SUPPLY DRIVEN INPUT-OUTPUT ANALYSIS: CASE OF 2010-2011 FOOT-AND-MOUTH DISEASE IN KOREA

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Abstract
The objective of this study is to determine the direct and indirect economic impacts of the 2010-2011 Foot-and-Mouth Disease (FMD) outbreaks in Korea using a supply-driven input-output (IO) model. The supply-driven model is better than a standard demand-driven IO model in situations where the event alters sectoral production not the final demand. Obviously, the FMD outbreak is a supply reduction question and the standard IO approach may not completely reflect all the economic impacts. Both backward linkage (upstream sectors) and forward linkage (downstream sectors) effects of the FMD outbreaks are measured. The study shows that backward linkage effects in feed and manufacturing sectors and forward effects in dairy and livestock processing sectors are strong. Total direct and indirect economic impact is estimated to be 7.6 trillion Korean Won which is much larger than the economic impact from the standard final demand-driven IO analysis.

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I. Introduction

The objective of this study is to determine the direct and indirect economic impacts of the 2010-2011 Foot-and-Mouth Disease (FMD) outbreaks in Korea.[1] The 2010-2011 FMD outbreaks were severe and caused large impacts on livestock sectors in Korea. The number of culled animals was up to 3.5 million heads and more than 90% of the culled animals were swine. KREI (2011) estimates the direct supply reduction in the swine sector to be 32% of the total value of the production, while the direct supply reductions in dairy cattle and beef cattle sectors to be 8.4% and 3.9%, respectively (KREI, 2011, p. 283). KREI (2011) also estimates the direct and indirect economic impact from the supply reduction to be more than 4 trillion Korean Won (» USD 3.6 billion) using the Input-Output (IO) analysis (KREI, 2011, p. 283). The value added falls by 0.96 trillion Korean Won (» USD 0.86 billion) (KREI, 2011, p. 283). The number of employment is reduced by 47,813 persons (KREI, 2011, p. 283).

The IO model used in KREI (2011) and other studies that are listed below is constructed from a detailed set of industry accounts that measure the commodities produced by each industry and the use of these commodities by other industries and (exogenous) final users. IO multipliers can trace the impact of the (exogenous) final demand changes on particular industry sectors within a region by incorporating information about inter-industry relationships or direct requirement. Among others, regarding the livestock sector in Korea, Kim and Lee (2011) analyze the structure of the Korean feed industry on Korea economy using the IO model. Ji (2013) investigates the structural changes in the livestock industry in Korea using the IO model and reports the (final demand-driven) multipliers. Ji (2013) shows that livestock industries in Korea are closely related and have positive effect on the growth of the Korean economy.

The IO model drawn up for the economic impact of the FMD outbreaks is not new. Previous studies that have used the IO approach to investigate the economic impacts of the FMD outbreaks are Garner and Lack (1995) for FMD disease in Australia, Ekboir (1999) for hypothetical FMD outbreaks

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[1] The 2010-2011 FMD outbreaks in Korea are well-documented in KREI (2011) white-paper including origin and type of FMD, its transmission and progress, government responses, and the regional economic impacts.

in California, U.S., Mahul and Durand (2000) for France, and Cozzens et al. (2010) for a hypothetical swine-transmitted FMD for Missouri, US. Lee et al. (2012) present estimates of economic impacts of a hypothetical agro-terrorism attack in the U.S. that uses FMD pathogens using the IO framework. Pendell et al. (2007) analyze the hypothetical FMD impacts on southwest Kansas economy using the Social Accounting Matrix approach that is the extended IO model. Caskie, Davis, and Moss (1999) have used the IO model to quantify the effects of a BSE-induced reduction for Northern Ireland. Moon, Park and Soh (2013) analyze the multiplier effects for the FMD outbreak in Korea in 2000, 2002, and 2010 using the IO model. The total economic impact of FMD outbreak in Korea in 2010 was estimated to be 3.5 trillion Korean Won. Also Moon, Park and Soh (2013) show that the FMD disease may have the stronger impact on household than (other) industries.

However, some studies such as Leung and Pooley (2002), Fernandez-Macho, Gallastegui and Gonzales (2008), and Seung and Waters (2009) have argued that it is more appropriate to use a supply-driven model than the (final) demand-driven IO model in situations where the output level is altered, i.e., "supply reduction" occurs, as in the FMD case in Korea, since the change is not on final demand and/or the change in (final) demand is not known. In addition, Groenewold, Hagger, and Madden (1987) suggest to use the final demand-driven IO model for industries with a high ratio of final demand to output. Most of products from livestock sectors become the intermediate inputs for other sectors such as livestock processing and dairy, and are not consumed directly by household or government. Thus the final demand-driven IO analysis may not be appropriate. Johnson and Kulshreshtah (1982) and Roberts (1994) are among the first to consider the use of the supply-driven IO multipliers. Both backward linkage (upstream sectors) and forward linkage (downstream sectors) effects of the FMD outbreaks can be estimated using the supply-driven IO multipliers as explained in subsequent sectors.

In sum, this study investigates the economic impacts of the 2010-2011 FMD outbreaks in Korea on the Korean economy using the supply-driven IO framework. Section 2 provides an overview of the FMD and section 3 discusses the supply-driven IO model. Section 4 presents the results and implications of the research and section 5 concludes the study.

II. Overview of FMD

FMD is a highly contagious viral disease that affects cloven-hoofed animals such as cattle, swine, sheep and goats. The disease can be transmitted directly through animal movement or indirectly through non-animal fomites or airborne transmission. Typically, fewer than six percent of adult animals are killed by the disease (Mahul and Gohin, 1999) while mortality is about 80 percent in young animals (Rich, Miller, and Winter-Nelson, 2005). Despite the low mortality and non-zoonotic nature of FMD, an outbreak results in animal debilitation and substantial losses in both milk and meat production. Since it is highly infectious and spreads quickly, culling or killing exposed animals is inevitable, which might cause huge economic losses. FMD impacts every stage of animal production such as breeding, feeding and marketing (Noguiera et al., 2011). The impact of the potential FMD outbreak on international trade has grown to be a major concern for livestock exporters as food supply chains have become globalized increasingly (Park, Jin, and Bessler, 2008). KREI (2011) whitepaper has documented the 2010-2011 Korean FMD in detail including definition, history, symptoms, diagnosis, zoonoses, international trends, government reaction, vaccination, and so on.

Regarding the FMD outbreaks, Pendell et al. (2007) emphasize the role of the FMD management strategy and the type of emergency responses because the expected economic impact of the disease depends on them. The FMD management strategies are "… if FMD is discovered, aggressive quarantines, substantial restrictions on animal movement, and stamping-out of exposed animals are strategies enacted to attempt to rapidly arrest and eradicate the disease…. vaccination strategies may be employed..." (Pendell et al., 2007, p. 21).

The United Kingdom (UK) experienced a severe FMD outbreak in 2001 following 34 years of being an FMD-free country. At least 57 premises were infected by the time the first case was identified in February 2001 (Scudamore, 2002). By September 2001 over 6 million animals were killed and the disease spread to Ireland, France and the Netherlands (Scudamore, 2002). Thompson et al. (2002) estimate losses from the FMD in the UK at USD 5 billion. As Pendell et al. (2007) point out, the UK FMD outbreak demonstrates the need to understand the economic impacts of the FMD to develop effective public policies.

In Korea, the FMD was considered to have been terminated since 1934 but it occurred in 2000, 2002 and 2010 (KREI, 2011). The FMD outbreaks in 2000 and 2002 were not severe and the number of killed animals was 2,216 heads in 2000 and 160,155 heads in 2002, respectively (KREI, 2011). The 2010-2011 FMD in Korea, however, was much severe and caused large impacts on livestock sectors in Korea. The number of culled animals was up to 3.5 million heads (mostly swine). KREI (2011) estimates the direct "supply reduction" in the swine sector to be 32% of the total value of swine production, while the direct "supply reductions" in dairy cattle and beef cattle sectors to be 8.4% and 3.9%, respectively (KREI, 2011, p. 283).

III. Supply Driven Input-Output Model

The IO model is represented by **x=Ax+y** for an economy of n sectors (industries), where **x** is the output vector, **y** is the final demand vector (household consumption, government expenditure and export), and **A** is the direct requirement (or technical coefficients) matrix. Elements in the matrix **A**, a_{ij}, are calculated as $a_{ij} = x_{ij}/x_j$, where x_{ij} is the transaction between sector i and j, and x_j is the sectoral output which is $x_j = \sum_i^n x_{ij}$. This relation indicates that the sum of output **x** equals to the direct uses in final demand **y** and its indirect uses in intermediate production, **Ax**.

The solution of **x=Ax+y** can be obtained by rewriting it to $\mathbf{x=(I-A)^{-1}y}$, where **I** is the $n \times n$ identity matrix. The matrix $\mathbf{(I-A)^{-1}}$ is called the Leontief inverse matrix showing the total-requirements matrix for the economy. This can be interpreted as $\mathbf{\triangle x=(I-A)^{-1}\triangle y}$, which means that changes in total industry output due to changes in the final demand are predicted using the Leontief inverse matrix. The column sum of $\mathbf{(I-A)^{-1}}$ is interpreted as the total changes in output from the changes in the final demand, output multipliers.

As argued, however, (output) multipliers based on the final demand approach do not completely reflect all the economic impacts from the FMD outbreaks which are considered as a "supply reduction." Leung and Pooley (2002), Fernandez-Macho, Gallastegui and Gonzales (2008), and Seung and Waters

(2009) have discussed that it is more appropriate to use a supply-driven model in situations where the output level is altered, not the final demand. In addition, Groenewold, Hagger, and Madden (1987) suggest to use the final demand-driven IO model for industries with a high ratio of final demand to output.[2] Following Leung and Pooley (2002), the standard IO model, $\mathbf{x}=\mathbf{A}\mathbf{x}+\mathbf{y}$, can be partitioned as follows

$$(1)\quad \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} y_1 \\ y_2 \end{bmatrix},$$

where a subscript "1" indicates the exogenized sectors where the supply reduction occurs, e.g., dairy cattle, beef cattle, and swine sectors, and "2" indicates the other endogenous sectors. Thus, $\mathbf{x_1}$ is a vector of outputs of the exogenized sectors, $\mathbf{x_2}$ is a vector of outputs of the endogenous sectors, $\mathbf{y_1}$ is a vector of the final demands of the corresponding exogenized sectors, and $\mathbf{y_2}$ is a vector of the final demands of the corresponding endogenous sectors. The direct requirement matrix $\mathbf{A}$ is partitioned into four sub-matrices as in equation (1) correspondingly. We obtain equation (2) by solving equation (1) for $\mathbf{x_2}$ (endogenous sectors) assuming that change in $\triangle\mathbf{y_2}$ is zero:

$$(2)\quad \mathbf{x_2}=\mathbf{(I-A_{22})^{-1}A_{21}x_1},$$

where $\mathbf{(I-A_{22})^{-1}A_{21}}$ is the "backward linkages" (Leung and Pooley, 2002). The backward linkage is "a sector's relationship with upstream sectors (suppliers) that provide goods and services used as intermediate inputs" (Seung and Waters, 2007), which measures the change in output in endogenous sectors due to change in the output of exogenized sectors. In case of the FMD outbreaks, the reduction in output in dairy cattle, beef cattle and swine sectors may reduce

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[2] FMD impacted sectors are identified as dairy cattle, beef cattle and swine sectors. Ratios of final demand (household demand + government expenditure + export + changes in inventory) to output for these sectors are relatively small (7.6%, 15.0%, and 3.0%, respectively). If only household consumption and government expenditures are considered as the final demand, ratios of the final demands to outputs are all zero. Ratios of final demands to outputs for livestock processing and dairy sectors are large (37% and 66%, respectively). In case of swine sector, the direct impact is estimated roughly 32% of the value of output, which cannot be the final demand change.

the sector's demand for inputs purchased from other sectors such as feed, manufactured items, transportation of animals, financial supports (banking service, insurance), legal services, and so on.

Following Leung and Pooley (2002) again, a similar framework can be extended to the forward linkage effects using the Ghosh model (Ghosh, 1958). The Ghosh model can be expressed as $\mathbf{x'=x'B+v}$, where **B** represents the output distribution pattern of each sector as opposed to **A**, i.e., the forward linkage (it is the column sum of the IO table). Elements in the matrix **B**, b_{ij}, are calculated as $b_{ij} = x_{ij}/x_i$. It is the allocation of a sector's output to other sectors including value-added, **v** (Leung and Pooley, 2002). Using the similar partition, the Ghosh model can be rewritten as follows:

$$(3)\quad [x'_1\ x'_2]=[x'_1\ x'_2]\begin{bmatrix}B_{11} & B_{12}\\ B_{21} & B_{22}\end{bmatrix}+[v_1\ v_2],$$

where $\mathbf{v_1}$ is a vector of value added of the exogenized sectors and $\mathbf{v_2}$ is a vector of value added of the endogenous sectors. Assumed $\triangle\mathbf{v_2=0}$, equation (3) becomes

$$(4)\quad \mathbf{x'_2=x'_1B_{12}(I-B_{22})^{-1}},$$

where the row sum of the matrix $\mathbf{B_{12}(I-B_{22})^{-1}}$ in equation (4) can be considered as the forward linkage multipliers. Seung and Waters (2009) define the forward linkages as "a sector's relationship with its downstream demanders who purchase goods and services from the exogenized sectors." In case of the FMD outbreaks, the reduction in output in dairy cattle, beef cattle and swine sectors may reduce the output of dairy procession, livestock processing (manufacturing sectors) and wholesale sectors that purchase inputs from dairy cattle, beef cattle and swine sectors.

IV. Supply Driven Economic Impacts and Implications

4.1. Direct FMD Impacts

The corresponding industrial sectors which are affected by the FMD outbreaks

are identified from the 2010 Korea Input-Output Table to estimate direct FMD impacts. Bank of Korea (2014) provides the 2010 Korea IO Table with detailed sectoral levels (384 endogenous sectors in total). Among them, three sectors, dairy cattle (sector 014), beef cattle (sector 015), and swine (sector 016), are the sectors where the supply reductions occur due to the FMD outbreaks. From the 2010 IO Table, total production of dairy cattle was 1.81 trillion Korean Won (» USD 1.63 billion), beef cattle was 4.70 trillion Korean Won (» USD 4.23 billion), and swine was 4.86 trillion Korean Won (» USD 4.38 billion).

Direct FMD impact is basically the cumulative number of animals depopulated. KREI (2011) estimates the direct supply reduction in the swine sector to be 31.98% of the total value of swine production, while the direct supply reductions in dairy cattle and beef cattle sectors to be 8.73% and 3.90% of the total value of dairy cattle and beef cattle production, respectively (KREI, 2011, p. 283). Thus, direct FMD impacts are estimated to be 1.89 trillion Korean Won (» USD 1.70 billion).[3]

4.2. Aggregated 2010 Input-Output Table

The Korean economy is constructed to 18 aggregated sectors from 384 disaggregated (endogenous) sectors. While most of sectors are highly aggregated, those sectors assumed impacted by the FMD outbreaks, e.g., dairy cattle (sector 014), beef cattle (sector 015), and swine (sector 016) sectors are broken out in detail. In addition, the poultry sector, dairy sector, livestock processing sector and feed sector are also broken out in detail that might be vulnerable to the event of the FMD outbreaks. Table 1 contains the aggregation of industries with description. As seen in Table 2, the gross regional product (sum of total value added or GDP) was 1,182 trillion Korean Won (» USD 1.06 trillion) in 2010. Major sectors include manufacturing and FIRES (finance, information, real estate, education, and other services).

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[3] 1.890 trillion Korean Won = % reduction × total value of production in each sector = 8.37%×1.8065 trillion + 3.09%×4.7012 trillion + 31.98%×4.8637 trillion.

Table 1. Aggregation for Economic Sectors in Korea

Sectors in this study	IO sectors (384 sectors)	Description
Agriculture, forestry, and fishery	001-013, 019-025	Grain, fruit & vegetable, forestry, fisheries, Agr. service
Dairy cattle	014	Dairy cattle
Beef cattle	015	Beef cattle
Swine	016	Swine
Poultry	017	Poultry
Other livestock	018	Other livestock
Mining	026-034	Coal, oil, gas, minerals
Livestock processing	035-037	Slaughter, meat processing
Dairy	038,039	Dairy, milk
Feed	055	Feed
Manufacturing	040-054,056-273	Food manufacturing, wood and paper, beverages, textiles, petroleum, coal products, chemical, rubber, plastic, ferrous metals, motor vehicles, transportation & electricity equipment, machinery
Utility	274-286	Electricity, gas distribution, water, waste
Construction	287-301	Construction
Whole and retail sales	302,303	Wholesale, retail service
Transportation	304-317	Transportation
Accommodation and restaurant	318-321	Restaurant, accommodation
FIRES[1]	322-345, 347-359, 363, 364, 366, 367, 370, 372-384	Finance, communication, real estate, leasing, administration, private health, private education, business services, insurance, other services
Government	346, 360-362, 365, 368, 371	Government service (defense), public education, public health

1 FIRES = finance, information, real estate, education and (other) services

Table 2. Aggregated Sectors in Korea

(unit: billion Korean Won)

Sectors	Output	Total value added[2]
Agriculture, forestry, and fishery	36,203	23,795
Dairy cattle	1,807	807
Beef cattle	4,701	1,484
Swine	4,867	1,182
Poultry	4,661	1,006
Other livestock	733	439
Mining	3,788	2,218
Livestock processing	16,114	1,006
Dairy	6,309	1,475
Feed	8,775	1,109
Manufacturing	1,541,979	343,399
Utility	92,284	29,476
Construction	180,179	60,447
Whole and retail sales	196,497	103,745
Transportation	129,513	49,440
Accommodation and restaurant	82,022	33,339
FIRES[1]	678,652	412,067
Government	155,322	115,180
Total	3,144,403	1,181,615

1 FIRES = finance, information, real estate, education and (other) services

2 Total value added = sum of employment compensation, proprietor income, capital depreciation, and indirect business tax

4.3. Supply Driven Output Multipliers

Using equations (2) and (4), supply driven output multipliers, backward and forward linkages effects, are estimated and reported in Table 3. The backward linkage is "a sector's relationship with upstream sectors (suppliers) that provide goods and services used as intermediate inputs" (Seung and Waters, 2007), which measures the change in output in endogenous sectors due to change in the output of exogenized sectors. As in Table 3, in case of the FMD outbreaks, the reduction in output in the dairy cattle sector, beef cattle sector, and swine sector may reduce the sector's demand for inputs purchased from other sectors, especially from feed and manufacturing sectors. Also agriculture, whole and retail sales, and FIRES sectors have the strong backward linkage impacts (Table 3).

Table 3. Backward and Forward Linkage Multipliers (Coefficients)

	Backward linkage Multipliers			Forward linkage Multipliers		
	Dairy Cattle	Beef Cattle	Swine	Dairy Cattle	Beef Cattle	Swine
Agr, forestry, and fishery	0.087	0.087	0.062	0.005	0.015	0.007
Poultry	0.001	0.001	0.001	0.001	0.002	0.002
Other livestock	0.000	0.000	0.000	0.000	0.000	0.000
Mining	0.001	0.001	0.003	0.000	0.000	0.000
Livestock processing	0.006	0.008	0.010	0.014	0.863	1.002
Dairy	0.005	0.001	0.001	0.947	0.001	0.001
Feed	0.328	0.463	0.572	0.002	0.004	0.005
Manufacturing	0.185	0.233	0.234	0.101	0.141	0.160
Utility	0.032	0.034	0.038	0.001	0.004	0.004
Construction	0.004	0.002	0.002	0.005	0.014	0.016
Whole and retail sales	0.104	0.138	0.165	0.012	0.035	0.040
Transportation	0.055	0.068	0.081	0.003	0.009	0.011
Accmd & restaurant	0.010	0.013	0.016	0.170	0.305	0.352
FIRES[1]	0.109	0.120	0.137	0.048	0.139	0.160
Government	0.001	0.001	0.001	0.009	0.021	0.025
Sum	0.929	1.170	1.323	1.318	1.554	1.787

1 FIRES = finance, information, real estate, education and (other) services

The forward linkage is the relationship with its downstream demanders who purchase cattle and swine for further processing (Seung and Waters, 2007). As in Table 3, in case of the FMD outbreaks, the reduction in output in the dairy cattle sector, beef cattle sector, and swine sector reduces the output of livestock processing, dairy production, manufacturing, and accommodation and restaurant sectors. Also, like backward linkage, the FIRES sector has the strong forward linkage impacts (Table 3).

Table 4 displays the comparison of the supply-driven multipliers with the standard final demand-driven output multipliers. As shown in Table 4, the supply-driven multipliers are larger than the final demand-driven multipliers. The final demand-driven multipliers are calculated directly from the 2010 Korea IO table. The difference between the supply-driven and the final demand-driven multipliers comes from the different impacts on livestock processing and dairy sectors, especially from forward industry linkages (See Tables 3 and 4).

Table 4. Comparison of Backward and Forward Multipliers with Standard Demand-based IO Multipliers (Coefficients)

	Sum of Backward and Forward Multipliers			Standard Demand-based IO Multipliers		
	Dairy Cattle	Beef Cattle	Swine	Dairy Cattle	Beef Cattle	Swine
Agr, forestry, and fish	0.092	0.102	0.069	0.088	0.088	0.063
Poultry	0.001	0.002	0.003	0.001	0.001	0.001
Other livestock	0.000	0.000	0.000	0.000	0.000	0.000
Mining	0.001	0.001	0.003	0.001	0.001	0.003
Livestock processing	0.020	0.871	1.013	0.006	0.008	0.011
Dairy	0.952	0.001	0.002	0.005	0.001	0.001
Feed	0.330	0.467	0.577	0.333	0.467	0.574
Manufacturing	0.286	0.374	0.394	0.032	0.034	0.038
Utility	0.033	0.038	0.042	0.004	0.002	0.002
Construction	0.009	0.017	0.018	0.106	0.139	0.166
Whole and retail sales	0.116	0.173	0.206	0.046	0.055	0.066
Transportation	0.059	0.077	0.092	0.010	0.014	0.016
Accmd & restaurant	0.180	0.319	0.368	0.111	0.121	0.137
FIRES[1]	0.158	0.259	0.297	0.001	0.001	0.001
Government	0.010	0.022	0.025	0.001	0.001	0.001
Dairy cattle	1.000			1.004	0.000	0.000
Beef cattle		1.000		0.006	1.006	0.002
Swine			1.000	0.001	0.002	1.003
Sum	3.247	3.724	4.110	1.942	2.174	2.319

1 FIRES = finance, information, real estate, education and (other) services

The regional economic impact of 2010-2011 FMD outbreaks in Korea is computed using the coefficients in Table 3 with direct impacts calculated in section 4.1. As shown in Table 5, livestock processing, feed, and manufacturing sectors are most damaged sectors. All told, total indirect impact (impacts on other industries) is estimated to be 5.68 trillion Korean Won (» USD 5.11 billion) and the total impact to be 7.57 trillion Korean Won (» USD 6.81 billion). If one used the final demand-driven multipliers in assessing the impact of the FMD outbreaks, the economy-wide impact would have been 4.30 trillion Korean Won (»USD 3.87 billion), which is consistent with KREI (2011) esti-

mate and much smaller. This is because the standard IO approach emphasizes the direct requirements of impacted sectors (mostly backward linkage) and doesn't include the forward linked sectors such as dairy and livestock processing. Note that the index of the sensitivity of dispersion from the standard IO model measures the impact of forward linkage but it is the measurement of the increase in the production of the industry driven by changes in the final demand for all industries in the system (Rasmussen, 1956; Vom Hofe and Bhatta, 2007; Bank of Korea, 2014), which is very different from the forward linkage impact in the supply-driven IO model.

If the closed form of IO Table or the extended Social Accounting matrix model are given, the induced impact (impacts on value added) and impacts on households can be estimated using equations (2) and (4), too.

Table 5. Direct and Indirect Impacts of 2010-2011 FMD Outbreak in Korea

(unit: billion Korean Won)

Sectors	Dairy Cattle		Beef Cattle		Swine		Total
Direct impacts	151.21		183.35		1,555.42		1,889.97
Impact on industries	Backward	Forward	Backward	Forward	Backward	Forward	
Agr, forestry, and fish	13.20	0.69	15.98	2.72	96.78	10.92	140.29
Poultry	0.09	0.08	0.14	0.29	1.42	2.81	4.83
Other livestock	0.02	0.01	0.03	0.02	0.23	0.19	0.49
Mining	0.11	0.02	0.15	0.06	4.25	0.55	5.13
Livestock processing	0.91	2.05	1.54	158.14	16.27	1559.19	1738.09
Dairy	0.72	143.24	0.11	0.16	1.87	1.54	147.65
Feed	49.64	0.24	84.87	0.82	888.93	8.06	1032.56
Manufacturing	27.99	15.31	42.68	25.92	364.00	249.33	725.24
Utility	4.85	0.20	6.23	0.69	58.99	6.79	77.76
Construction	0.67	0.73	0.44	2.60	3.16	25.45	33.05
Whole and retail sales	15.75	1.86	25.22	6.43	256.88	62.87	369.02
Transportation	8.36	0.50	12.45	1.70	126.48	16.65	166.13
Accmd & restaurant	1.49	25.65	2.46	55.99	24.26	547.96	657.82
FIRES1	16.52	7.33	22.09	25.48	212.66	249.02	533.09
Government	0.17	1.31	0.12	3.91	1.06	38.36	44.92
Total indirect impacts (not including direct effects)	140.48	199.23	214.51	284.93	2,057.25	2,779.70	5,676.09
Total impact (including direct effects)							7,566.06

V. Concluding Remarks

The standard IO analysis based on the final demand approach may not completely reflect all the economic impacts from the FMD outbreaks because the FMD outbreaks alter the production levels in impacted sectors directly. It is more appropriate to use a supply-driven model than the (final) demand-driven IO model in situations where the supply reduction occurs as in the FMD case in Korea. Using the supply-driven IO multipliers both backward linkage and forward linkage effects of the FMD outbreaks are measured for the 2010-2011 FMD outbreaks in Korea.

As expected, the 2010-2011 FMD outbreaks have caused severe economic implications. This study shows that backward linkage effects in feed and manufacturing sectors and forward effects in dairy and livestock processing sectors are strong. Total indirect impact (impacts on other industries) is estimated to be 5.68 trillion Korean Won (» USD 5.11 billion) and the total impact to be 7.57 trillion Korean Won (» USD 6.81 billion), which is much larger compared to the total impact from the standard IO analysis, 4.30 trillion Korean Won. This is because the standard IO analysis fails to capture the forward industry linkages such as dairy and livestock processing sectors.

The total impact of the FMD outbreaks was severe in Korea, which is the similar to the conclusions from other past FMD studies. Pendell et al. (2007) point out, "…research on FMD has drawn the same general conclusion; an FMD outbreak has severe economic implications…" (Pendell et al., 2007, p 29). Differing from past studies, on the other hand, this study explains how to apply the supply-driven IO analysis on the FMD outbreaks and shows that the total economic impact is much larger than the damage from the standard IO analysis.

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