	0.017	1.465
Poultry	0.066	0.024	1.673	1.764
Other food products	-0.006	-0.001	-0.013	-0.020
Non-food products	-0.011	-0.004	-0.008	-0.023
All products (cpi)	0.000	0.000	0.000	0.000

as 1.96 per cent, 1.78 per cent and 1.91 per cent. The simulated effects are noticeably lower than these impact effects. As we will see in Table 2, part of the cost increases in processing are passed back to farmers as reductions in farm prices and in farm incomes.

The results in the fourth column of Table 1 for the effects of a 10 per cent increase in primary factor requirements per unit of output in *all* three meat-processing industries are approximately sums of the results in the other three columns. For shocks of this magnitude, the percentage responses of endogenous variables in USAGE-Food are well-approximated by linear functions of percentage changes in exogenous variables.

The shares of Beef, Other animals and Poultry in household expenditure on meat-processing products are 0.498, 0.171 and 0.331, and the share of meat products in household expenditure on food is 0.233. These shares in combination with the price results for the three meat products explain the price results in Table 1 for meat-processing products and food. For example, in the fourth simulation, the percentage movement in the price of meat-processing products is 1.596, given by 0.498*1.529 + 0.171*1.465 + 0.331*1.764, and the percentage movement in the price of food is 0.356, given by 0.233*1.596 + (1-0.233)*(-0.020).

3. Effects on real farm incomes and the allocation of extra processing costs between farmers and consumers of meat products

The top panel of Table 2 shows percentage effects of increased processing costs on real farm incomes, defined as returns to farm land, farm capital and farmer-supplied labour. We treat farmer labour as a fixed factor, and we allow only limited possibilities for moving farm land between agricultural industries. Consistent with economic theory, USAGE-Food indicates that increases in processing costs are partially passed back to the owners of fixed factors. In the first three simulations, increased costs in a meat-processing industry are passed back as reductions in the basic (farm-gate) price of the corresponding farm product (second panel, Table 2) with consequent income losses for the corresponding farm industry. Also consistent with economic theory, cost increases in meat processing are partially passed forward through higher basic (factory-door) prices for processed-meat products (third panel, Table 2). These increases in the basic prices of processed products are passed on in damped form to supermarket prices (Table 1) and prices for meals from restaurants and other food-serving industries. For example, in the Beef-processing simulation, the basic price of Beef processing increases by 2.341 per cent (Table 2) whereas the supermarket price increases by

Table 2. Percentage effects on real farm incomes and basic prices of increased costs in meat processing

(effects after 5 years of 10% increases in primary-factor input per unit output in meat processing industries)

	Beef processing	Other-animal processing	Poultry processing	Total meat processing
Oil seeds	0.000	0.005	-0.040	-0.036
Grains	-0.138	0.004	-0.133	-0.268
Vegetables & melons	-0.026	-0.005	-0.023	-0.055
Fruit & nut farms	-0.011	-0.001	-0.014	-0.026
Green nurseries	-0.021	-0.006	-0.013	-0.040
Other crops	-0.098	-0.001	-0.010	-0.110
Cattle ranching	-2.405	0.083	0.132	-2.191
Dairy cattle	0.001	0.001	-0.011	-0.008
Other animals (mainly pigs)	0.094	-1.036	0.050	-0.893
Poultry & eggs	0.246	0.088	-1.517	-1.183
All farms	-0.326	-0.108	-0.156	-0.591
Basic prices, farm products				
Cattle ranching	-0.894	0.024	0.038	-0.832
Other-animal farm	0.032	-0.518	0.019	-0.467
Poultry & eggs	0.069	0.029	-0.408	-0.311
Basic prices, processed prods				
Beef processing	2.341	0.010	0.065	2.417
Other-animal processing	0.015	2.242	0.035	2.292
Poultry processing	0.101	0.037	2.362	2.502

only 1.488 per cent (Table 1). Consumer prices include the prices of imported processed-meat products (as well as domestic processed-meat products) and the costs of margins incurred in transferring meat products from processors to households. The prices of imports and the costs of margins are largely independent of U.S. processing costs.

How are cost increases in meat processing distributed between farmers and consumers? Items from the USAGE-Food 2020 baseline database and calculations necessary to answer this question are presented in Table 3.

As set out in the table, value added in Beef processing is $34.998 billion, the basic (factory door) value of beef processing sales is $120.597b, and farm income in Cattle ranching is $25.816b. With a 10 per cent increase in primary-factor requirements, the Beef-processing industry passes $2.823b to its customers in the form of higher prices (= 2.341% of $120.597b, row 7, Table 3). At the same time, Cattle-ranch farmers suffer a reduction in their incomes of $0.621b (= 2.405% of $25.816b, row 6, Table 3). Together, the loss to farmers and the increased cost to consumers total $3.444b (=0.621+ 2.823). This closely matches the impact cost of the increase in primary-factor requirements in Beef processing, $3.5b (= 10% of 34.998, row 1).

For Other-animal processing, the USAGE-Food baseline database shows: value added of $12.098b; basic value of sales of $47.268b; and income in Other-animal farming of $22.783b. As shown in Table 3, a 10 per cent increase in primary-factor requirements in Other-animal processing imposes a loss on farmers of $0.236b (= 1.036% of $22.783b) and an extra expense to consumers of $1.060b (= 2.242% of $47.268). Together, the loss to farmers and the increased cost to consumers total $1.296b (=0.236+1.060), closely matching the impact cost in the processing industry of $1.210b (= 10% of 12.098b).

Table 3. Back-of-the-envelope calculation of allocation of extra processing costs between farmers and consumers of meat products

		Beef processing	Oth animal processing	Poultry processing
	Items from 2020 baseline data			
1	Value added in processing industry, $b	34.998	12.098	21.942
2	Basic value of sales from processing ind., $b	120.597	47.268	81.986
3	Income in farm industry, $b	25.816	22.783	19.316
	Simulation results (percentage changes)			
	Basic prices of meat processing			
4i	Beef processing in 1st simulation	2.341		
4ii	Other-animal processing in 2nd simulation		2.242	
4iii	Poultry processing in 3rd simulation			2.362
	Real farm income			
5i	Cattle ranching in 1st simulation	-2.405		
5ii	Other animals in 2nd simulation		-1.036	
5iii	Poultry in 3rd simulation			-1.517
	Back-of-the-envelope (BOTE) calculations			
6	Loss of farm income, $b (= row3*row5/100)	0.621	0.236	0.293
7	Cost to customers, $b (= row2*row4/100)	2.823	1.060	1.937
8	Total cost to households & farmers $b, (= row 6 + row 7)	3.444	1.296	2.230
9	Farmer % of total costs (=100*row 6/row 8)	18.03	18.21	13.14

For Poultry processing, the relevant database items are: value added and basic value of sales in the processing industry of $21.942b and $81.986b; and income in Poultry farming of $19.316b. A 10 per cent increase in primary-factor requirements in Poultry processing reduces the income of farmers by $0.293b (= 1.517% of $19.316b) and increases costs to consumers by $1.937b (= 2.362% of $81.986b). Together, the loss to farmers and the increased cost to consumers total $2.230b, closely matching the impact cost in the processing industry (10% of 21.942b).

To us, a surprising aspect of Table 3 is the smallness of the farmer shares in extra processing costs. In the Beef-processing simulation, Cattle ranchers pick up only 18.03 per cent of the explained extra cost of processing, row 9. In the Other-animal-processing simulation, farmers pick up 18.21 per cent of the explained extra costs, and in the Poultry-processing simulation, farmers pick up 13.14 per cent.

A priori, our simple picture was of farmers with inelastic supply curves selling their product to processing industries with a fixed ratio of farm product to processed product. This picture is a reference case sometimes used in discussions of the long-run effects on returns to farmers of changes in farm-to-retail price spreads, see for example, Hahn (2004, page 8). It suggests that farmers would pick up very high shares of extra processing costs. What does the model know that is missing from this simple picture? This question is answered in section 6 where we conduct sensitivity analysis to identify the key parameters that explain the split of extra processing costs between farmers and households.

4. Effects on outputs and employment by industries

Tables 4 and 5 show results for employment and output by industry. We present the results in full detail for agricultural and food-related industries. To keep the tables manageable, results for other industries are presented in aggregated form.

Beef processing

As we saw in Table 1, a 10 per cent increase in primary-factor requirements per unit of output in Beef processing increases the consumer price of the processed product. This leads to a reduction in demand and a consequent reduction in output (-1.933 per cent, row 32, col 1, Table 4). Households substitute towards other meat products. This explains the positive results in Table 4 for Other-animal processing, Poultry processing and Seafood in rows 33, 34 and 35 of column 1, and corresponding positive results in column 1 for the primary industries Other animals, Poultry & eggs and Fishing & hunting (rows 10, 11 and 13). The output of Cattle ranching declines, but by a smaller percentage than the output of Beef processing (-1.175 per cent, row 8 compared with -1.933 per cent). Cattle ranchers mitigate the effects of reduced processing output by partly replacing imports. In our database, these imports are about 3.3 per cent of total sales of the Cattle-ranch product in the U.S.

With the exception of the Beef processing industry, the employment results in column 1 of Table 5 follow the same general pattern as the corresponding output results in Table 4. For Beef processing, employment increases by 6.219 per cent (row 32, Table 5) whereas output falls by 1.933 per cent (row 32, Table 4). This sharp increase in the labour/output ratio for Beef processing reflects the assumed 10 per cent increase in the industry's primary-factor inputs per unit of output. For all other industries, the change in the labour/output ratio is small. For most farm industries, there is a small amount of substitution of land, released from Cattle ranching, for other primary factors leading to a reduction in the labour/output ratio. For most non-farming industries, the labour/output ratio increases reflecting a reduction in the real wage rate to be discussed in section 5.

Other-animal processing

Column 2 of Tables 4 and 5 give industry results for the effects of a 10 per cent increase in primary-factor requirements per unit of output in Other-animal processing. These show a reduction in the output of Other-animal processing of 1.958 per cent (row 33, col 2, Table 4) and a smaller percentage reduction in the output of the corresponding farm industry, 0.595 per cent (row 10, col 2, Table 4). Other-animal farmers partly mitigate the effects of reduced demand from the processing industry by replacing imports and expanding exports. In our database, imports of Other-animal products are 11.7 per cent of total sales of these products in the U.S. and exports are 3.7 per cent of U.S. output. Other effects that can be seen in column 2 of Tables 4 and 5 include: substitution towards other meat products with positive output results for Beef processing, Poultry processing and Seafood (rows 32, 34 and 35); positive output results for Cattle ranching, Poultry & eggs and Fishing & hunting (rows 8, 11 and 13); a sharp increase in the labour/output ratio for Other-animal processing (compare row 33, col 2, Table 5 with the corresponding entry in Table 4); small negative movements in labour/output ratios for most farm industries; and small positive movements in labour/output ratios for most non-farm industries.

In the USAGE-Food database, value added in Other-animal processing is only about 1/3rd of that in Beef processing. Thus, the 10 per cent shock in the second simulation is on a smaller base than the 10 per cent shock in the first simulation. This is the reason that the results in column 2 of Tables 4 and 5 for industries apart from those directly affected by the shock are generally smaller in magnitude than those in column 1.

Table 4. Percentage effects on industry outputs of increased costs in meat processing
(effects after 5 years of 10% increases in primary-factor input per unit output in meat processing industries)

		Beef processing (1)	Other-animal proc (2)	Poultry processing (3)	Total meat processing (4)
1	Agriculture	-0.159	-0.029	-0.093	-0.282
2	Oil seeds	0.038	0.005	0.009	0.052
3	Grains	-0.060	0.005	-0.063	-0.118
4	Vegetables & melons	0.004	-0.001	0.002	0.005
5	Fruit & nuts	0.035	0.002	0.027	0.065
6	Green nurseries	-0.005	-0.001	-0.003	-0.009
7	Other crops	-0.038	0.002	0.008	-0.028
8	Cattle ranching	-1.175	0.044	0.075	-1.057
9	Dairy cattle	0.016	0.003	0.000	0.020
10	Other animals (mainly pigs)	0.065	-0.595	0.035	-0.496
11	Poultry & eggs	0.142	0.046	-0.780	-0.592
12	Forestry & logging	0.004	0.003	-0.002	0.004
13	Fishing & hunting	0.087	0.031	0.061	0.179
14	Agriculture support	-0.092	-0.003	-0.030	-0.125
15	Mining	0.000	0.001	-0.002	-0.001
16	Utilities	-0.009	-0.003	-0.006	-0.018
17	Construction	-0.005	-0.002	-0.004	-0.011
18	Manufacturing, excl. food	-0.003	0.000	-0.006	-0.009
19	Food manufacturing	-0.299	-0.101	-0.168	-0.541
20	FlourMaltMill	0.004	0.002	-0.029	-0.023
21	WetCornMill	0.022	0.009	-0.006	0.024
22	SoyOilProc	0.022	0.006	-0.057	-0.028
23	FatsOils	-0.015	-0.005	-0.022	-0.042
24	BreakCereal	-0.019	-0.006	-0.014	-0.039
25	SugarConfect	-0.011	-0.004	-0.010	-0.025
26	FrozFood	-0.073	-0.028	-0.081	-0.181
27	FrtVegCanning	-0.061	-0.022	-0.012	-0.095
28	MilkButter	0.005	0.001	-0.008	-0.003
29	Cheese	0.023	0.007	0.012	0.042
30	DryCondEvapDairy	0.010	0.001	-0.005	0.006
31	IceCream	0.042	0.017	0.026	0.085
32	BeefProc	-1.933	0.058	0.065	-1.810
33	OthAnimProc	0.169	-1.958	0.082	-1.711
34	PoultryProc	0.104	0.034	-1.840	-1.702
35	Seafood	0.140	0.072	0.096	0.308
36	BreadBakery	-0.013	-0.003	-0.007	-0.023
37	CookiePasta	-0.020	-0.006	-0.006	-0.033
38	SnackFood	-0.021	-0.008	-0.010	-0.038
39	CoffTea	0.012	0.006	0.001	0.018
40	FlavorSyrup	0.013	0.007	0.011	0.031
41	SeasoningDressing	-0.055	-0.018	-0.006	-0.079
42	OthrFoodManu	-0.026	-0.004	-0.010	-0.040
43	SoftDrinks	-0.007	-0.002	-0.004	-0.013
44	OtherServices	-0.012	-0.004	-0.008	-0.023
45	Health	-0.011	-0.004	-0.006	-0.022
46	FoodServingSpecialists	-0.022	-0.008	-0.018	-0.048
47	Accom. & hotels	-0.012	-0.004	-0.010	-0.026
48	Full serv restaurants	-0.025	-0.009	-0.019	-0.054
49	Lim. serv restaurants	-0.022	-0.008	-0.020	-0.051

Table 5. Percentage effects on industry employment of increased costs in meat processing
(effects after 5 years of 10% increases in primary-factor input per unit output in meat processing industries)

		Beef processing (1)	Other-animal proc (2)	Poultry processing (3)	Total meat processing (4)
1	Agriculture	-0.121	-0.071	-0.034	-0.226
2	Oil seeds	0.016	0.004	-0.006	0.014
3	Grains	-0.050	0.003	-0.050	-0.096
4	Vegetables & melons	-0.003	-0.001	-0.004	-0.008
5	Fruit & nuts	0.019	0.002	0.012	0.033
6	Green nurseries	-0.006	-0.001	-0.004	-0.011
7	Other crops	-0.038	0.001	0.002	-0.034
8	Cattle ranching	-0.941	0.035	0.057	-0.850
9	Dairy cattle	0.008	0.003	-0.001	0.011
10	Other animals (mainly pigs)	0.060	-0.574	0.033	-0.482
11	Poultry & eggs	0.099	0.034	-0.557	-0.424
12	Forestry & logging	0.003	0.003	-0.003	0.003
13	Fishing & hunting	0.099	0.036	0.069	0.203
14	Agriculture support	-0.109	-0.004	-0.035	-0.148
15	Mining	-0.001	0.001	-0.004	-0.003
16	Utilities	-0.012	-0.003	-0.008	-0.024
17	Construction	-0.005	-0.002	-0.004	-0.011
18	Manufacturing, excl. food	-0.001	0.000	-0.004	-0.005
19	Food manufacturing	0.913	0.313	0.584	1.778
20	FlourMaltMill	0.004	0.003	-0.036	-0.030
21	WetCornMill	0.021	0.009	-0.006	0.023
22	SoyOilProc	0.023	0.008	-0.059	-0.028
23	FatsOils	-0.013	-0.003	-0.027	-0.043
24	BreakCereal	-0.017	-0.005	-0.013	-0.035
25	SugarConfect	-0.011	-0.004	-0.011	-0.026
26	FrozFood	-0.060	-0.023	-0.070	-0.153
27	FrtVegCanning	-0.042	-0.015	-0.012	-0.068
28	MilkButter	0.005	0.001	-0.009	-0.003
29	Cheese	0.022	0.008	0.010	0.040
30	DryCondEvapDairy	0.009	0.002	-0.006	0.004
31	IceCream	0.044	0.019	0.026	0.088
32	BeefProc	6.291	0.061	0.090	6.453
33	OthAnimProc	0.174	6.290	0.090	6.571
34	PoultryProc	0.148	0.050	6.387	6.599
35	Seafood	0.147	0.070	0.099	0.317
36	BreadBakery	-0.013	-0.003	-0.007	-0.022
37	CookiePasta	-0.020	-0.006	-0.008	-0.033
38	SnackFood	-0.021	-0.007	-0.011	-0.038
39	CoffTea	0.012	0.006	0.001	0.018
40	FlavorSyrup	0.016	0.008	0.012	0.036
41	SeasoningDressing	-0.023	-0.007	-0.005	-0.035
42	OthrFoodManu	-0.023	-0.002	-0.008	-0.034
43	SoftDrinks	-0.006	-0.002	-0.004	-0.012
44	OtherServices	-0.012	-0.004	-0.008	-0.025
45	Health	-0.011	-0.004	-0.006	-0.020
46	FoodServingSpecialists	-0.019	-0.007	-0.016	-0.042
47	Accom. & hotels	-0.012	-0.004	-0.010	-0.026
48	Full serv restaurants	-0.021	-0.008	-0.016	-0.044
49	Lim. serv restaurants	-0.021	-0.008	-0.019	-0.047

Poultry processing

Value added in Poultry processing is about 2/3rds of that in Beef processing and about twice that in Other-animal processing. Consequently, the magnitude of results in column 3 of Tables 4 and 5 for industries apart from those directly affected by the shock is generally between that in columns 1 and 2.

For Poultry processing, the reduction in output in column 3 is quite similar to the reductions in output of Beef processing in column 1 and Other-animal processing in column 2. For the farm industry Poultry & eggs, the output reduction in column 3 (-0.780 per cent, row 11, Table 4) is greater than that for Other animals in column 2 (-0.595 per cent) but less than that for Cattle ranching in column 1 (-1.175 per cent). Of the three meat-producing farm industries, Poultry & eggs has the least direct exposure to international trade, giving it the least opportunity to replace imports and expand exports. On this basis, we might expect Poultry & eggs to be poorly placed to mitigate the effects of reduced demand from the processing industry. However, Poultry & eggs has considerable direct sales to households (sales of eggs) that do not depend on demand from the processing industry.

5. Effects on macro variables

Macro results are given in Table 6. We focus on the results in column 4.

A good framework for looking at these results is the aggregate production function:

$$Y = A * F(K, L) \tag{1}$$

where

Y is output or GDP,
A is technology,
K is aggregate capital,
L is aggregate labour, and
F is a constant-returns-to-scale production function.

In percentage-change form (1) can be written as:

$$y = a + S_L * \ell + S_K * k \tag{2}$$

where

y, a, ℓ and k are percentage changes in Y, A, L and K, and
S_L and S_K are the shares of labour and capital in GDP (0.62 and 0.38).

As mentioned in section 1, we assume that our 5-year simulation period is sufficiently long for wage adjustment to eliminate effects on aggregate employment. Consequently, Table 6 shows zeros in row 7. With employment fixed, equation (2) can be reduced to

$$y = a + 0.38 * k \tag{3}$$

In total, primary factors in Beef processing, Other-animal processing and Poultry processing account for 0.300 per cent of GDP (about \$69b out of \$23t). Thus, a 10 per cent increase in primary-factor requirements per unit of output in meat processing is equivalent to a technological deterioration of 0.030 per cent. In terms of equation (3), a = -0.030. Our simulations imply that changes in meat-processing costs have only tiny effects on the economy's aggregate K/L ratio. In column 4, the K/L ratio declines by 0.005 per cent (row 8 compared with row 7). Using equation (3) we now have a back-of-the-envelope (BOTE)

Table 6. Percentage effects on macro variables of increased costs in meat processing
(effects after 5 years of 10% increases in primary-factor input per unit output in meat processing industries)

		Beef processing (1)	Other-animal proc (2)	Poultry processing (3)	Total meat processing (4)
1	Real GDP (Y)	-0.016	-0.005	-0.010	-0.031
2	Real private consumption (C)	-0.016	-0.006	-0.011	-0.033
3	Real investment (I)	0.001	-0.003	-0.002	-0.004
4	Real public consumption (G)	-0.017	-0.006	-0.011	-0.033
5	Real exports (X)	-0.023	-0.006	-0.014	-0.042
6	Real imports (M)	-0.004	-0.004	-0.004	-0.012
7	Aggregate employment (L)	0.000	0.000	0.000	0.000
8	Aggregate capital (K)	-0.002	0.001	-0.002	-0.005
9	Real wage (W/P_c)	-0.015	-0.005	-0.009	-0.029
10	Exchange rate (+ = appreciation)	0.007	0.001	0.007	0.015
11	Price deflator for C (P_c)	0.000	0.000	0.000	0.000

approximation to the percentage movement in GDP

$$y = -0.030 - 0.38 * 0.005 = -0.032 \quad (4)$$

This is close to the simulated effect on GDP of -0.031 (row 1, col 4, Table 6).

Broadly consistent with the reductions in GDP and capital, column 4 of Table 6 shows reductions in real private and public consumption of 0.033 per cent and real investment of 0.004 per cent. With the percentage reductions in real private and public consumptions being about the same as that in GDP and the percentage reduction in investment being less than that in GDP, exports must decline relative to imports (rows 5 and 6). This is facilitated by real appreciation (row 10).

By reducing the marginal product of labour, a deterioration in technology causes a reduction in real wage rates (-0.029 per cent, row 9). This is another way of understanding how households would pay for extra costs in meat processing.

6. Understanding the split between farmers and consumers in paying for extra processing costs: sensitivity analysis

In this section we return to the question raised at the end of section 3: what are the major determinants in USAGE-Food of the split of extra processing costs between farmers and consumers? We start with a BOTE diagrammatic analysis. This points to the parameters that are likely to be important in determining the split. Guided by this information we perform sensitivity simulations.

6.1 BOTE diagrammatic analysis

Figure 1 is a 4-quadrant diagram. The upward-sloping schedule A in the north-east quadrant represents market clearing for a U.S. farm product. If the price of the farm product P_F (vertical axis) is low then domestic output (supply) will be low. At the same time there will be strong import-replacement and export sales. Thus, for market clearing, demand from the processing industry must be low, requiring a low quantity for processed output, Q_P (horizontal axis). Similarly, if P_F is high, then as indicated by the A schedule, Q_P must be high. In stylized form we can represent the demand and supply equations underlying the A schedule as:

$$Q_F = a_d * P_F^{-\eta} * Q_P^{SH} \qquad \text{demand for farm product} \qquad (5)$$

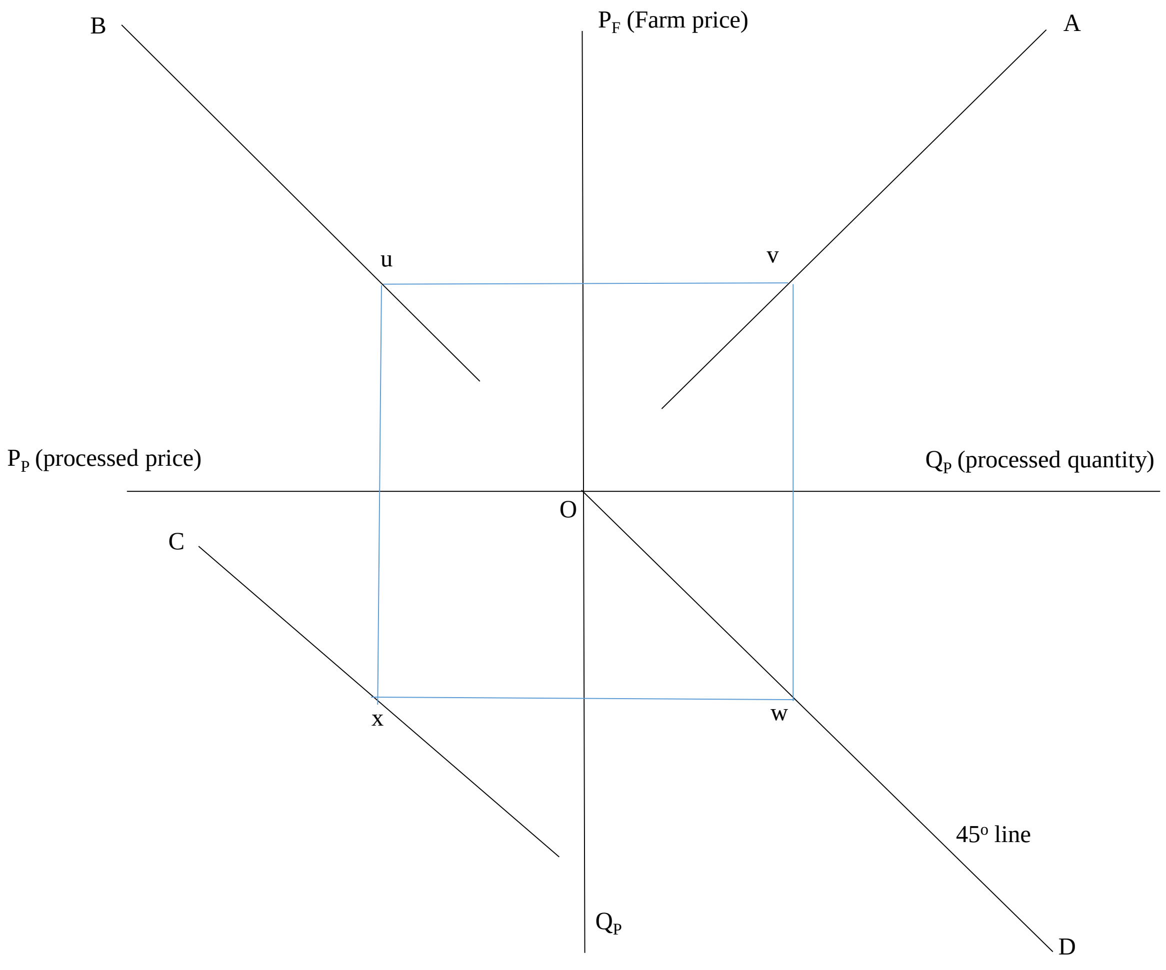
$$Q_F = a_s * P_F^{\varepsilon} \qquad \text{output of farm product} \qquad (6)$$

where a_d, a_s, SH, η and ε are positive parameters. SH can be thought of the share of farm-product sales that goes to the processor. This is close to one. η and ε are demand and supply elasticities for the farm product. From (5) and (6) we obtain a stylized equation for the A schedule:

$$P_F = \left(\frac{a_d}{a_s} * Q_P^{SH} \right)^{1/(\eta+\varepsilon)} \qquad \text{market clearing} \qquad (7)$$

The upward-sloping B schedule in the north-west quadrant represents the relationship between the price of the processed product, P_P (horizontal axis) and the price of the farm product, P_F (vertical axis). B has a positive slope because increases in input costs to the processor lead to increases in the processor's output price.

Figure 1. The determination of the prices and outputs of a farm product and the associated processed product



The downward-sloping C schedule in the south-west quadrant is the demand curve for the processed product: increases in the price of the processed product reduce demand.

The 45 degree line, OD, in the south-east quadrant represents balance between demand for (vertical axis) and supply of (horizontal axis) the domestically produced processed product.

The solution of the model in Figure 1 occurs at the vertices of the rectangle uvwx.

Figure 2 introduces an increase in the cost of processing. This causes in the schedule in the north-west quadrant to shift to the left, from B to B′: at any given value for P_F, there is an increase in P_P. The new solution is at points $u^1v^1w^1x^1$. The effects of the increase in processing costs can be seen by comparing this new solution with the original solution (uvwx). Consistent with the simulation results in sections 2 to 4, the outputs of both the farm and processed products fall, and the cost increase is shared between farmers and consumers. Farmers get a lower price for their output (a reduction in P_F) and consumers pay a higher price for the processed product (an increase in P_P).

In Figures 3 and 4 we examine the sensitivity of these price and quantity effects to changes in the elasticities of the C schedule in the south-west quadrant and the A schedule in the north-east quadrant.

Figure 2. Prices and outputs of a farm product and the associated processed product: the effect of an increase in processing cost

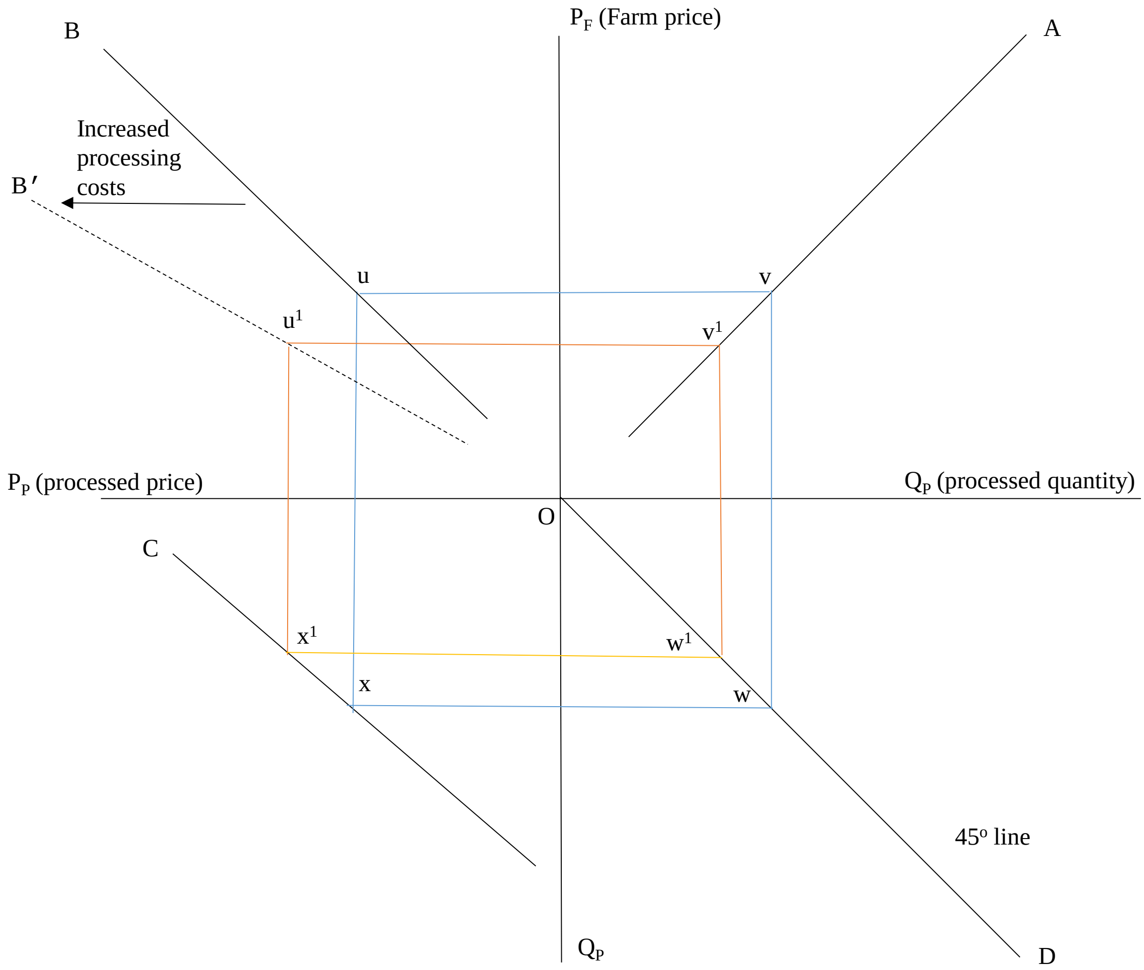


Figure 3. The effect of increased processing costs with lower elasticity of demand for the processed product

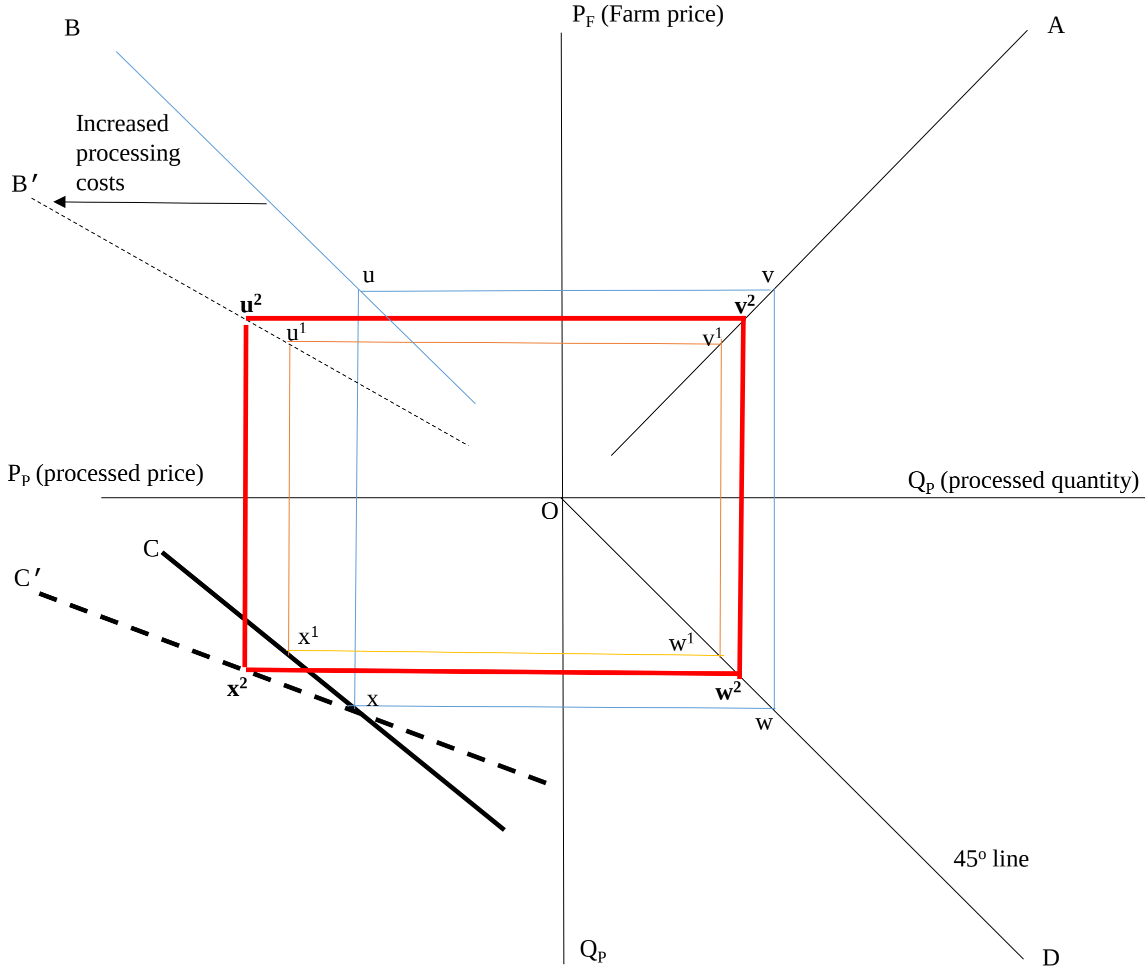
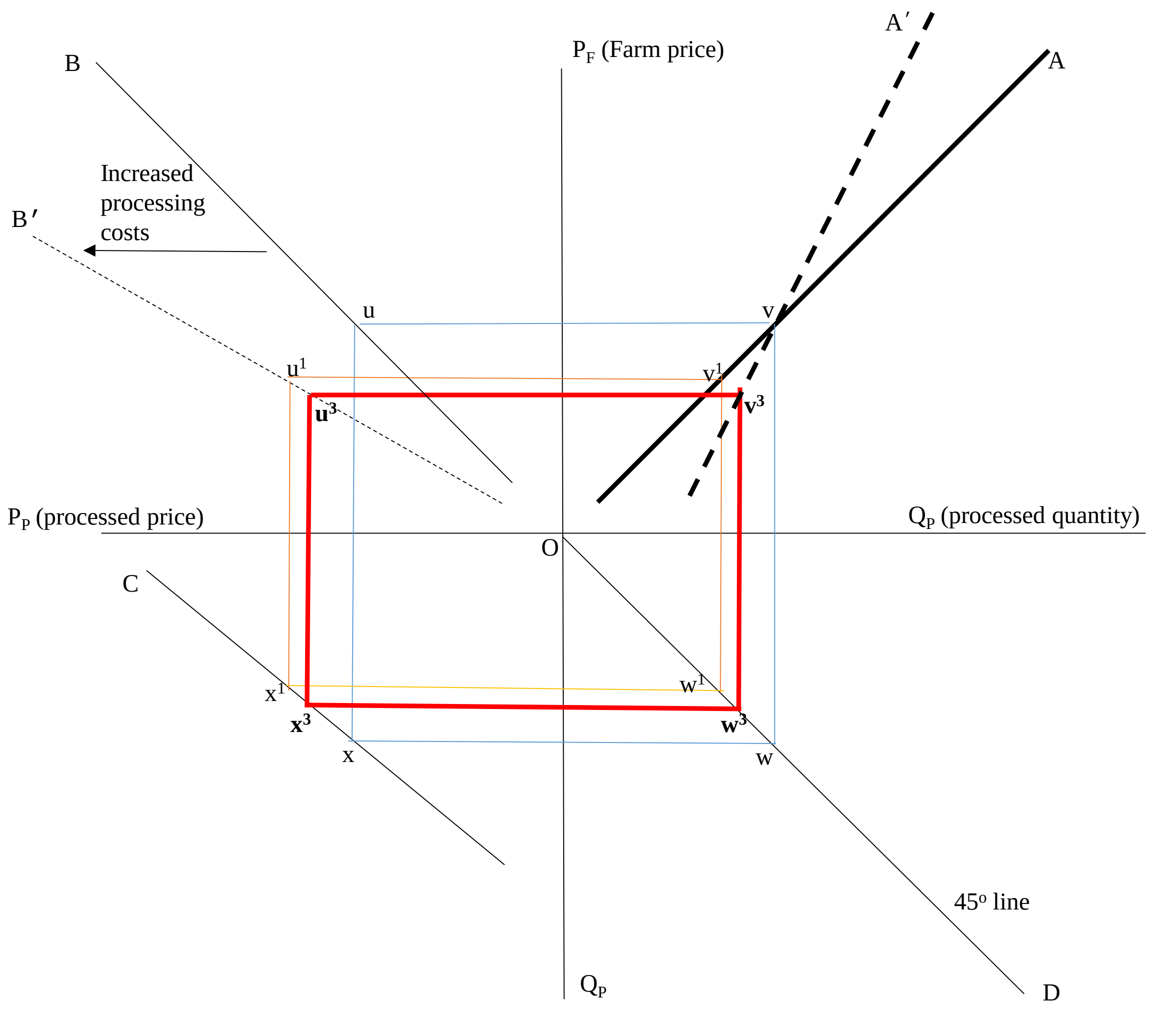


Figure 3 shows that a lower demand elasticity for the processed product (replacement of C with C′) moves the solution from $u^1v^1w^1x^1$ to $u^2v^2w^2x^2$. This is good for farmers and bad for consumers. With less elastic demand for the processed product, the increase in processing costs causes a smaller reduction in the farm price and a larger increase in the price to consumers of the processed product.

Figure 4 shows the effects of adopting a larger elasticity (steeper slope) for the farm-product market-clearing schedule. In equation (7), this elasticity is $1/(\eta+\varepsilon)$. Thus, we can think of the replacement of A with A′ as either the adoption of a lower supply elasticity (ε) for the farm product or a lower demand elasticity (η). With a higher market-clearing elasticity, the solution moves from $u^1v^1w^1x^1$ to $u^3v^3w^3x^3$. This is bad for farmers and good for consumers. With farmers having either a lower supply elasticity or facing a lower demand elasticity for their product, an increase in processing costs causes a greater reduction in the farm price. The lower farm price feeds though to a lower processed price, benefitting consumers.

Figure 4. The effect of increased processing costs with a lower total for the demand and supply elasticities (η+ε) for the farm product



6.2. Sensitivity simulations

The diagrams in subsection 6.1 suggest that there are three elasticities that play major roles in determining the split of processing costs between farmers and consumers:

(1) the elasticity of demand for the processed product;

(2) the elasticity of supply of the farm product; and

(3) the elasticity of demand for the farm product.

In USAGE-Food, these elasticities are not parameters. There are many data items and parameters that contribute to their values. These are cost shares, sales shares and substitution parameters occurring in CES-nested production functions for meat-farm and associated processing industries, and in the utility functions for U.S. and foreign households. The share coefficients are derived from input-output data published by official statistical agencies, in this case the Bureau of Economic Analysis. By contrast, the statistical basis for the substitution parameters is weak. In most CGE models, including USAGE-Food, the values adopted are based on judgement, informed over many years by what has produced credible results in a large number of applications. However, judgements can differ. Given this situation, we provide sensitivity analysis by varying the values adopted for the substitution parameters that are important in our current application.

Table 7 lists the relevant parameters classified by the critical elasticity to which they contribute. The table also shows values adopted in earlier sections for these parameters for Cattle ranching (a meat-farm industry) and Beef processing (the corresponding processing industry). These are denoted as standard values. We restrict the sensitivity analysis to the Beef processing simulation. Similar sensitivity analyses could be conducted for the simulations concerned with Other-animal processing and Poultry processing.

Higher values for items (i) to (iv) in Table 7 contribute to a higher overall demand elasticity for a processed product by generating for any given price increase larger shifts in household demand away from the product towards other meat products and non-meat products, and a larger shift towards imports and a larger reduction in exports.

Higher values for items (v) to (vii) contribute to a higher overall supply elasticity of the farm product by generating for any given price increase a larger uptake of hired labour to be combined with fixed farm-family labour, and larger increases in labour, capital and intermediate inputs to be combined with fixed land.

Higher values for items (viii) to (x) contribute to a higher overall demand elasticity for the farm product by generating for any given price increase a larger increase in imports, a larger reduction in exports, and a larger reduction in the use of farm product per unit of output of processed product.

Column (0) in Table 8 contains results from the Beef-processing simulation with standard parameters setting. These results were analyzed in previous sections. Columns (1) to (8) contain results from the Beef-processing simulation with different parameter settings for Cattle ranching and Beef processing.

In simulation (1) the category-1 parameters from Table 7, those contributing to the elasticity of demand for Beef processing, are doubled. All other parameter values are maintained at their standard values. In simulation (2) the category-1 parameters from Table 7 are halved.

In simulations (3) and (4) the category-2 parameters from Table 7, those contributing to the elasticity of supply for the Cattle-ranch product, are doubled and halved. All other parameter values, including the category-1 parameters are maintained at their standard values.

In simulations (5) and (6) the category-3 parameters from Table 7, those contributing to the demand elasticity for the Cattle-ranch product, are doubled and halved. Again, all other parameter values are maintained at their standard values.

Simulations (7) and (8) are included in the table to show what has to be assumed about parameter values to support the view that farmers pick up the bulk of extra processing costs. We delay the description of these two simulations until after we have considered simulations (1) to (6).

Rows 1 to 3 of Table 8 contain data items for 2020 from the baseline. These differ slightly across the nine simulations. As explained in section 1, USAGE-Food was set up with a database for 2015. The baseline data for 2020 is affected by parameter settings. In all simulations, the impact cost of a 10 per cent increase in primary factor requirements in

Table 7. Parameters in USAGE-Food that determine how extra processing costs are split between farmers and meat consumers

	Value
Category 1. Contributing parameters to the elasticity of demand for a processed meat product	
(i) Household elasticity of substitution between the processed product and all other meat products	1.0
(ii) Household elasticity of substitution between meat products and all other food products	0.5
(iii) Elasticity of substitution between the domestic processed product and the corresponding imported product	2.0
(iv) Absolute value of the elasticity of demand for U.S. exports of processed meat product	3.0
Category 2. Contributing parameters to the elasticity of supply of a farm meat product	
(v) Elasticity of substitution between farm-family labour and hired labour in farm industry	2.0
(vi) Elasticity of substitution in the farm industry between labour, capital and land	0.5
(vii) Elasticity of substitution in the farm industry between primary-factors and intermediate inputs	0.2
Category 3. Contributing parameters to the elasticity of demand for a farm meat product	
(viii) Elasticity of substitution between the domestic farm product and the corresponding imported product	2.0
(ix) Absolute value of the elasticity of demand for U.S. exports of the farm product	3.0
(x) Elasticity of substitution in the processed-meat industry between primary-factors and intermediate inputs	0.2

processing is about $3.5b, 10 per cent of the value-added numbers in row 1. As can be seen from row 9, in each simulation the costs allocated to farmers and consumers adds closely to this total impact cost.

Results from sensitivity simulations (1) to (6)

We start with simulation (2). Consistent with Figure 3, this simulation shows that halving the category-1 parameters (thereby reducing the implied demand elasticity for processed beef) favours farmers relative to consumers. There is a smaller reduction in the farm price (-0.48 per cent rather than -0.90 per cent) and a larger increase in the processed price (2.56 per cent rather than 2.34 per cent). The farmer share of extra processing costs falls to 10 per cent, down from 18 per cent under standard parameter settings (row 10). Doubling the category-1 parameters has opposite effects. In simulation (1) the farmers' share of extra processing costs moves to 31 per cent.

Consistent with Figure 4, simulation (4) shows that halving category-2 parameters (thereby reducing the implied supply elasticity for the ranch product) hurts farmers relative to consumers. There is a larger reduction in the farm price (-1.27 per cent rather than -0.90 per cent) and a smaller increase in the processed price (2.13 per cent rather than 2.34 per cent). The farmers' share of extra processing costs rises to 25 per cent (row 10). Doubling the category-2 parameters in simulation (3) reduces the farmers' share to 12 per cent.

Table 8. The split between farmers and meat consumers of extra processing costs: how is this affected by changes in parameter values underlying demand & supply elasticities for Cattle-ranch and Beef-processing products?

	Simulation	(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Demand elasticity		Supply elasticity		Demand elasticity		D&S elasticity	
			Processed beef		Ranch product		Ranch product		Ranch product	
			high	low	high	low	high	low	low	very low
	Parameters	Standard	Cat1*x*2	Cat1*x*0.5	Cat2*x*2	Cat2*x*0.5	Cat3*x*2	Cat3*x*0.5	Sims (4) & (6). Also (1)	Cats2&3 set at 0.01
Items from 2020 baseline data										
1	Value added in beef processing industry, $b	35.00	35.02	34.98	35.06	34.93	35.35	34.81	34.67	33.42
2	Basic value of sales from beef processing ind., $b	120.60	120.63	120.56	119.94	121.38	120.50	120.65	121.32	124.63
3	Farm income in cattle ranching, $b	25.82	25.84	25.80	24.71	27.01	25.63	25.92	27.17	32.88
Simulation results (percentage changes)										
4	Basic price of domestic processed beef product	2.34	2.00	2.56	2.51	2.13	2.52	2.24	1.57	0.14
5	Basic price of domestic cattle-ranch product	-0.90	-1.53	-0.48	-0.60	-1.27	-0.56	-1.09	-2.34	-4.76
6	Real farm income in cattle ranching	-2.41	-4.11	-1.29	-1.70	-3.19	-1.50	-2.92	-5.87	-9.66
Back-of-the-envelope (BOTE) calculations										
7	Loss of farm income, $b (= -row3*row6/100)	0.62	1.06	0.33	0.42	0.86	0.38	0.76	1.59	3.18
8	Cost to customers, $b (= row2*row4/100)	2.82	2.42	3.09	3.01	2.59	3.03	2.70	1.90	0.17
9	Total BOTE loss $b, (= row 7 + row8)	3.44	3.48	3.42	3.43	3.45	3.42	3.46	3.50	3.35
10	**Farm income loss as per cent of simulated processing cost (=100*row 7/row 9)**	**18**	**31**	**10**	**12**	**25**	**11**	**22**	**46**	**95**

Also consistent with Figure 4, simulation (6) shows that farmers are hurt relative to consumers by halving category-3 parameters (thereby reducing the implied demand elasticity for the ranch product). The farmer share of extra processing costs rises to 22 per cent (row 10). Doubling the category-3 parameters in simulation (5) reduces the farmers' share to 11 per cent.

Results from sensitivity simulations (7) and (8)

In sensitivity simulation (7) we move all the parameters against the farmers: category-1 parameters are set at twice their standard values [as in simulation (1)] and the category-2&3 parameters are set at half their standard values [as in simulations (4) & (6)]. This raises the farmers' share of additional processing costs to 46 per cent. However, it unlikely that the standard parameter settings are systematically biased in favour of farmers. Consequently we think that the farmers' share is likely to be well below 46 per cent.

Simulation 8 is set up in accordance with the *a priori* picture described at the end of section 3. In that picture, farmers with inelastic supply curves sell their product to users (mainly meat-processors) whose demand for the farm product is also inelastic. With regard to our understanding of the model and as a check of its computational integrity, it is reassuring that the simulation shows farmers as bearing almost all of the costs of extra processing requirements. The simulation also helps us understand what is wrong with the *a priori* picture. What the model captures, but is missed by the simple picture, is that farmers *do* have considerable elasticity on both the supply and demand sides. Farmers can adjust supply by varying hired labour, capital and intermediate inputs. Taking trade opportunities into consideration, farmers are not faced with totally inelastic demands. Thus, in terms of our modelling, it is not plausible to set category 2&3 elasticities at close to zero as was required in simulation 8 to generate the *a priori* picture.

7. Concluding remarks

It is possible that Covid will produce permanent changes in work practices that increase costs in U.S. meat-processing plants. These changes may be beneficial for the safety of meat-processing workers and the health of the community more generally. However, they will have economic costs. In this paper, we used a detailed CGE model to work out how those costs would be distributed between farmers and consumers of meat products. We also calculated the macroeconomic effects.

A strength of CGE models is that they sometimes produce results that were unexpected *a priori* but seem reasonable *ex post*. This was the case here. Elementary theory suggests that farmers would bear the additional meat-processing costs. However, the CGE model produces a different picture. By taking account of farm production flexibility and demand responses in the different markets in which farmers can sell their products, the CGE model showed that the bulk of additional meat-processing costs would be borne by customers for meat products, not the farmers. Nevertheless, processing costs still impact significantly on farm incomes. Our central simulations of the effects of 10 per cent increases in labour and capital requirements in processing show reductions in farm incomes of between 1 and 2.5 per cent.

By contrast, the macro results did not produce any surprises. In general, the macroeconomic implications of Covid-related increases in meat-processing costs are negative, but small. We find that a 10% increase in primary-factor requirements in all meat-processing industries reduces GDP in the long run by about 0.03%.

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