Asian Journal of Agricultural Extension, Economics & Sociology
17(1): 1-17, 2017; Article no.AJAEES.33022
ISSN: 2320-7027

SCIENCEDOMAIN *international*
www.sciencedomain.org

Sustainable Productivity Growth in Philippine Swine Production

Maria Angeles O. Catelo[1*]

[1]*Department of Economics, College of Economics and Management, University of the Philippines Los Baños, Laguna, Philippines.*

Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/AJAEES/2017/33022
Editor(s):
(1) Jurislav Babic, Faculty of Food technology, University of Osijek, Croatia.
Reviewers:
(1) Oluyemi Adeleye, Development Resource Initiative Kaduna, Nigeria.
(2) Juliet Libanda, Jiangsu University of Science and Technology, China.
Complete Peer review History: http://www.sciencedomain.org/review-history/18903

Original Research Article

Received 27th March 2017
Accepted 28th April 2017
Published 4th May 2017

ABSTRACT

Few published papers have taken the undesirable input effects in productivity change analysis particularly in swine production of developing countries in which it is a major economic activity and a potential pathway for poverty reduction. Untreated and improperly disposed swine waste can lead to environmental degradation such as groundwater pollution and nitrous oxide emission from the soil. These environmental impacts occur because of huge nutrient surpluses of nitrogen and phosphorus in the soil and increased biological oxygen demand in the wastewater. As green growth initiatives are being promoted in the context of improving swine productivity growth sustainably, there is urgent need to consider these unpriced environmental impacts. The objective of this paper is to clarify if swine farm productivity growth has become environmentally sustainable in a developing country like the Philippines. The Environmentally Sensitive Malmquist Productivity Index (ESMPI) is applied to a balanced panel dataset involving 40 small-scale and commercial swine farms in the top swine-producing regions of Central Luzon and Southern Luzon for the years 2002 and 2015. The results of the estimations show that only 12 or less than one-third of the 40 swine farms experienced productivity growth at the frontier. Their ESMPIs ranged from 1.001 to 1.642 with a mean of 1.151, implying an increase in the environmentally sensitive productivity growth between 2002 and 2015. Such increases were largely due to efficiency rather than technological improvements. For majority of the swine farms, however, productivity growth, inclusive of environmental impacts, has declined.

**Corresponding author: E-mail: mocatelo@up.edu.ph;*

Keywords: Green growth; swine farms; environmentally sensitive Malmquist productivity index; Philippines.

1. INTRODUCTION

In 2009, the Organization for Economic Co-operation and Development (OECD) laid the groundwork for green growth [1] as a global strategy for dealing with some of the world's most daunting challenges: an escalating world population that is projected to grow to 9.3 billion by 2050, the required annual growth of an additional one billion tons of cereals and 200 million tons of meat in order to feed that population, and meet the current daily 3,130 kcal per capita average food consumption (UN 2010 and Bruinsma 2009 as quoted in [2]).

Green growth involves an "actionable framework that fosters conditions for investment, innovation, and competition that give rise to new sources of economic growth consistent with resilient ecosystem." It is "growth that not only helps green economies, but also helps move towards sustainable development by ensuring that environmental sustainability contributes to, or at least does not come at the expense of, social progress" [3]. In a nutshell, the move toward growing green implies three requisites: low carbon or pollution, resource efficiency, and social inclusion [4].

The motivation for green growth particularly in the global livestock sector comes into play as a cross-cutting priority especially for emerging and developing countries where much, if not all, of the world's population expansion is expected to occur. Furthermore, the increased demand for meat will create significant pressure upon scarce natural resources that are particularly used in the sector.

Thus, agriculture in general, but the livestock sector in particular, faces significant challenges in implementing the green growth strategy. This is because alongside important windows of opportunities especially for smallholder livestock producers, new perils such as environmental pollution and health risks have emerged [5,6]. At the same time, reservations arise as to whether there is still room for agricultural productivity to increase, where it is most desired, and the role that small-scale farming will play in the future if any. These doubts are expressed in recognition that increasing agricultural productivity seems to be the "single most important determinant of economic growth and poverty reduction" [2] which are also the elements of pursuing green growth.

Now, just like many developing and emerging countries in Asia (e.g., Vietnam, Cambodia, Lao PDR), the swine sector in the Philippines, which is still prevalently small-scale, is a vital source of economic growth. This is because pork is an important source of animal protein and demand for pork has historically been increasing with an annual per capita consumption of 15.07 kg [7]. Moreover, the share of pork in meat production has been maintained at 55% for more than two decades or between 1990 to 2016 [8]. In 2016, the sector's output was valued at USD 4.4 billion and its contribution to the gross value added in agriculture (GVAA) was estimated at 13.8%, which was second to the share of paddy rice. This share in GVAA has also been consistent over the past two decades. The swine sector predominates in both volume and value of livestock production with about 80% share and growing at an average annual rate of 3% between 1990 and 2016 and at 6.5% rate for the first half of 2016 [8]. But despite being recognized by the World Organization for Animal Health (OIE) as foot-and-mouth-disease (FMD)-free without vaccination since 2011, the country's pork exports are nil because domestic production in recent years has not been adequate to supply domestic needs. Self-sufficiency in pork seems to be gradually slipping from 98% in 2000 to only 92 % in 2013 [8]. Some disease outbreaks also occurred during this period which were aggravated by rising fuel and feed costs and, hence, the country had to increase its importation of pork in order to meet growing demand.

An additional economic benefit from swine production is its potential for social inclusion since 43% of the four million Filipinos in the agriculture sector continue to be employed by this sector. In particular, 64% of the 12.5 million swine inventories in 2016 were produced by backyard or smallholder producers [8]. By 2022 and 2027, per capita pork consumption is projected to grow to 15.6 kg and 16.4 kg per year, respectively. In order to support this projected increase in per capita consumption, the 2016 swine population of 12.5 million heads will have to grow by at least 10 percent to reach 13.72 million heads by 2027 [9]. Although the share of smallholder swine producers in terms of animal population has been slowly decreasing from 80% in 2000 due to the intensification or commercialization of swine production, they are still considered the backbone of rural economies, and because of this, they should be supported especially with respect to increasing their productivity growth sustainably.

The swine sector in the Philippines is also ranked eighth in the world in terms of volume of production or carcass equivalent [10]. It is consistently the second most important contributor to the value of agricultural production in the Philippines [8]. Being also the largest subsector of the livestock and poultry industries of the country, it plays a major role in achieving national food security and providing employment and income opportunities particularly to smallholder producers. As a very important agricultural subsector, with vital forward and backward linkages, the economic, environmental, and social impacts of neglecting the productivity growth of swine production and its environmental ramifications will definitely be immense.

But despite the aforementioned benefits that the economy derives from the swine sector, swine production is not environmentally sustainable as corroborated by [6,11,12,13]. This is because it uses the environment as an input or waste sink which consequently results in water (and even air) pollution. For instance, nitrogen and phosphorus loading from swine manure and rising biological oxygen demand (BOD) in the wastewater can contribute to groundwater pollution as well as nitrous oxide emission from the soil [6]. Aggravating the situation is the non-point source nature of pollution that is contributed by backyard swine farms who constitute the greater majority of swine producers in the Philippines. Thus, to be able to determine whether the swine sector is developing along the green growth path, it is necessary to first measure the productivity growth of the sector. Specifically, an assessment of the productivity growth in the swine sector that incorporates environmental impacts is imperative. If we ignore undesirable input effects in efficiency analysis, this could bring about misleading results [14].

Having set the background and motivation of this study, the main objective of this paper is to clarify if swine productivity growth in the Philippines has become environmentally sustainable. The research questions that the paper addresses are as follows:

(1) What is the influence of incorporating environmental impacts on measured productivity growth in swine production?
(2) What is the nature and extent of productivity growth and efficiency in swine production?

The rest of the paper is organized as follows: Section 2 gives an overview of the data sources and methodology. Section 3 presents the results and discussion and Section 4 provides the conclusion and implications based on empirical findings. Section 5 offers some recommendations arising from the findings of the study.

2. METHODOLOGY

Very few published papers have taken the undesirable input effects in productivity change analysis particularly in the livestock sector of developing countries [14]. The literature of using the Malmquist Total Factor Productivity (TFP) Index that is adjusted for environmental impacts in agricultural studies is also rather limited, although it has been fairly recently extended and applied in other fields such as in [15,16] and [17]. Highlights of the very limited studies that were done in the international literature on the use of this particular approach and the tracing of significant efforts that have been made are given by [16] and [17]. The first study that investigated the effect of including four environmental impacts on productivity growth of US agricultural sector and derived a set of marginal abatement elasticities for these four environmental indicators is [14] [1]. They constructed an environmentally sensitive Malmquist TFP index because 'environmental impacts cannot be incorporated into the more commonly used Fisher or Törnqvist productivity indexes without price information that will be used to weight the impacts'. Environmental impacts are generally non-marketed and thus, do not have prices. On the other hand, [18] developed a new measure of TFP growth that satisfies the materials balance condition which, accordingly, was the main criticism against earlier studies that traditionally modeled environmental effects as "either a bad output or an environmentally detrimental input in production models." The nutrient-oriented TFP (NTFP) index which is a Malmquist productivity index that is adjusted for environmental impacts

[1] *These four environmental indicators include risk to human health from exposure to pesticide leaching, risk to human health from exposure to pesticide runoff, risk to aquatic life from exposure to pesticide leaching and risk to aquatic life from exposure to pesticide leaching [14].*

was conducted by [18]. They applied this to the agriculture sector of 28 OECD member countries for the years 1990 to 2003.

In the domestic arena, there are studies that have investigated the total factor productivity (TFP) growth in the Philippine agriculture. A comprehensive account of these past applications between the years 1980 to 2005 which were mostly estimated at the national or aggregate level using growth accounting and econometric approaches was presented by [19]. On the other hand, [20] estimated TFP growth in the Philippine agriculture sector using the Törnqvist index number approach. Moreover, [7] used the stochastic frontier approach that estimated a Cobb-Douglas production function to analyze TFP in the Philippine swine sector using balanced panel data of 27 swine farms for the years 2002 and 2008. However, none of these studies reviewed so far included environmental impacts in their TFP analysis. Thus, this paper contributes to the literature on using the Malmquist Productivity Index (MPI) in three ways: 1) It attempts to incorporate undesirable inputs into productivity change measurement by introducing new environmental factors or emission variables such as the Biological Oxygen Demand (BOD) and Nitrogen and Phosphorus loadings from swine waste; 2) Among the past empirical studies that were reviewed in this paper, this is the first to apply the Malmquist Productivity Index that incorporates environmental impacts as they affect productivity growth over time to a balanced panel data in a developing country setting; it also has a four-category comparison of swine farms according to scale and production arrangement[2], i.e., i) small independent farms, ii) small contract farms, iii) commercial independent farms, and iv) commercial contract farms. This has not been done in the literature[3] but was suggested by [22] and [7] who used the 2002 survey of swine farms as baseline; and 3) No micro-level study has yet investigated this aspect and none so in the context of green growth. As [23] put it, there is a dearth of empirical studies of productivity growth in the Philippine agriculture, especially those that focus on commodity-specific productivity growth. While agricultural productivity studies that make use of the econometric approach is desirable, there are constraints in the Philippine agricultural database systems (which may also be the case for many developing countries) and, thus, the use of the Data Envelopment Analysis (DEA)-based Malmquist productivity index approach can address some of these data constraints. In addition, more researches are needed to fill this critical gap in the existing literature in order to provide scientific-based evidence to “support the design of a productivity-oriented strategy to rejuvenate Philippine agriculture” [23].

2.1 Data Sources

The original intent of this paper is to use the parametric approach to measure productivity growth in the swine sector. The parametric empirical approach, among other advantages, allows for the derivation of the productivity measurement and its causal factors using only a one-step procedure that typically involves fitting parameters into a system of equations [19].

However, the parametric approach is very strict with respect to data requirements as compared to non-parametric approaches. As [7]) also point out, there are no time series data on farm inputs for the swine sector in the Philippines that could complement the time series data on output, both of which could be used for productivity growth estimation. The best alternative then is to estimate productivity growth over two periods. So far, the only systematic and comprehensive data set on swine production that has been collected is the survey that was done by [21] in 2002 on 100 backyard (small farms) and commercial swine farms in the top two swine-producing regions in the Philippines: Central Luzon and South Luzon. In order to determine the growth in productivity of swine farms over two periods, a verification survey on the continued existence of swine farms and respondent households that were interviewed in period 1, i.e., in 2002, was conducted by the author from May to July 2015 using the same instrument as that in the 2002 survey. However, only 40 out of the target 100 original respondent households in Central Luzon and South Luzon were still around and still

[2] A small swine farm is defined by the Bureau of Agricultural Statistics (BAS) as one that holds not more than 20 head of pigs in adult-equivalent. However, the 2002 and 2015 surveys did not make this restriction but put a greater emphasis on the criterion of swine production being household-based, that is, using mainly household's resources such as land, labor, and capital [21]. Thus, in the implementation of the survey, this study categorized small swine farm as having an inventory of 1-99 animals. A commercial swine farm has 100 or more animals in its inventory. The sample swine farms were further categorized by type of production arrangement, i.e., whether the farms were operated by independent growers or by contract growers.

[3] [7] attempted to estimate TFP in swine production using panel data but their results were rather inconclusive and did not include environmental impacts.

raising pigs. Twenty-nine (29) of the original sample households cannot be identified by the respective Offices of the Municipal Agriculturist, 18 have exited from swine production, and 13 were not available during the time of survey. The 40 respondent households from period 1 (2002) and period 2 (2015) now form the balanced panel data set of this study. Admittedly, this sample size of a panel of 40 observations for two periods may not be sufficient for a parametric approach to measuring and explaining productivity growth. Thus, the author resorted to the use of the non-parametric approach that incorporates environmental impacts.

2.2 Analytical Procedure

As will be recalled, the more commonly used Törnqvist productivity index requires price data and cannot include environmental impacts that are usually non-marketed and non-priced [14]. Hence, this study makes use of the conventional Malmquist productivity index (CMPI) as the "benchmark scenario' and the environmentally sensitive Malmquist productivity index (ESMPI) as the 'comparison scenario" following [14][4] .

The DEA-based CMPI is defined using 'input and output distance functions that permit the designation of a multi-input, multi-output production technology even without specifying whether producers aim for cost minimization or profit maximization' [24]. It involves the construction of an efficiency frontier with respect to the technology of the initial period and using input and output data over the whole panel data of 40 swine producers that are considered as the decision-making units (DMUs). Then, the distance of individual observations (distance functions) from the frontier are computed for two data points, in this case, for the year 2002 (the base period, t) and for 2015 (period 2, t+1). Underlying these (hyperbolic) distance functions is a production function or benchmark technology against which the productivity growth is calculated. The constant returns to scale, other similar restrictions, and assumptions imposed on the benchmark technology follow those of Färe, Grosskopf, and Lovell (1985) as quoted in [14].

The environmental impacts arising from swine production are incorporated and treated as an additional input vector since the environment is asserted to serve as waste sink into which swine producers dispose of the non-marketed 'environmental by-products'. As such, the conventional distance functions are modified to reflect the addition of this environmental impact vector. Furthermore, the modified conventional distance functions now correspond to the environmentally sensitive (hyperbolic) distance functions from which the environmentally sensitive (hyperbolic) Malmquist productivity index (ESMPI) can be derived.

The conventional Malmquist productivity index (CMPI) is presented as:

$$CMPI\ (x^t, y^t, x^{t+1}, y^{t+1}) = \{[DC^t_{CMPI}\ (x^{t+1}, y^{t+1})] / [DC^t_{CMPI}\ (x^t, y^t)]\}^{2} \quad (1)$$

Where:

- x - input vector
- y - output vector
- DC - distance function
- t - base period, period 1
- t+1 - period 2

It is noted here that the hyperbolic distance functions, DC^t_{CMPI}, also provide a 'natural index of technical efficiency' of period t+1 data relative to period t benchmark technology. The ratio of the respective distance functions gives the conventional hyperbolic Malmquist productivity index. Moreover, in order to avoid problems in choosing the benchmark, the CMPI is specified as the geometric mean of the two distance function indexes [14]. Expanding Equation 1 gives the following:

$$CMPI\ (x^{t+1}, y^{t+1}, x^t, y^t) = \{[DC^{t+1}_{CMPI}\ (x^{t+1}, y^{t+1})] / [DC^t_{CMPI}\ (x^t, y^t)]\} \bullet$$

$$\{[DC^t_{CMPI}\ (x^{t+1}, y^{t+1})] / [DC^{t+1}_{CMPI}(x^{t+1}, y^{t+1})] \bullet [DC^t_{CMPI}\ (x^t, y^t)] / [DC^{t+1}_{CMPI}\ (x^t, y^t)]\}^{0.5} \quad (2)$$

If CMPI is >1, this implies that the swine farm is efficient, improving its productivity over time; If CMPI < 1, then productivity is decreasing over time and the swine farm is inefficient. If CMPI =1, then productivity of the swine farm has not changed or has stagnated.

The environmentally sensitive Malmquist productivity index (ESMPI) is similar to the CMPI but with the inclusion of the input vector of environmental impacts, z, as follows:

$$ESMPI\ (x^{t+1}, y^{t+1}, z^{t+1}, x^t, y^t, z^t) = \{[DC^{t+1}_{ESMPI}\ (x^{t+1}, y^{t+1}, z^{t+1})] / [DC^t_{ESMPI}\ (x^t, y^t, z^t)]\} \bullet$$

[4] *The analytical procedure in this section draws heavily from [14]. Readers are referred to this material for the intricate details and assumptions of constructing the environmentally sensitive Malmquist productivity index.*

$$\{[DC^{t}_{ESMPI}(x^{t+1},y^{t+1},z^{t+1})]/[DC^{t+1}_{ESMPI}(x^{t+1},y^{t+1},z^{t+1})]\bullet[DC^{t}_{ESMPI}(x^{t},y^{t},z^{t})]/[DC^{t+1}_{ESMPI}(x^{t},y^{t},z^{t})]\}^{0.5} \quad (3)$$

If the value of ESMPI is >, = , or < 1, then it implies that between the two periods (t and t+1), there has been increasing, stagnating, or decreasing productivity, respectively, inclusive of environmental impacts.

Table 1. Description of variables used for CMPI and ESMPI

Variable	Description
Output (Y_i)	Total weight of pigs sold and unsold (kg) per cycle
Inputs (X_i)	
Feeds	Feeds purchased per cycle (kg)
Labor	Labor (total number of hired, operator and family labor $cycle^{-1}$)
Water	Water used per cycle (in liters)
Capital investment	
Housing	Animal housing and storage facilities (in m^2)
Waste facilities	Biogas digesters and lagoons (in m^2)
Land	Size of cropland for manure application (in ha)
Environmental impacts (Z_i)	
BOD	Biological oxygen demand (kg $cycle^{-1}$); computed in equivalencies per animal unit
Nitrogen Loading	Nitrogen loading (kg) from waste, computed as net loading dependent on capacity of facilities to assimilate animal waste
Phosphorus Loading	Phosphorus loading (kg) from waste, computed as net loading dependent on capacity of facilities to assimilate animal waste

It is further noted that for both the conventional and environmentally sensitive MPIs, the term in the first square bracket measures the efficiency change between the two periods (t and t+1), while the term in the second square bracket measures the technical change. Thus, the Malmquist productivity index is also the product of efficiency change and technical change.

Efficiency change reflects the capability of swine farms in 'catching up' with efficient ones between the periods 2002 and 2015. Technical change measures the shift in the technology frontier between the periods 2002 and 2015 that may come from technology improvements which in turn can arise from increased public investments in agricultural research, development, and extension [23]. It can also come from increased innovation through the adoption of technologies that contract environmental impacts along with purchased inputs and expand marketed outputs.

2.3 Description of Variables

Table 1 presents output, input, and environmental impact indicators used to construct the conventional and environmentally sensitive Malmquist productivity indexes in the study.

3. RESULTS AND DISCUSSION

3.1 Description of Variables

Table 2 shows that 32 (80%) out of the 40 swine farms were managed by independent producers and only eight swine farms (20%) were contract swine farms. Scale-wise, the proportion of small farms (52%) is almost equal to that of large or commercial swine farms (48%) in the sample. The results of the analysis of variance (ANOVA) tests indicate that there are significant differences in the means of the output and input variables among the four categories of swine farms particularly for the period 2015.

In the previous section, the Malmquist productivity indexes were defined relative to a reference technology for the periods 2002 and 2015 and also adjusted for environmental impacts. With this information, the measurement of productivity growth over the two periods is decomposed into efficiency change (the 'catching-up' effect) and technical change (the 'frontier shift' effect). Table 2 gives the details of the variables that were used in constructing the indexes of productivity growth, efficiency change, and technical change for each category of swine farm. In general, marketed output and important inputs such as feeds, labor, and water have decreased between the periods 2002 and 2015. Consequently, it is expected that a conventional productivity index would show decrease in productivity growth at the aggregate level. This aggregation, however, may not show an inter-farm variation and some farms may actually exhibit a productivity growth.

Table 2. Data summary statistics of output and input variables, by category of swine farms

Variables	Small independent (n=19)	Small contract (n=2)	Commercial independent (n=13)	Commercial contract (n=6)	Grand average (n=40)	ANOVA F-value
Output (kg) 2002	5,591	4,528	12,322	21,587	10,125	1.40
Output (kg) 2015	718	2,462	7,072	15,904	5,148	4.18***
Feeds (kg) 2002	18,408	9,855	21,335	43,467	22,690	0.62
Feeds (kg) 2015	1,518	7,198	13,883	35,190	10,871	6.78***
Labor 2002	4	5	8	5	5	2.24*
Labor 2015	2	1	8	4	4	9.05***
Water (liters) 2002	27,612	14,783	32,003	65,201	34,036	0.62
Water (liters) 2015	2,277	10,797	20,824	52,785	16,307	6.78***
Housing (m^2) 2002	333	68	872	314	492	0.72
Housing (m^2) 2015	34	899	1,183	384	503	4.34***
Land (has.) 2002	0.37	0.88	0.75	0.41	0.52	1.34
Land (has.) 2015	0.47	1.25	1.37	2.66	1.13	9.05***
Waste Facility (m^2) 2002	15	9	83	193	64	1.28
Waste Facility (m^2) 2015	13	9	107	74	53	3.00***

*Note: ***, **, * mean significant at 1%, 5%, and 10% probability levels, respectively*
Sources: 2002 data from [21]; 2015 data from 2015 field survey by the author

Table 3. Environmental indicators, 2002 and 2015, by category of swine farms

Indicator	Small independent (n=19)	Small contract (n=2)	Commercial independent (n= 13)	Commercial contract (n=6)	Grand average (n=40)	ANOVA F-value
BOD (kg) 2002	2,662	557	7,652	4,150	4,402	1.17
BOD (kg) 2015	696	9,018	5,636	3,632	3,158	6.64***
Nitrogen Loading (kg) 2002	861	605	2,210	1,329	1,357	1.85
Nitrogen Loading (kg) 2015	356	501	2,158	1,293	1,089	5.27***
Phosphorus Loading (kg) 2002	383	287	1,110	430	622	1.42
Phosphorus Loading (kg) 2015	95	276	1,017	1,212	571	4.08***

*Note: *** means significant at 1% probability level.*
Sources: 2002 data from [21]; 2015 data from 2015 field survey by the author

On the other hand, Table 3 above shows the generally declining trend of the three environmental impact indicators at the aggregate level. However, there is a divergent path of the environmental impact indicators among swine farm categories which makes it difficult to establish an expected relationship between conventional and environmentally sensitive Malmquist productivity indexes.

3.2 Results of the Conventional Malmquist Productivity Index (CMPI) and Environmentally Sensitive Malmquist Productivity Index (ESMPI) Estimations

To reiterate from the Introduction section of this paper, the motivation to move along the green growth path particularly in the livestock sector of developing countries is a cross-cutting priority. But livestock production causes environmental impacts and conventional measures of productivity growth do not include these. Thus, this paper estimates an environmentally sensitive Malmquist productivity index (ESMPI) for swine production and then compares it with an estimated conventional Malmquist productivity index (CMPI) so that the influence of incorporating environmental impacts on measured productivity growth in swine production can be determined. The nature and extent of productivity growth and efficiency in swine production can also be determined from the comparison of the results of the ESMPI and CMPI estimations. In general, if the CMPI is greater than ESMPI, then the conventionally measured productivity growth is said to be overstated because the environmental impacts such as increases in the BOD level in the wastewater of swine farms as well as increases in the nitrogen (N) and phosphorous (P) loadings from swine manure have not been included. In the same manner, if the CMPI is less than the ESMPI, then this means that productivity growth is understated by a conventional MPI since the reductions in the Biological oxygen demand (BOD) level in the wastewater from swine farms and the reductions in the N and P loadings arising from the use of waste treatment facilities by swine farms have not been accounted for.

Table 4 presents the aggregate results of estimating productivity growth based on a panel data of the 40 swine farms for the periods 2002 and 2015 using the CMPI and the ESMPI. The results are arranged in ascending order of the CMPI.

The over-all geometric mean of CMPIs for the entire sample is only 0.88 which is less than 1.0. This implies that, on the average, the conventional productivity growth of swine farms, as a group, has decreased between the periods 2002 and 2015. Table 5 presents the average values of the CMPIs by category of swine farms. The CMPIs are also decomposed into the conventional efficiency change (CEC) and the conventional technical change (CTC). Although there are absolute differences in the average levels of the CMPIs and their components, these differences are not statistically significant across categories of swine farms.

At the individual swine farm level, however, the conventional productivity growth rates vary from a range of 0.1% to 52.3% but only 12 of the 40 swine farms (30%) had the increase in productivity between the periods 2002 and 2015. These are Farm Nos. 29 to 40 in Table 4. A comparison of the average (or mean) levels of CMPI, CEC, and CTC of these top 12 swine farms with those of the rest of the 40 swine farms would show significantly higher levels for the 12 swine farms (Table 6).

A further look into the salient output and input characteristics of these top 12 swine farms that achieved the increase in conventional productivity growth is given by Table 7. Of these top 12 swine farms, five (5) or 42% are small independent farms, three (3) or 25% are commercial independent farms, two (2) are small farms under contracts and another two (2) are commercial farms under contracts.

Furthermore, Table 7 shows that the two (2) commercial contract farms achieved the highest average of CMPI at 32%. Going back to Table 4, it can be seen that the highest CMPI of 1.523 (or 52.3% increase) was achieved by a commercial farm that is operated under contract. In terms of output, these top 12 farms, as a group, had only an 11% average decrease in output between the periods 2002 and 2015 as compared to the rest of the 40 swine farms which had an average decrease in output of almost 60%. What is not shown in Table 7 is that four of the top 12 swine farms actually increased their output and the contract farm with the highest CMPI of 1.523 (Farm No. farms 40 in Table 4) increased its output by five times (5x) between the periods 2002 and 2015. In terms of the important inputs such as feeds, Farm No. 40 increased its use of feed by three times (3x) between the periods 2002 and 2015. On the other hand, the general trend for the rest of the top 12 swine farms is also a reduction in the use of feed between the periods 2002 and 2015 by an average of 53%, 27% and 42% for small independent farms, small contract farms, and commercial independent farms, respectively. For the rest of the 40 swine farms, the decrease in the use of feed input went down by as much as 66% on the average. The use of the labor input also decreased for the top 12 swine farms with small independent farms and small contract farms having the largest decrease of about 77% on the average. The rest of the 40 swine farms had the least reduction in labor input use of only 18% on the average. As for the land input, the general trend for the top 12 swine farms is in the upward direction with commercial contract farms having the largest increase at 92% on the average.

Since the change in the CMPI is a multiplicative composite of conventional efficiency change (CEC) and conventional technical change (CTC), the next discussion is on the CEC. Referring back to Table 4, the increase in conventional CEC ranged from 1.058 to 1.111 or an increase of 5.8%-11.1%. But only three (3) of the 40 swine farms achieved this growth - Farm Nos. 33, 35 and 38 in Table 4- which are categorized as commercial contract, commercial independent and small independent farms, respectively. The rest of the 40 swine farms did not achieve increases in technical efficiency but they were not very inefficient either because they are not too far from the frontier. Only six swine farms had CEC values that were less than 1.0 which ranged from 0.900 to 0.999. The remaining 31 swine farms had CEC values that were equal to 1.0. This implies that in general, the 40 swine farms are able to catch up with each other in terms of conventional efficiency change.

Table 4. Conventional and Environmentally Sensitive Malmquist productivity indexes, 40 swine farms, 2002 and 2015

Farm no.	Category of swine farm	Conventional MPI (CMPI)	Conventional efficiency change (CEC)	Conventional technical change (CTC)	Environmentally sensitive MPI (ESMPI)	Environment efficiency change (EEC)	Environment technical change (ETC)	Remarks on CMPI
1	Small Independent	0.517	1.000	0.517	0.704	1.111	0.633	Understated
2	Small Independent	0.520	1.000	0.520	0.520	1.000	0.520	
3	Small Independent	0.552	0.900	0.613	0.552	0.900	0.613	
4	Commercial independent	0.564	0.980	0.575	0.564	0.980	0.575	
5	Commercial independent	0.589	0.942	0.626	0.607	1.000	0.607	Understated
6	Small Independent	0.640	1.000	0.640	0.691	1.000	0.691	Understated
7	Commercial contract	0.671	0.900	0.746	0.671	0.900	0.746	
8	Small Independent	0.686	1.000	0.686	0.686	1.000	0.686	
9	Small Independent	0.740	1.000	0.740	0.710	0.919	0.772	Overstated
10	Commercial independent	0.746	1.000	0.746	0.785	1.000	0.785	Understated
11	Small Independent	0.769	0.954	0.806	0.774	0.968	0.800	Understated
12	Commercial contract	0.814	1.000	0.814	0.814	1.000	0.814	
13	Commercial independent	0.814	1.000	0.814	0.819	1.012	0.809	Understated
14	Commercial independent	0.831	1.000	0.831	0.831	1.000	0.831	Understated
15	Commercial contract	0.837	1.000	0.837	0.837	1.000	0.837	
16	Commercial independent	0.849	1.000	0.849	0.849	1.000	0.849	
17	Commercial independent	0.860	0.945	0.910	0.779	0.920	0.846	Overstated
18	Commercial independent	0.875	1.000	0.875	0.875	1.000	0.875	
19	Small independent	0.890	1.000	0.890	0.844	0.900	0.938	Overstated
20	Small independent	0.891	1.000	0.891	0.938	1.106	0.847	Understated
21	Small independent	0.895	0.999	0.896	0.895	0.999	0.896	
22	Commercial independent	0.921	1.000	0.921	0.937	1.034	0.906	Understated
23	Small independent	0.934	1.000	0.934	0.892	1.000	0.892	Overstated
24	Commercial contract	0.940	1.000	0.940	0.940	1.000	0.940	
25	Small independent	0.970	1.000	0.970	1.022	1.111	0.920	Understated
26	Small independent	0.977	1.000	0.977	0.666	0.900	0.740	Overstated
27	Commercial independent	0.982	1.000	0.982	0.982	1.000	0.982	
28	Small independent	0.999	1.000	0.999	0.999	1.000	0.999	

Farm no.	Category of swine farm	Conventional MPI (CMPI)	Conventional efficiency change (CEC)	Conventional technical change (CTC)	Environmentally sensitive MPI (ESMPI)	Environment efficiency change (EEC)	Environment technical change (ETC)	Remarks on CMPI
29	Small independent	1.001	1.000	1.001	1.001	1.000	1.001	
30	Commercial independent	1.055	1.000	1.055	1.077	1.044	1.032	Understated
31	Small independent	1.061	1.000	1.061	1.118	1.111	1.007	Understated
32	Small contract	1.064	1.000	1.064	1.064	1.000	1.064	
33	Commercial contract	1.111	1.058	1.051	1.110	1.052	1.054	Overstated
34	Small independent	1.155	1.000	1.155	0.813	0.900	0.903	Overstated
35	Commercial independent	1.160	1.111	1.044	1.160	1.111	1.044	
36	Small independent	1.200	1.000	1.200	1.200	1.000	1.200	
37	Commercial independent	1.245	1.000	1.245	1.245	1.000	1.245	
38	Small independent	1.283	1.111	1.154	1.157	1.111	1.041	Overstated
39	Small contract	1.309	1.000	1.309	1.221	0.900	1.357	Overstated
40	Commercial contract	1.523	1.000	1.523	1.642	1.111	1.478	Understated
	Overall geometric mean	0.88	1.00	0.88	0.87	1.00	0.87	
	Productivity growth	**No. of farms**						
	Zero (=1.000)	0	31	1	0	18	0	
	Increasing (>1.000)	12	3	12	12	11	11	
	Decreasing (<1.000)	28	6	27	28	11	29	
	Total	40	40	40	40	40	40	

Sources: 2002 data from [21]; 2015 data from 2015 field survey by the author

Table 5. Estimates of Conventional MPI by category of swine farms

Category of farms	CMPI	CEC	CTC
Small independent (n=19)	0.878	0.998	0.876
Small contract (n=2)	1.187	1.000	1.187
Commercial independent (n=13)	0.884	0.998	0.883
Commercial contract (n=6)	0.983	0.993	0.985
ANOVA F-value	1.369	0.032	1.628
P-value	0.268	0.991	0.200

Sources: 2002 data from [21]; 2015 data from 2015 field survey by the author

Table 6. Difference in CMPI, CEC, and CTC between swine farms that achieved increases in productivity and those that did not

Category	Conventional MPI (CMPI)	Conventional efficiency change (CEC)	Conventional technical change (CTC)
12 farms			
Min	1.001	1.058	1.001
Max	1.523	1.111	1.523
Mean	1.181	1.093	1.155
Other farms (Mean)	0.796	0.986	0.805
Difference (Mean)	0.385***	0.107**	0.350***
T-test P-value	0.000	0.018	0.000

*Note: **, *** mean significant at 5% and 1% probability levels, respectively*

Sources: 2002 data from [21]; 2015 data from 2015 field survey by the author

Table 7. Output and input characteristics of swine farms that achieved increases in conventional productivity

Category	CEC	CTC	Output 2002	Output 2015	Feed 2002	Feed 2015	Land 2002	Land 2015	Labor 2002	Labor 2015
Small independent (n=5)	1.022	1.114	1,302	885	4,893	2,271	0.48	0.74	5	1
Small contract (n=2)	1.000	1.187	4,528	2,462	9,855	7,198	0.88	1.25	5	1
Commercial independent (n=3)	1.037	1.115	13,765	11,174	30,580	17,699	0.85	1.83	10	7
Commercial contract (n=2)	1.029	1.287	13,661	16,051	28,875	55,036	0.08	1.10	7	4
Average of 12 farms	1.023	1.155	7,015	6,248	16,139	15,743	0.57	1.16	7	3
Average of other farms	0.986	0.805	11,457	4,677	25,495	8,784	0.50	1.12	5	4

Sources: 2002 data from [21]; 2015 data from 2015 field survey by the author

The other component of CMPI is the conventional technical change (CTC). Going back to Table 4 to Table 7, the same top 12 swine farms that achieved the increase in conventional productivity also achieved the increase in the CTC which ranged from 1.001 to 1.523 or an increase of 0.1% to 52.3%. In the previous discussion, it was seen that the variation in the CEC of the 40 swine farms was not very large, ranging from 0.900 to a high of 1.11. Thus, while the CEC is an important component in increasing the conventional productivity growth of swine farms, it is CTC that causes more variation in the increase in productivity of these swine farms. For the top 12 swine farms, or the so-called 'leaders of the pack', what differentiates them from the rest of the 40 swine farms is their much higher levels of CTC. The remaining 28 swine farms have CTCs ranging from as low as 0.517 (Farm No. 1 in Table 4) to 0.999 (Farm No. 28 in Table 4). Table 6 shows that the average CTC of 1.155 of the top 12 swine farms is significantly much higher than the 0.805 average CTC achieved by the rest of the 40 swine farms. This implies then the majority of the swine farms are not able to take advantage of or are constrained to have access to the technological innovations that can increase the technical change component of their conventional productivity growth. It can imply also that there may not be any technology available to them, especially to the small independent farms and the commercial independent farms who constitute the majority of those with lower levels of CTC.

The succeeding discussions now pertain to the results of estimating productivity growth using the Environmentally Sensitive Malmquist Productivity Index (ESMPI). The aggregate results of the ESMPI are also given in Table 4. The over-all geometric mean of ESMPIs for the entire sample is only 0.87 which is also less than 1.0. This implies that, on the average, the environmentally sensitive productivity growth of swine farms, as a group, has decreased between the periods 2002 and 2015. Table 8 presents the average values of the ESMPIs by category of swine farms. The ESMPIs are also decomposed into the environment efficiency change (EEC) and environment technical change (ETC). The absolute differences in the mean levels of the

ESMPIs and EEC components across categories of swine farms are not statistically significant but the differences in the ETCs are marginally significant (p = 0.06).

As in the case of the CMPI, there are also only 12 swine farms (30%) that have achieved the increase in productivity growth using the ESMPI. Eleven (11) of these swine farms are the same farms that attained the increase in conventional productivity growth with the exception of Farm No. 34 (in Table 4), but the inclusion of Farm No. 25 (in Table 4), both of which are small independent farms. The value of Farm No. 34's ESMPI is 0.813 which is now lower than its CMPI level of 1.155. This implies that the CMPI is overstated and misleading since it does not consider the environmental effects of swine production that are now considered in estimating the ESMPI. Relative to the productivity frontier, what seemed to be an increase in conventional productivity growth of 15.5% is actually a decrease in productivity growth of about 18.7% i.e., [(1-0.813) x 100] when environmental effects are taken into consideration. On the other hand, Farm No. 25's CMPI value of 0.970 which is interpreted as a decrease in productivity growth is now understated because it is lower than the ESMPI estimate of 1.022 which implies a 2.2% increase in productivity growth after including the environmental effects of swine production.

Table 9 presents the ESMPI, EEC, and ETC estimates of the top 12 farms. The range of the ESMPIs is from 1.001 to 1.642 with a mean of 1.151. This implies an increase in the environmentally sensitive productivity growth between 2002 and 2015 from 0.1% to 64.2% with an average of 15.1%. When compared to the ESMPIs of the rest of the 40 swine farms, the differences at the means is highly statistically significant.

With regard to EEC of the ESMPI, Table 4 reveals that there are now 11 swine farms that achieved increases in EEC which is almost four times the number of farms that attained increases in CEC. The EEC values of these 11 swine farms ranged from 1.012 to 1.111 with a mean of 1.028 (Table 9). The additional swine farms with increases in EEC are mostly commercial in scale. When compared to the average or mean of the EECs of the rest of the 40 farms (i.e., 0.991), there are no significant differences between them. Similar to the case of the CEC, this implies that there is not much variation in the efficiency change of swine farms when environmental effects are considered.

While the efficiency change component of the ESMPI certainly makes an important contribution toward increasing the productivity growth of swine farms, Table 4 and Table 9 would show that it is ETC that causes much of the variation in the ESMPI. The ETC of the top 11 swine farms range from 1.001 to 1.478 with an average of 1.119. This means that there are increases in technical change of about 0.1%-47.8% at the individual farm level. Table 9 also reveals that there are highly significant differences between the mean ETCs of the 11 farms and those of the rest of the 40 swine farms whose ETCs range from a low of 0.520 to 0.999. The majority of these farms with low ETCs belong to the small independent farm category. It can be inferred then that there are again constraints faced by this particular group of farms with respect to having access to technological innovations that can reduce the environmental effects that are by-products of swine production. It is either that small independent farms find difficulty in taking advantage of the available technology that can address the undesirable environmental impacts of swine production or these types of technologies may not be available at all to small swine farms.

Table 8. Environmentally sensitive MPI by category of swine farms

Production arrangement/scale	With waste facility	Size of waste facility (m^2)	Mean environmentally sensitive MPI (ESMPI)	Mean environment efficiency change (EEC)	Mean environment technical change (ETC)
Independent (n=21)	17	49.80	0.87	1.00	0.87
Small (n=19)	8	12.80	0.86	1.00	0.86
Commercial (n=2)	9	106.73	0.89	1.01	0.88
Contract (n=19)	6	66.32	1.03	0.99	1.03
Small (n=13)	1	18.82	1.22	0.90	1.36
Commercial (n=6)	5	74.23	1.00	1.01	0.98
Total	23	52.69	0.90	1.00	0.89

Sources: 2002 data from [21]; 2015 data from 2015 field survey by the author

Table 9. Difference in ESMPI, EEC, and ETC between swine farms that achieved increases in productivity and those that did not

Category	Environmentally sensitive MPI (ESMPI)	Environment efficiency change (EEC)	Environment technical change (ETC)
12 farms			
Min	1.001	1.012	1.001
Max	1.642	1.111	1.478
Mean	1.151	1.028	1.119
Other Farms (Mean)	0.792	0.991	0.798
Difference (Mean)	0.359***	0.037	0.321***
Ttest P-value	0.000	0.153	0.000

*Note: *** means significant at the 1% probability level*
Sources: 2002 data from [21]; 2015 data from 2015 field survey by the author

Table 10. Environmental indicator characteristics of swine farms that achieved increases in environmentally sensitive productivity

Category	EEC	ETC	Waste facility 2002	Waste facility 2015	BOD 2002	BOD 2015	Nitrogen 2002	Nitrogen 2015	Phosphorus 2002	Phosphorus 2015
Small Independent (n=5)	1.024	1.030	8	14	1,156	1,382	188	400	51	157
Small Contract (n=2)	0.950	1.210	9	9	557	9,018	605	501	287	276
Commercial Independent (n=3)	1.052	1.107	214	233	6,542	3,231	2,092	3,628	1,915	576
Commercial Contract (n=2)	1.081	1.266	2	35	1,954	5,536	2,355	543	597	94
Average of 12 Farms	1.028	1.119	59	72	2,536	3,809	1,095	1,248	648	271
Average of Other Farms	0.991	0.798	66	45	5,201	2,879	1,469	1,021	611	700

Sources: 2002 data from [21]; 2015 data from 2015 field survey by the author

Table 11. Mean environmentally sensitive MPI of swine farms with waste facility

Production arrangement/ Scale	With waste facility	Size of waste facility (m^2)	Mean environmentally sensitive MPI (ESMPI)	Mean environment efficiency change (EEC)	Mean environment technical change (ETC)
Independent (n=21)	17	49.80	0.87	1.00	0.87
Small (n=19)	8	12.80	0.86	1.00	0.86
Commercial (n=2)	9	106.73	0.89	1.01	0.88
Contract (n=19)	6	66.32	1.03	0.99	1.03
Small (n=13)	1	18.82	1.22	0.90	1.36
Commercial (n=6)	5	74.23	1.00	1.01	0.98
Total	23	52.69	0.90	1.00	0.89

Sources: 2002 data from [21]; 2015 data from 2015 field survey by the author

Table 10 gives the environmental indicator characteristics of swine farms that achieved increases in ESMPI relative to those farms that did not. In general, there is an increase in the size of waste facilities that have been installed in the swine farms between 2002 and 2015. In particular, commercial contract farms have increased the size of their waste facilities by as much as 15 times between the periods 2002 and 2015. It has to be recalled from the CMPI section that the output of these contract farms have also grown five times during this period. This tremendous growth in waste facilities suggest that commercial contract farms have relatively easier access to these technological innovations and are not constrained to use them. In terms of the environmental indicators, there is, on the average, an upward trend in the BOD and nitrogen loading levels but a marked decrease in the phosphorus loading. Thus, the question on the effectivity of the available technological innovations that can address the undesirable environmental impacts of swine production surfaces.

Furthermore, Table 11 provides more details on the apparent relationship between the installation/construction of waste facilities and the growth in the ESMPI. Of the 40 swine farms, 23 (58%) of them have installed waste facilities to assimilate environmental impacts. Across production arrangement, 6 of the 8 contract farms installed larger waste facilities than those of the independent farms. In terms of scale, the commercial farms had expectedly larger waste facilities. Contract farms, regardless of scale, had higher environmental productivity growth that is driven by both efficiency change and much higher levels of technical change as compared to the independent farms.

4. CONCLUSIONS AND IMPLICATIONS

In the period of 2002 to 2015, only one-third of the 40 swine farms experienced productivity growth at the frontier. This was largely the result of efficiency improvements rather than technological improvements or shifts in the production frontier. Thus, productivity growth in the swine sector, inclusive of environmental impacts, has declined. As to characteristics of productivity growth in swine production, the CMPI actually tends to overstate the productivity growth of swine farms. However, incorporating three environmental impacts such as N and P loadings and the BOD reduces the level of productivity growth.

It was found that the efficiency change (both CEC and EEC) of swine farms across categories did not significantly differ. The range of CEC and EEC is about 0.900 to 1.111 which implies that swine farms are able to catch up with the best practice and their technical efficiency levels are not too far from the frontier. On the other hand, the technical change (both CTC and ETC) is the main driver causing much variation in productivity growth. The range of CTC and ETC is wide, from a low of 0.512 to 1.64. Moreover, while there are 11 or 12 out of the 40 swine farms that achieved increases in productivity growth (both for CMPI and ESMPI), particularly the contract farms, the majority (70%) of the 40 swine farms, especially the small independent farms, seem to be constrained in terms of gaining access to available technological innovations that can increase the level of their productivity growth. It is also uncertain if such technological innovations are available to them. Thus, an interesting insight from this finding is that the underlying policy environment in the past decade, or in the past 13 years, could not also encourage or did not provide swine farms with sufficient incentives to adopt game-changing technology. Particularly for small independent farms who constitute the majority of the 40 swine farms in the sample, the past 13 years have not seen them investing in green technology as reflected by the relatively smaller size of their waste facilities and increased levels of environmental indicators such as the BOD and nitrogen and phosphorus loadings between the periods 2002 and 2015.

An important implication based on the empirical findings of this study is that technical change is crucial to the movement toward green growth and sustainable development. It cannot be ‘business as usual’ especially for the small-scale swine farms who produce 64% of the animal inventories at the national scale. While the commercial and contract swine farms apparently have access to technologies that can improve their productivity growth and reduce environmental impacts of swine production, small-scale swine farms have to be supported to enable them to become agents or developers of green growth.

Another crucial implication arising from the findings of this study is that the concept of promoting contract farms as a production arrangement that can increase the productivity growth of swine farms, especially small farms in the Philippine swine sector is worth revisiting. This is similar to the findings of [12], [13] and [25] that documented the case of contract farming as an institutional arrangement that can reduce constraints such as transaction costs in many aspects of swine production and environmental impact mitigation which can also be a source of productivity growth. Small-scale swine farms would need a policy environment that will enable them to access and adopt “game changing” and green growth technology that can increase their productivity growth.

5. RECOMMENDATIONS

It was found that technical change is the main driver causing much variation in environmental productivity growth of swine production. Technical change that reduces environmental impacts of swine production is also crucial particularly for the small-scale swine farms that still account for about two-thirds of the swine population, in order for them to gain sustainability improvements. However, only a few swine farmers have been progressive over time. To be able to effect such environmentally-friendly technical change to the much larger group of smallholder swine producers, this paper recommends three incentives that have to be put in place: 1) the incentive for agricultural extension programs to sustain the dissemination of information that enhances small-scale swine farms’ awareness on, access to, and use of available technologies that improve their human capital skills and productivity growth and also reduce environmental impacts; 2) the incentive for small-scale swine farmers to organize themselves so as to take advantage of economies of scale in the input and output markets and improve their adoption of green technologies and practices (e.g., installing of biogas digesters) through credit for investment in farm-level innovation; and 3) the incentive for local government environmental regulators to seriously enforce existing environmental laws.

The effects of other factors that may affect environmental productivity growth of swine farms such as structural changes, institutional arrangements, policy and investment instruments, public and private research and extension, transaction costs, and other economic incentives that may promote the access to and adoption of green technology innovation can be further investigated in future research. The impact of environmental regulations, compliance and abatement costs on the environmental performance of the swine sector may also present opportunities in the design of environmental policies toward achieving sustainable productivity and green growth.

ACKNOWLEDGEMENTS

The 2002 field survey [21] was part of the IFPRI-FAO-UPLB LISHE project funded by DFID through FAO-LEAD.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. OECD. Towards green growth. A summary for policymakers; 2011. (Accessed 10 August 2015) Available:https://www.oecd.org/greengrowth/48012345.pdf
2. Blandford, D. The contribution of agriculture to green growth; 2012. (Accessed 20 January 2016) Available:http://www.oecd.org/greengrowth/sustainable-agriculture/48258861.pdf
3. AfDB, OECD, the UN and the World Bank. A toolkit of policy options to support inclusive green growth. N.d. (Accessed 15 April 2015) Available:http://www.afdb.org/fileadmin/uploads/afdb/Documents/GenericDocuments/A%20Toolkit%20of%20Policy%20 Options %20to%20 Support%20 Inclusive % 20Green %20Growth.pdf
4. United Nations Environmental Program (UNEP). What is the green economy? 2012. (Accessed 10 January 2015) Available:http://www.unep.org/green economy/AboutGEI/WhatisGEI/tabid/29784/Default.aspx
5. Catelo MAO. Livestock and health. In: IFPRI 2020 Vision for food, agriculture and the environment. Understanding the links between agriculture and health. 2006. Focus 13 Brief No. 9 of 16. Washington, D.C.: IFPRI. Available:https://www.spring-nutrition.org/sites/default/files/understanding_the_linkages_between_agriculture_and_health-ifpri_2006.pdf
6. Gerber P, Henderson B, Makkar P, Editors. Mitigating greenhouse gas emissions from livestock. Italy: FAO; 2012.
7. Cabanilla LS, Rodriqguez UPE, Quilloy AJA. Hog Industry. In Briones, R., M.

Sombilla, and A. Balisacan, Editors. Productivity Growth in Philippine Agriculture. Philippines: SEARCA-DA-BAR-PhilRice; 2014.

8. Philippine Statistics Authority (PAS). Swine industry performance report, January to June 2016.
Available:https://psa.gov.ph/content/swine-industry-performance-report-january-june-2016
9. Bureau of Animal Industry (BAI). Hog industry road map (2017-2027).
(Accessed 19 April 2017)
Available:www.bai.gov.ph/index.php/download/category/97-publications?download...hog...
10. United States Department of Agriculture. Foreign Agricultural Services (USDA FAS).
(Accessed 20 January 2017)
Available:https://www.fas.usda.gov/databases/global-agricultural-trade-system-gats
11. Catelo MAO, Dorado M, Agbisit E. Jr. Backyard and commercial piggeries in the Philippines: Environmental conse-quences and pollution control options. In: Economy and environment: Selected readings in the Philippines. Francisco, H. and Angeles, M, Editors. Philippines: EEPSEA; 2003.
12. Costales A, Delgado C, Catelo MAO, Lapar ML, Tiongco M, Ehui S, Bautista AZ. Scale and access issues affecting smallholder hog producers in an expanding per-urban market, Southern Luzon, Philippines. IFPRI Research Report 151; 2007. Washington DC: IFPRI.
Available:http://www.ifpri.org/pubs/pubs.htm#rreport
13. Delgado C, Narrod C, Tiongco M, Camargo G, Catelo MAO, Costales Mehta AC, Naranong V, Poapongsakorn N, Sharma V, de Zen S. Determinants and implications of the growing scale of livestock farms in four fast growing developing countries. IFPRI Research Report No. 157. Washington D.C.: International Food Policy Research Institute; 2008.
Available:http://www.ifpri.org/pubs/pubs.htm#rreport
14. Ball VE, Lowell CEK, Luu H, Nehring R. Incorporating environmental impacts in the measurement of agricultural productivity growth. J Agr Resour Econ. 2004;29(3): 436-460.
(Accessed 15 April 2015)
Available:geconsearch.umn.edu/bitstream/30911/ 1/29030436.pdf
15. Graham M. Developing a social perspective to farm performance analysis. Ecol. Econ. 2009;68(8-9):2390-2398.
DOI: 10.1016/j.ecolecon.2009.03.013.
RePEc.
(Accessed 12 January 2016)
16. Choi J, Roberts DC. Impacts of air pollution on productivity growth in the air and truck transportation industries in the US: An application of the data envelopment analysis Malmquist environmental productivity index. Open Journal of Social Sciences. 2015;(3):120-129.
Available:http://dx.doi.org/10.4236/jss.2015. 32016
17. Yu-Ying Lin, Chen EP, Chen C. Measuring green productivity of country: A generlized metafrontier Malmquist productivity index approach. Energy.
(Accessed 08 March 2016)
Available:http://dx.doi.org/10.1016/j.energy.2013.03.055
(Article in press). 2013.
18. Hoang VN, Coelli T. Measurement of agricultural total factor productivity growth incorporating environmental factors – a nutrients balance approach. CEPA Working Paper Series No. 03; 2009.
(Accessed 15 August 2015)
Available:http://www.uq.edu.au/economics/cepa/docs/WP/WP032009.pdf
19. Teruel R, Briones R, Paredes A. Measuring and explaining productivity and growth: Theory and methods. In: Briones, R., Sombilla, M., and Balisacan, A. Editors. Productivity growth in Philippine agriculture. Philippines: SEARCA-DA-BAR-PhilRice; 2014.
20. Teruel R, Dumagan J. Total factor productivity growth in Philippine agriculture. In: Briones, R., Sombilla, M., and Balisacan, A., Editors. Productivity growth in Philippine agriculture. Philippines: SEARCA-DA-BAR-PhilRice; 2014.
21. Costales A, Delgado C, Catelo AO, Tiongco MA, Delos Reyes A. Annex I: Livestock industrialization project: Phase II – Policy, technical, and environmental determinants and implications of scaling-up of broiler and swine production in the Philippines. 2003. In: Policy, technical, and environmental determinants and implication of the scaling-up of livestock production in four fast growing developing

countries: A synthesis. In: Delgado, C. Narrod, C., and Tiongco, M., Editors. Italy: FAO; 2008.

22. Mugera A, Featherstone A. Backyard hog production efficiency: Evidence from the Philippines. Asian Economic Journal. 2008;22(3):267-287. (Accessed 10 August 2015) Available:http://onlinelibrary.wiley.com/doi/10.1111/j.1467-8381.2008.00278.x/
23. Briones R. Introduction. In: Briones, R., Sombilla, M., and Balisacan, A. Editors. Productivity growth in Philippine agriculture. Philippines: SEARCA-DA-BAR-PhilRice; 2014.
24. Rao DSP, Coelli T, Alauddin M. Agricultural productivity growth, employment and poverty in developing countries, 1970-2000. Employment Strategy Papers; 2004. (Accessed 15 May 2015) Available:http://www.oit.org/wcmsp5/groups/public/@ed_emp/@emp_elm/documents/publication/wcms_114323.pdf
25. Catelo MAO, Costales AC. Contract farming and other market-linking institutions as mechanism for integrating rural smallholder livestock producers in the growth and development of the livestock sector in developing countries. FAO-PPLPI Working Paper No. 45. Italy: FAO; 2008.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/18903