Avian Influenza outbreaks and poultry production mitigation strategies in the U.S.

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Abstract: In this paper, two AI mitigation strategies are examined, quarantine and vaccination. Meanwhile, associated welfare changes are evaluated by using FASOM. Results found that changes of total national welfare of U.S are insignificant with or without vaccination. Once comes to livestock produers, impacts become significant although magnitudes are small. For example, under 20% demand shocks, vaccination strategy dominates no vaccination at the production, market and natioanl level. Howver, vaccination has no advantage when there is no demand shifts.

Keywords: AI outbreak, mitigation strategies, vaccination, demand shift, FASOM, welfare

JEL code: Q1

1 Introduction

The continuous outbreaks of Avian Influenza (AI) in Asia, Europe and Africa and their economic consequences raise concerns about prevention methods, mitigation options and their cost effectiveness. Referring to the U.S., different AI strains caused outbreaks among poultry during 2003 and 2004 (H7N2 in New York in 2003, and Delaware, New Jersey and Maryland in 2004; H5N2 in Texas in 2004), all of which caused large loss to farmers as well as to international trade of poultry and/or poultry products. If taking account of wild bird migration activities, AI outbreaks among poultry become more unpredictable since most of states in the U.S. are on the wild bird flyways both internationally and domestically. Although there was no large AI outbreak in the U.S. after 2004, mitigation strategies are still necessary and important for preventing a potential outbreak of AI and for reducing the economic costs of a new outbreak.

There are two disease control options in the AI context, one is a quarantine strategy and the other is the vaccination strategy. The former recommends establishing a quarantine strategy zone in a 5-miles radius around the outbreak site within which every flock is depopulated, and then a varying surveillance radius around that zone plus movement restrictions and testing (CDC, 2004). The vaccination strategy suggests vaccinating all susceptible flocks in near proximity to the quarantine zone in addition to the quarantine strategy stated above in terms of reducing the probability of infection and the amount of virus produced by an infected flock (WHO, 2005). Both strategies depend on the probability of AI outbreaks and the densities of poultry flocks. Therefore, the decision of choosing the quarantine or vaccination response is determined by the expected economic costs due to AI outbreaks.

The objective of this study is to evaluate both mitigation strategies under the assumption that there may be a large AI outbreak across regions in the U.S. due to the wild bird mitigation activities. By using a set of economic-epidemic constraints and the Forest and Agriculture Sector Optimization Model (FASOM), this study examines how a large AI outbreak affects poultry production strategies in the U.S. considering not only meat markets but also feed markets and market. In pursuing of the objective, this study does analyses of: (1) developing a scenario loop of AI that includes disease control options; (2) applying the developed model to simulate the case of a hypothetical outbreak in the U.S. under a deterministic disease spread assumption; (3) examining the welfare implications of two mitigation strategies under different demand shifts.

Few studies of AI mitigation strategies have been done partly because of the difficulty in selecting an appropriate estimation model. Previous studies of animal diseases focus on the improvement of model selection and suggest that studies which contain more through integration of economic and epidemic models would improve the analysis quality (Paarlberg et al., 2005; Pritchett et al., 2005). Therefore, Rich and Nelson (2007) and Carpenter et al. (2007) study simulated foot-mouth disease (FMD) outbreaks by employing the integrated animal disease models.

Elbakedze (2008) presents a conjecture model for the analysis of AI mitigation options within the small poultry farm sector (backyard flocks) by incorporating epidemiologic susceptible-infected-recovered (SIR) methodology into an economic cost-minimization framework. In an expended study, Egbendewe (2009) examines the outbreak of AI in Texas by evaluating both mitigation strategies as discussed above. However, Both Elbakedze (2008) and Egbendewe (2009) studies were limited in geographic scope and in the markets considered when regarding AI outbreaks. Therefore, this paper employs data derived from Egbendewe (2009)'s results, but does the analysis at the national level by using FASOM.

This paper is organized as follows. Section 2 introduces backgrounds; Section 3 shows data and constructs scenarios; Section 4 presents results from FASOM; and Section 5 provides conclusions and policy implications.

2 Backgrounds

The outbreaks of AI recently have been costly for U.S. poultry producers. The 1993-1994 outbreaks of LPAI in Pennsylvania resulted in the depopulation of over 17 million birds and cost the federal government over $60 million dollars (Akey, 2003). Cupp et al. (2004) also estimate that the U.S 1983-1984 AI outbreaks cost $63 million and the 2002 case led to a producers' loss of between $130 and $140 million. More recently, a high HPAI strain was diagnosed in Gonzales County, Texas in a flock of infected broiler chickens in February 2004, which involved a broiler farm of 6,608 birds plus 5 live bird markets. Forty-four countries banned imports on either Texas or U.S.-origin poultry or poultry products (Pelzel et al., 2006). The overall value of all poultry and poultry products produced and exported from Texas was 123 million, which represented 5.4% of the total value of U.S. poultry and poultry product in 2002.

The link between AI outbreaks and welfare changes could be examied by FASOM (Adams et al., 2005). FASOM is a dynamic, nonlinear programming model of the forest and agricultural sectors in U.S. and it was developed to evaluate the welfare and market impacts of public policies that cause land transfers between the sectors and alterations of activities within the sectors (Adams et al., 2005). FASOM incorporates the Agriculture Sector Model (ASM) which is specifically used in this paper. The ASM model is a spatially disaggregated agricultural sector model representing the U.S. in terms of 63 production regions and 10 market regions depicting trade with a number of foreign countries. ASM also depicts production in an equilibrium year and is thus an intermediate run model giving implications for policy after it has been fully worked into the sector (Adams et al., 2005).

Basically, FASOM is a partial equilibrium model and one advantage of FASOM is that it allows price to be exogenous or endogenous. Actually, the assumption of price is very important. If price is exogenous, as in Egbendewe (2009), the impacts of a regional AI outbreak could be limited. However, if allowing price changes along with demand and supply, impacts would be passed nationally or internationally. Based on this fact, it is more realistic letting price be endogenous, which is the main reason for using FASOM in this paper. On the other hand, demand of poultry could change due to extensive outbreaks of AI in other countries, so a regional outbreak could affect producer's welfare nationally through the demand chain. Therefore, in stand of using the national data of poultry supply, we want to see how a small AI outbreak causes national effects.

3 Data and Scenarios

Because of the 2004 AI outbreaks in Texas, it has been chosen as the target of this study, and the corresponding sub-regions in FASOM are Texas East (district 5-N and district 5-S) and Texas Central Black (district 8-N). To construct the scenario loop in FASOM, we have to adjust budget constraints of meat supply, management costs and feed inputs. Data associated with these constraints are discussed below and parts of them are based on Egbendewe (2009)'s simulated results.

Based on the U.S. Agriculture Census of 2002, poultry farms in each district can be categorized into five types of farms as follows:

(1) large size layers operations of more than 100,000 birds (layersl)

(2) small size layers operations between 400 birds to 100,000 birds (layerss)

(3) backyard operations of layers less than 400 birds (backyard)

(4) broiler operations (broiler)

(5) turkey operations (turkey)

So the total number of farms in each of sub-region is given in table 1.

Table 1 Number of farms per sub-region

sub-region	layersl	layerss	backyard	broiler	turkey
Texas Central Black	10	54	395	235	1526
Texas East	6	111	923	282	1847

Source: calculated from Egbendewe (2009)

According to Egbendewe (2009), at each time period, individual farms are assumed to be in one of the four states of the disease progression. Those states are susceptible, latent infectious, symptomatic infectious and removed. If vaccines are utilized during the outbreak period, the vaccinated farms are immune and are therefore subtracted out each period from the susceptible farms because they are not vulnerable to the disease anymore.

Therefore, by the end of the period, the proportion of each type of birds at each stage is shown in Table 2, Table 3, Table 4 and Table 5 with different intervention strategies and demand shifts. To note, these numbers are calculated from Egbendewe (2009)'s simulation results and then we put them in FASOM as the initial values of each parameter. It can be seen that by the end of the AI outbreak period, the percentage of each farm type at each stage does not vary along with the changes of demand.

Table 2 Percentage of each farm type at each stage in Texas Central Black with no vaccination and demand shift

	Susceptible	Latent	Infected	Removed	Quarantined
			0% of demand shift		
layersl	0.911	0.007	0.003	0.079	9.11E-05
layerss	0.932	0.005	0.002	0.061	9.32E-05
backyard	0.945	0.004	1	0.05	9.45E-05
broiler	0.991	0.001	3.25E-04	0.008	9.91E-05
turkey	0.976	0.002	8.15E-04	0.021	9.76E-05
			20% of demand shift		
layersl	0.911	0.007	0.003	0.079	9.11E-05
layerss	0.932	0.005	0.002	0.061	9.32E-05
backyard	0.945	0.004	1	0.05	9.45E-05
broiler	0.991	0.001	3.25E-04	0.008	9.91E-05
turkey	0.976	0.002	8.15E-04	0.021	9.76E-05

Source: calculated from Egbendewe (2009)

Table 3 Percentage of each farm type at each stage in Texas East with no vaccination and demand shift

	Susceptible	Latent	Infected	Removed	Quarantined
			0% of demand shift		
layersl	0.9593	0.0077	0.0029	0.031	9.59E-05
layerss	0.9902	0.0022	0.0007	0.0072	9.91E-05
backyard	0.5403	0.0005	0	0.0002	5.40E-05
broiler	0.9997	0.001	0	0.0003	1.00E-04
turkey	0.9979	0.0015	0.0002	0.002	9.98E-05
			20% of demand shift		
layersl	0.9593	0.0077	0.0029	0.031	9.59E-05
layerss	0.9902	0.0022	0.0007	0.0072	9.91E-05
backyard	0.5403	0.0005	0	0.0002	5.40E-05
broiler	0.9997	0.001	0	0.0003	1.00E-04

turkey	0.9979	0.0015	0.0002	0.002	9.98E-05

Source: calculated from Egbendewe (2009)

Table 4 Percentage of each farm type at each stage in Texas Central Black with vaccination and demand shift

	Susceptible	Latent	Infected	Removed	Quarantined	Vaccinated
			0% of demand shift			
layersl	0.998	8.81E-04	9.14E-05	0.002	9.98E-05	0
layerss		7.78E-04	5.48E-05	0.002	0	0.998
backyard		7.07E-04	5.01E-06	1.45E-04	0	1
broiler		7.05E-04	3.86E-06	1.12E-04	0	1
turkey		7.14E-04	9.71E-06	2.80E-04	0	1
			20% of demand shift			
layersl	0.998	8.81E-04	9.14E-05	0.002	9.98E-05	0
layerss		7.78E-04	5.48E-05	0.002	0	0.998
backyard		7.07E-04	5.01E-06	1.45E-04	0	1
broiler		7.05E-04	3.86E-06	1.12E-04	0	1
turkey		7.14E-04	9.71E-06	2.80E-04	0	1

Source: calculated from Egbendewe (2009)

Table 5 Percentage of each farm type at each stage in Texas East with vaccination and demand shift

	Susceptible	Latent	Infected	Removed	Quarantined	Vaccinated
			0% of demand shift			
layersl	0.657333	0.005333	0.00257	0.030667	6.57246E-05	0.305
layerss	0	0.001721	0.000527	0.007045	0	0.990946
backyard	0	0.001	5.2E-05	0.000655	0	0.99954
broiler	0	0.001	2.09E-05	0.000311	0	0.999718
turkey	0	0.001	0.000136	0.002016	0	0.997901
			20% of demand shift			
layersl	0.657333	0.005333	0.00257	0.030667	6.57246E-05	0.305
layerss	0	0.001721	0.000527	0.007045	0	0.990946
backyard	0	0.001	5.2E-05	0.000655	0	0.99954
broiler	0	0.001	2.09E-05	0.000311	0	0.999718
turkey	0	0.001	0.000136	0.002016	0	0.997901

Source: calculated from Egbendewe (2009)

Management costs in this study include surveillance costs, costs of disposal and vaccination costs, all of which are measured in unit and are derived in different ways. For example,

(1) Only some proportion of the susceptible flocks in under surveillance and the surveillance cost depends only on the number of birds tested for the disease. According to Texas AI response document (2006), 20 birds are tested in each farm. So the unit cost of testing is estimated at $15 cents per bird (Egbendewe, 2009);

(2) The costs of carcass disposal are taken as the digging and the burial costs of removed or depopulated flocks and are estimated at $8000 for large farms, $6000 for small layers and broiler farms, $4000 for turkey farms and $1000 for backyard farms.

(3) Based on the Food and Agriculture Organization (FAO) report on the AI disease control in Vietnam (Smith, 2007), vaccine production cost is about $1.2 cents/dose. The Center for Infectious Disease Research and Policy (CIDRAP, 2005) reported that an Iowa based vaccine manufacturer was willing to produce vaccines at $1.2 cents/dose for the USDA. If including the labor costs, the estimated costs of vaccination is $5 cents/dose and only one doze is needed per bird.

To compare with the situation when there is no disease, no demand shift and no intervention, we set 4 scenarios, which are,

(1) no vaccination no demand shift : the market is affected by AI outbreaks in Texas. Quarantine strategy is used and market does not react immediately, so there is only supply shock and no demand shifts.

(2) no vaccination with 20% demand shift: consumers become fear of eating poultry meat, so consumption of poultry products decreases. It is assumed demand shifts 20% regarding to Beach and Zhen (2008)'s study in Italian and they find that demand shifts by 22% due to negative information of AI coverage.

(3) vaccination no demand shift: as the prevention strategy, vaccination is carried out at this scenario and there is no demand shift. To poultry producers, vaccination is a risk investment strategy. If there is no AI outbreak later, their management costs will increase because of vaccination; however, if AI does occur after vaccination, their farms are safe which will definitely reduce their economic loss.

(4) vaccination with 20% demand shift: although farms with vaccination will be safe if there is a AI outbreak. However, consumers' consumption patterns are affected by negative information of AI media coverage, then demand of poultry declines by 20%, poultry producers still face the situation of economic loss associated with AI outbreaks.

In order to get compatible results, we iterate each scenario by 256 times randomly and compare the difference of each scenario with the base. Results are discussed in next session.

3 Results

Here we go to the results part. Since there four alternatives for base, we have four pairs of comparisons. Based on our 256 iteration results, we compare the percentage difference for producer surplus with or with vaccination under different demand shifts.

Table 6 gives results for national welfare of U.S. with demand shifts and interventions. Without vaccination, the base welfare of U.S. is $1430.349 billion and 1471.33 billion with demand shifts from 0% to 20%. However, with AI outbreaks in Texas, national welfare increases to 1437.539 if no demand shock and to 1471.429 with 20% demand shift. Since consumers surplus take a large proportion of national welfare, a little change of supply in Texas of poultry production can not affect poultry price to much. Plus during the 2004 AI outbreaks, U.S. export of poultry was restricted due the safety of poultry consumption, consumers actually benefit of lower price which induce a welfare gain for the whole U.S. Once consumption also affected by AI information, welfare gains decrease. Similarly, the national welfare gains if there is no demand shift but with vaccination and welfare is declining because of decreased consumption.

Table 6 National welfare changes with demand shifts and interventions

(in billions of constant 2004 $)

	Without vaccination		With vaccination	
	0%	20%	0%	20%
base	1430.349	1471.33	1430.349	1413.074
national	1437.537	1471.429	1437.408	1362.171

It seems that results of the national welfare are difficult to understand directly since we don't calculate the national welfare change of consumer surplus separately. In addition, information was lost when aggregating to a national level. It is more precise if we could go to the 63 production level and 10 market level.

Table 7 shows the percentage difference from base agriculture livestock producer surplus for the specific two regions in Texas. Under the 20% demand shift, livestock producer surplus could increase by 0.046% without vaccination while by 0.275% with vaccination. Similar results in Texas Central Black. In general, vaccination increase livestock producer's surplus. Figure 1 and Figure 2 show the Cumulative Distribution Function (CDF) of vaccination and no vaccination under 20% demand shift in both regions and confirms that vaccination strategy is more cost-effectiveness although magnitudes are very small. Similar results can be found in Figure 3 and Figure 4 where there is no demand shock happens.

Table 7 Percentage difference from base agriculture livestock producer surplus

	without vaccination		With vaccination	
	mean	95% confidence interval [Lower, upper]	mean	95% confidence interval [lower, upper]
		20% demand shock		

Texas East	0.046	[0.046	0.046]	0.275	[0	0.276]
Texas Central Black	0.085	[0	0.086]	0.232	[0	0.233]
0% demand shock						
Texas East	-0.05	[-0.05	-0.05]	-0.120	[-0.120	-0.120]
Texas Central Black	-0.029	[-0.029	-0.029]	-0.050	[-0.050	-0.050]

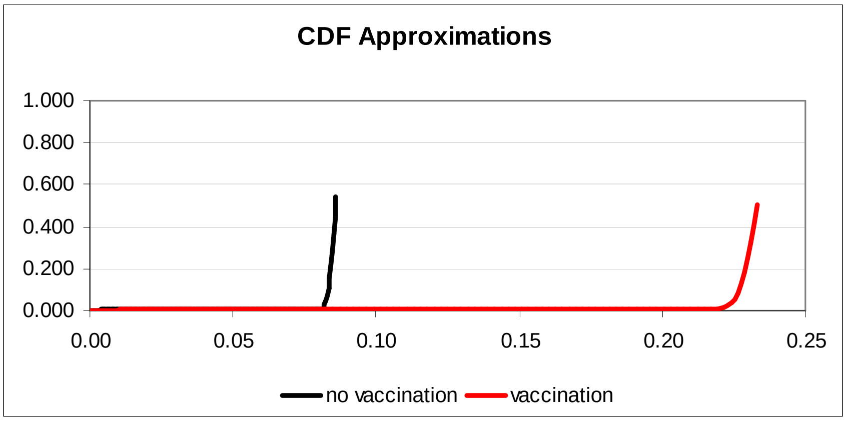

Figure 1 Texas Central Black: percentage difference from base agriculture livestock producer surplus under 20% demand shift

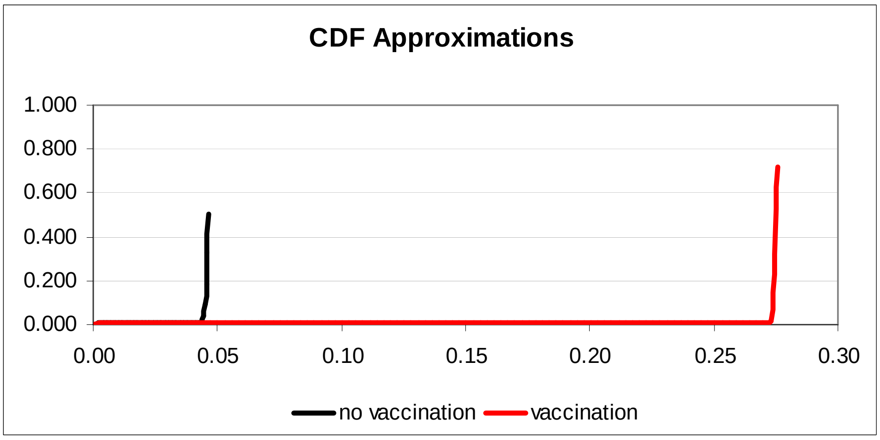

Figure 2 Texas East: percentage difference from base agriculture livestock producer surplus under 20% demand shift

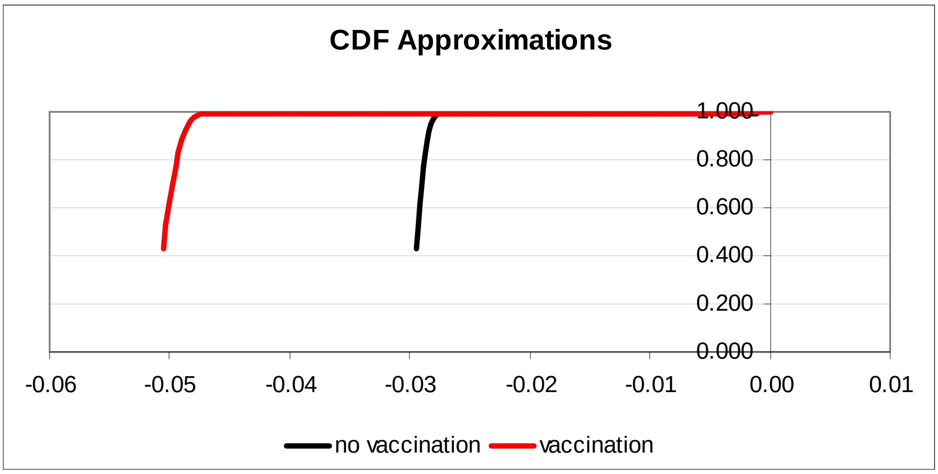

Figure 3 Texas Central Black: percentage difference from base agriculture livestock producer surplus under 0% demand shift

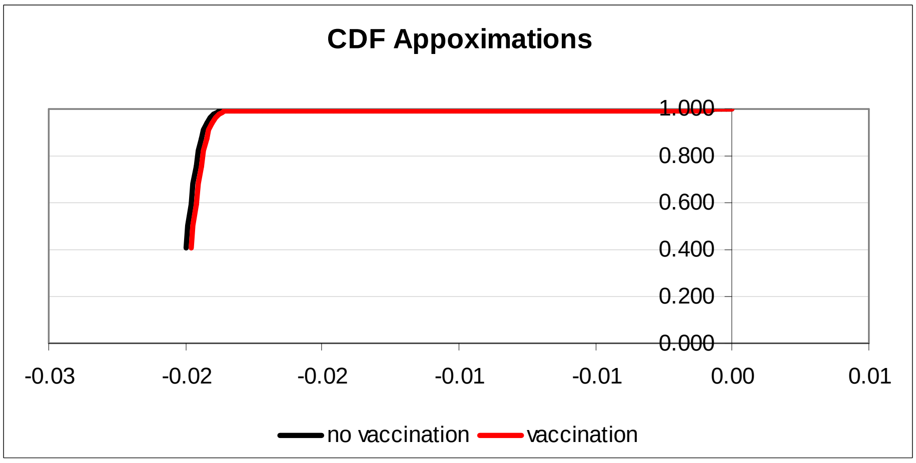

Figure 4 Texas East: percentage difference from base agriculture livestock producer surplus under 0% demand shift

According to the definition of 10 market regions in FASOM, Texas East is included in South Central (SC) and Texas Central Black is included in South West (SW). Table 8 presents the percentage difference from base agriculture regional and national livestock producer surplus. Producer surplus in south central would increase by 0.022% and it falls in the range of 95% confidence level. Compared to South Central, producers in South west could gain more without vaccination and less with vaccination under the same 20% demand shock. The reason is that South central produce more poultry than south west. If there is an AI outbreak and quarantine is operated, poultry producers would face more economic loss. In contrast, if vaccination is carried out before an AI occurs, producers in this subregion would gain more because poultry are safe once vaccinated.

Under no demand shock, producer surplus are losing for south central, south west and U.S. total. And the differences with or without vaccination are not significant. For example, livestock producer surplus decline by 0.019% for both case with or without vaccination, so does for U.S. total. Figure 8 and 10 show the results graphically. Therefore, vaccination does not save more costs for livestock producers if there is no demand shock, these probably because of the costs related to vaccination.

Nevertheless, results still suggest that vaccination is better than no vaccination under the 20% demand shock, though magnitudes of percentage difference are decreasing when production surplus are aggregated to a higher level. Based on our 256 iterations, Figure 5, 6 and 7 give CDF approximations of the percentage difference distribution under 20% of demand shift.

Table 8 Percentage difference from base agriculture regional and national livestock producer surplus

	without vaccination			With vaccination		
	mean	95% confidence interval		mean	95% confidence interval	
		[Lower,	upper]		[lower,	upper]
		20% demand shock				
South Central	0.022	[0.022	0.022]	0.263	[0.000	0.264]
South West	0.026	[0.026	0.026]	0.127	[0.000	0.127]
U.S. Total	0.012	[0.012	0.012]	0.158	[0.158	0.158]
		0% demand shock				
South Central	-0.019	[-0.019	-0.019]	-0.019	[-0.019	-0.019]
South West	-0.026	[-0.026	-0.026]	-0.024	[-0.024	-0.024]
U.S. Total	-0.024	[-0.024	-0.024]	-0.024	[-0.024	-0.024]

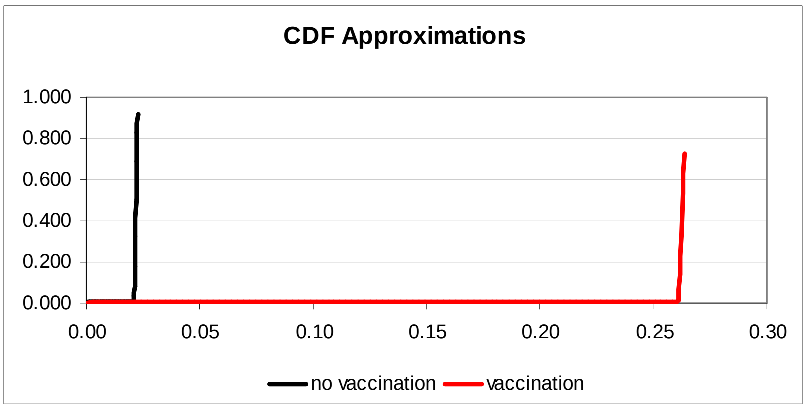

Figure 5 South Central: percentage difference from base agriculture regional and national livestock producer surplus under 20% demand shift

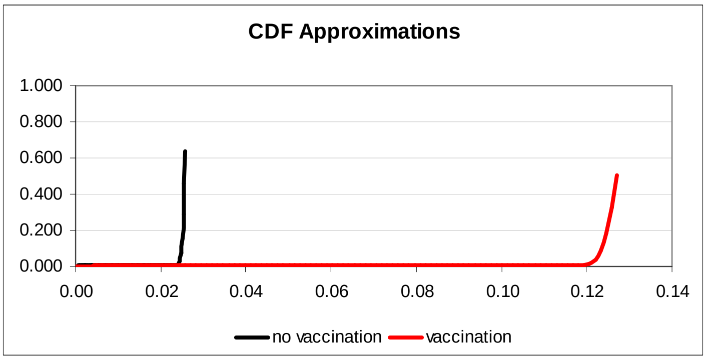

Figure 6 South West: percentage difference from base agriculture regional and national livestock producer surplus under 20% demand shift

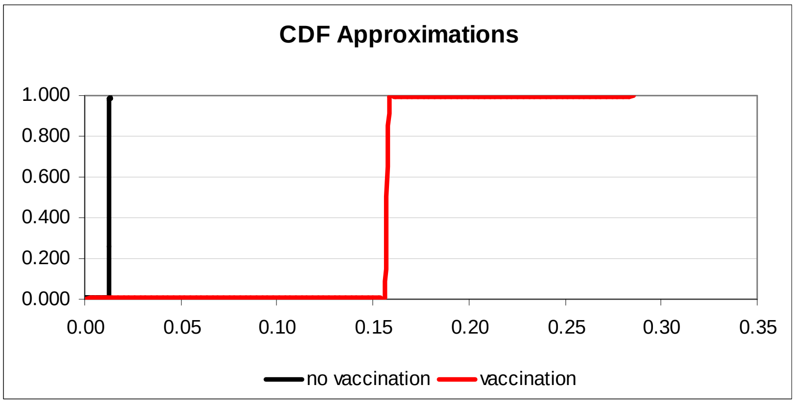

Figure 7 U.S. Total: percentage difference from base agriculture regional and national livestock producer surplus under 20% demand shift

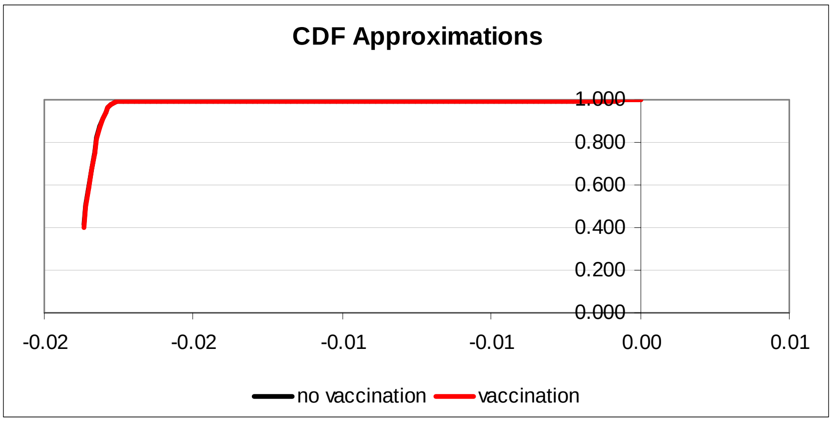

Figure 8 South Central: percentage difference from base agriculture regional and national livestock producer surplus under 0% demand shift

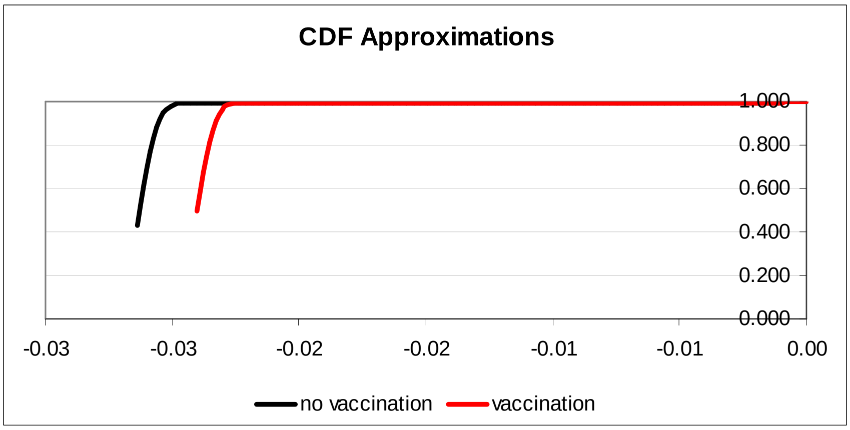

Figure 9 South West: percentage difference from base agriculture regional and national livestock producer surplus under 0% demand shift

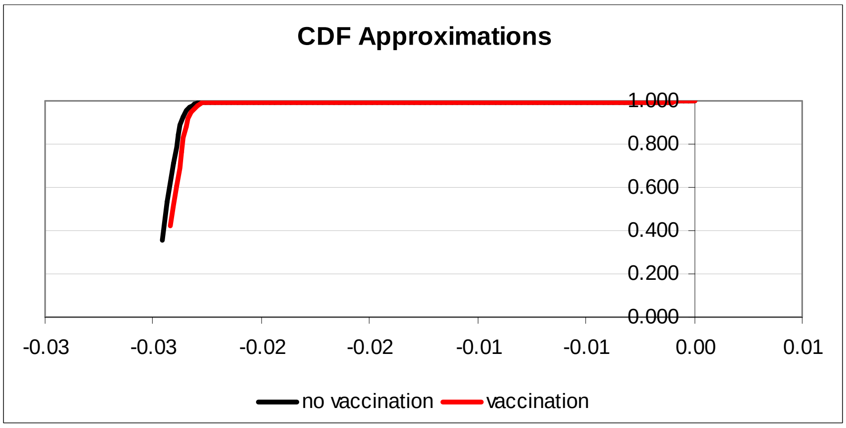

Figure 10 U.S. Total: percentage difference from base agriculture regional and national livestock producer surplus under 0% demand shift

In a general case, vaccination strategy donimates no vaccination strategy if there is a large demand shock and agriculture livestock producers always gain no matter they operate vaccination or not. If there is no demand shock, livestock producers will lose less if they adopt the vaccination strategy before AI outbreaks.

Table 9 presents the percent difference from base agricultural national prices. It can be seen that vaccination has no impacts on prices of eggs, broiler and chicken if there is no demand shock. Since only two regions of Texas are examined to have AI outbreaks and thus reduce supply of poultry, it can't change the national supply of poultry not only because Texas is not the largest poultry production states, but also prices are determined by demand as well. If there is no demand shift, price could change insignificantly with a slight change of supply. However, if there a large demand shock, price change a little bit. Prices of eggs, broiler and chicken would increase with decrease supply if vaccination is not adopted.

Table 9 Percent difference from base Agricultural National Prices

	Without vaccination		With vaccination	
	0%	20%	0%	20%
Eggs	-0.013	0.068	-0.013	-1.081
Broiler	-0.015	0.008	-0.015	-0.058
Chicken	-0.014	0.008	-0.014	-0.051

4 Conclusion

In this paper, a hypothetical AI outbreak impact on the U.S. livestock producers under disease mitigation strategies with vaccination and without vaccination is evaluated. By using the FASOM model, this paper finds that vaccination dominates no vaccination strategy only if there is a large demand shock due to AI outbreaks in U.S. or other countries. In other words, vaccination has no advantage for U.S. livestock producers if there is no demand shifts.

In specific, under the case of 20% demand shock, Texas east and central black livestock producers would gain 0.275% and 0.232% with vaccination and 0.046% and 0.085% without vaccination, respectively. To a market level, south central and south west could gain 0.263% and .0127% with vaccination and 0.022% and 0.026% without vaccination, respectively. U.S. total livestock produces would benefit by 0.158% with vaccination and 0.012% without vaccination. All of those results are compared to the base where there is no demand shift and no disease with price equals to 1.

For additional information, vaccination strategy at current stage does not affect national prices of eggs, broilers and chicken if there is no demand shock. However, prices are reduced by 1.081%, 0.058% and 0.056% for eggs, broiler and chicken with vaccination, respectively and 20% demand shift. Without vaccination, prices go up by 0.068%, 0.008% and 0.008%, respectively.

As a policy perspective, vaccination is not always a good strategy and it only effective if there is a large demand shift on the market due to the outbreak of AI. In most of the cases, animal disease could not be restricted within a region, so it is better to take account of international trade, especially U.S. is the second largest poultry export and the first largest egg exporter, demand shock might be the big issue for considering whether a vaccination should be considered or not. Meanwhile, costs related to vaccination should also be reinvestigated.

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