Evolution of the Smallholder Swine Production in the Philippines:

Catch Up with Green Growth?

by

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DISSERTATION

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LIST OF ACRONYMS AND ABBREVIATIONS

AEW - Agricultural Extension Worker

AFF - Agriculture, Forestry, and Fisheries

ATI - Agricultural Training Institute

BAI - Bureau of Animal Industry

BOD - Biological Oxygen Demand

BR - Board Resolution

CAO - City Agriculturist Office

CDD - Community Development Division

CENRO - City Environment and Natural Resources Office

CEC - Conventional Efficiency Change

CMPI - Conventional Malmquist Productivity Index

CTC - Conventional Technical Change

DA - Department of Agriculture

DEA - Data Envelopment Analysis

DENR - Department of Environment and Natural Resources

DLFS - Deep Litter Flooring System

DOST- Department of Science and Technology

EEC - Environment Efficiency Change

EBD-ITDI - Environment and Biotechnology Division of the Industrial Technology Development Institute

ESMPI - Environmentally Sensitive Malmquist Productivity Index

ETC - Environment Technical Change

FFS SPF - Farmer's Field School on Sustainable Pig Farming

FE - Feed Efficiency

FF - Farrow-to-Finishing

FW - Farrow-to-Wean

GF - Grow-to-Finishing

GGGI - Global Green Growth Institute

GHG - Greenhouse Gases

HDPED - High Density Polyethylene Digester

IEC - Information and Education Campaign

ITCPH - International Training Center on Pig Husbandry

LLDA - Laguna Lake Development Authority

MAO - Municipal Agriculturist Office

MB - Mass Balance

MMT- CWE - Million Metric Tons in Carcass Weight Equivalent

MPI - Malmquist Productivity Index

N - Nitrogen

NAWRMP - National Animal Waste Resource Management Program

NEDA - National Economic and Development Authority

OCVAS - Office of the City Veterinary and Agricultural Services

OECD - Organization for Economic Co-operation and Development

OPA - Office of the Provincial Agriculturist

OPVET - Office of the Provincial Veterinarian

P - Phosphorus

PBD - Portable Biogas Digester

PDP - Philippine Development Plan

PENRO - Provincial Environment and Natural Resources Office

RA - Republic Act

RFU - Regional Field Unit

SFA - Stochastic Frontier Analysis

SIDC - Sorosoro Ibaba Development Cooperative

SPEDD - Scalable Polyethylene Drum Digester

TPED - Tubular Polyethylene Digester

UN - United Nations

UNDP - United Nations Development Programme

UNEP - United Nations Environment Programme

USA - United States of America

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Chapter 1

Introduction

1.1 Background of the Study

In 2009, the Organization for Economic Co-operation and Development (OECD) laid the groundwork for green growth (European Union, 2012; OECD, 2010) 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 9.1 billion by 2050, the required annual growth of 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 energy intake in food consumption (UN, 2010 and Bruinsma, 2009 as cited by Blandford, 2012).

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" (OECD, 2013 p.3). In a nutshell, the move toward growing green implies three requisites: low carbon or pollution, resource efficiency, and social inclusion (UNEP, 2011).

The motivation for green growth particularly in the global livestock sector is a cross-cutting priority especially for emerging and developing countries where the increased demand for meat will create significant pressure on scarce natural resources that are practically utilized in the sector. Furthermore, almost all of the world's population growth is expected to occur in emerging and developing countries[1]. Thus, agriculture in general, but the livestock sector in particular, faces significant challenges in implementing the green growth strategy. This arises because alongside important windows of opportunities especially for smallholder livestock producers, new perils such as environmental pollution and health risks have emerged[2] (Catelo, 2006; Gerber, et al., 2012). At the same time, reservations arise as to whether there is still room for agricultural productivity to increase, where it is most desired, and what role smallholder farming will play in the future, if any.[3] These doubts are expressed in recognition that increasing agricultural productivity seems to be the 'single most important determinant of economic growth and poverty reduction' (Blandford, 2012) which are also the elements of pursuing green growth.

Now, like many developing and emerging countries in Southeast Asia (e.g., Thailand, Myanmar, Vietnam, and Lao PDR), where livestock is a significant component of the rural economy, the swine sector in the Philippines has the potential for achieving green growth since it is a vital source of economic growth. Forty-three percent (43%) of the 4 million Filipinos in the agriculture sector are employed here. Moreover, 64 percent of the 13.3 million swine inventories in 3rd quarter of 2018 were produced by smallholder swine farms (PSA, 2018), and, therefore, swine production has the potential for social inclusion. In terms of gross value added in agriculture, its share in 2017 was 13.7 percent, and this was the second only to the share of rice. Swine sector predominates in both volume and value of livestock production with 80 percent share between 1995 and 2017 (PSA, 2018). Meat, and pork in particular, are important

[1] http://www.oecd.org/environment/environment-development/50559116.pdf

[2] For instance, the total emission from global livestock sector by animal species and commodities in metric tons of carbon dioxide equivalent has reached an estimated 7.1 Gt of CO_2-eq, or about 18 percent of total global anthropogenic GHG emission (Steinfeld, et al. 2006).

[3] Agriculture, Growth and Poverty Reduction. Paper prepared by the Agriculture and Natural Resources Team of the UK Department for International Development (DFID) in collaboration with Anne Thomson of Oxford Policy Management, Oxford. Oct 2004.

sources of animal protein for Filipinos. Annual per capita consumption for meat in 1990 was 13.5 kg and this more than doubled to 29.7 kg in 2017. On the other hand, annual per capita consumption for pork was 8.6 kg in 1990 and this consistently increased to 16 kg in 2017[4] (PSA, 2018). Given the high and increasing demand for pork between 1990 and 2017, the OECD-FAO projected that pork production would grow by an average of 1.78 percent annually from 2018 to 2027 and by 2027, it will reach 2.35 million metric tons in carcass weight equivalent (mmt-cwe).

However, despite the swine sector's potential to achieve green growth, swine farm production, as generally practiced, is not environmentally sustainable (Catelo, et al., 2003; Costales, et al., 2007; Delgado, et al., 2008; Gerber, et al., 2012). The sector makes use of the environment as an input to production, or waste sink, which consequently results in water and even air pollution. For instance, nitrogen and phosphorus loadings 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 (Gerber, et al. 2012). This environmental degradation occurs primarily because of the volume of wastes - manure, wastewater, and animal mortalities - that are generated by swine farms and the manner by which these wastes are managed, treated, and disposed. For swine production to continue to be an important economic activity and achieve green growth, the conventional productivity of swine farms has to grow but this growth should be within the carrying capacity of natural asset base on which swine production depends. In other words, swine farms need to experience environmental productivity growth.

On the other hand, the volume of wastes that is generated by swine farms is affected by

[4] https://data.oecd.org/agroutput/meat-consumption.htm

the level of swine production and by waste management and disposal practices of swine farms which, in turn, are affected by two key drivers: technology adoption or innovation and changing structure of swine production. Technology adoption or innovation toward environmental productivity growth refers to the introduction of new knowledge, skills, know-hows or machineries and facilities that allow for the sustainable use of resources as well as proper waste management, treatment, and disposal. Use of technology or innovation such as biogas digesters and lagoons significantly decreases and treats the volume of wastes that needed to be disposed by swine farms. Thus, the adoption of these technologies helps to lessen the environmental damages that are caused by swine production. Innovations that are particularly supported based on the adoption of environmentally friendly technologies can increase environmental productivity that enables swine farms to achieve green growth. On the other hand, changing structure of swine production denotes the acquisition of additional fixed assets such as land, pens, or buildings so that adjustments and economies of size can be made possible. Changing structure of swine production may be a shift in size of production (smallholder or commercial) or production arrangement (contract or independent). The past two decades (i.e., 1990 to 2000 and 2000 to 2018) have witnessed the emergence of commercial or large-size, vertically integrated swine farms, and farms under contract in urban and peri-urban areas (Costales, et al., 2003; Delgado, et al., 2008). This changing structure of swine production determines the characteristics and operations of swine farms and can also influence the adoption of a technology or an innovation (USDA, 2002)[5] and, consequently the environmental productivity of swine farms.

Although it is common knowledge that commercial swine farms raise more swine

[5] https://www.nap.edu/read/10211/chapter/5

animals and will, therefore, generate a greater volume of waste than smallholder swine farms, commercial swine farms have the incentive to adopt or invest in waste treatment and disposal technologies because they have relatively greater financial capacity and are easily spotted by environmental regulators. Considering the non-point source nature of pollution that is contributed by smallholder swine farms who constitute the greater majority of swine producers in the Philippines, smallholder swine farms need to become 'developers of sustainable solutions' and have to be supported in order to achieve environmental productivity growth and green growth. 'Livelihoods will not be sustainable if farmers do not practice green growth' (European Union, 2012). Contract swine farms, on the other hand, are usually required by their contractors or integrators to properly manage, treat, and dispose their wastes as stipulated in their respective contracts. In contrast, independent swine farms have the sole decision on how to manage their wastes and may not have the incentive to adopt waste treatment and disposal technologies. Thus, in general, independent swine farms are expected to generate more wastes than contract swine farms with similar size of production.

Green growth is not yet mainstreamed in smallholder swine production in the Philippines (NEDA, 2017) due to constraints which may involve institutions and governance policies and environmental regulatory policies that can act as catalytic agents. The main channels, through which these policies may create impact, are discussed below:

1. Policies that facilitate the access to markets for outputs, inputs (e.g., feeds, breeds, animal health), waste (manure), information, and capacity building can provide incentives, skills, knowledge, and practices that are required for increasing the environmental productivity and the natural asset base (resource efficiency) in swine production. These skills, knowledge, capacity building, and

practices can be subsequently provided by sustained extension services of public agencies.

2. Environmental regulatory policies and standards for swine waste minimization, recycling/treatment, and disposal will increase the environmental productivity and the natural asset base (resource efficiency) of swine farms.
3. Policies that ease the adoption of pollution-decreasing and swine waste recycling/treatment technologies and lowers transactions cost[6] in accessing finance, credit, and tax provisions will pave the way for private investment in these green innovation and technologies.

However, in order for these aforementioned policies to eventually lead to the achievement of green growth in swine production, the potential solutions to address the spectrum of institutions and governance constraints in the effective implementation of these policies are important and crucial prerequisites. Figure 1.1 presents a framework that shows how policies, institutions and governance, and changing structure in swine production are inextricably linked to achieving green growth in swine production.

1.2 Problem Statement and Objectives of the Study

Given the foregoing background, the imperative for developing countries to achieve green growth in an economically growing but environmentally damaging agricultural subsector like swine production is duly recognized. But in the case of the Philippines where smallholder

[6] Transaction cost refers to cost that is entailed by economic agents for measures that they undertake in order to mitigate market transactions that are fraught with hazards. The level of transaction cost is influenced by uncertainty, asset specificity, and frequency of exchange which characterize a transaction (Catelo & Costales, 2008); transaction cost is also classified into three broad categories: search cost, bargaining cost, and policing and enforcement cost (Dahlman, 1979).

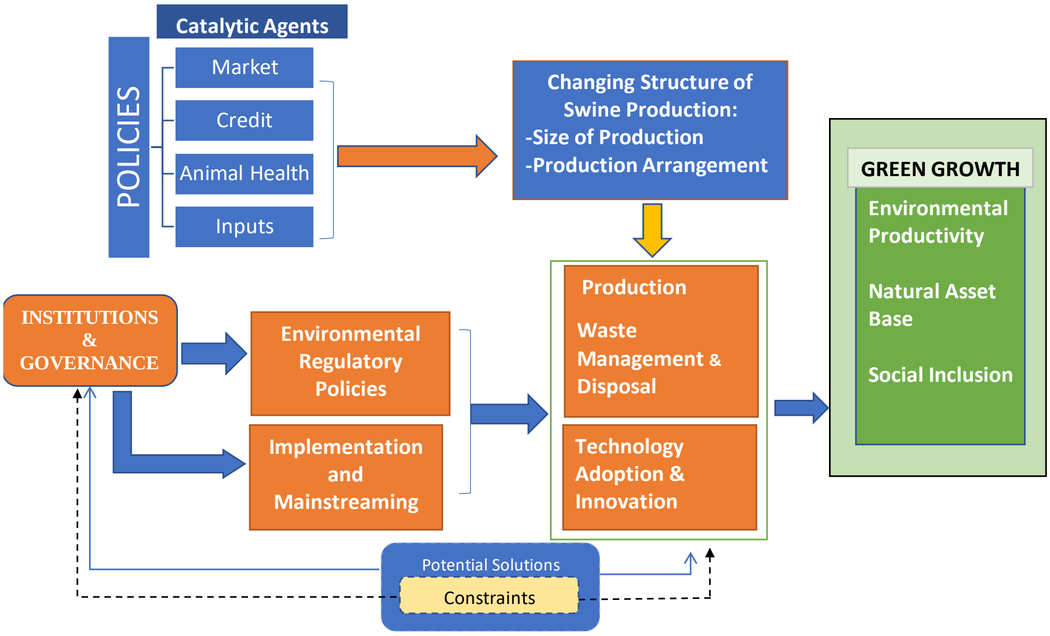


Figure 1.1 Framework showing how policies, institutions and governance, and changing structure in swine production are linked to achieving green growth in swine production

Source: Author (2019)

swine farms constitute the greater component of production, it is yet uncertain whether they can catch up with green growth either on their own or with suitable interventions devised by government policy, or both.

In order to assess if smallholder swine farms can catch up, it is necessary to examine if they are experiencing environmental productivity growth. Environmental productivity growth refers to an increase in conventional productivity between two time periods but this increase takes into consideration the internalization of the negative environmental impacts (Ball, et al., 2004) such as nitrogen and phosphorus loadings and BOD loadings that are associated with swine production.

The problem statements for this dissertation are summarized as follows:

1. Swine production causes serious environmental impacts but conventional productivity growth measurement does not include these adverse environmental impacts.
2. Smallholder swine farms are unable to increase their environmental productivity.
3. Policies that increase the environmental productivity of smallholder swine farms are impeded by a spectrum of constraints.

Accordingly, three objectives of the study are:

1. To determine the environmental productivity growth in swine production.
2. To examine factors affecting environmental productivity in swine production.
3. To examine a spectrum of constraints to the implementation of environmental regulatory policies that increase the environmental productivity of smallholder swine farms and recommend potential solutions.

1.3 Significance of the Study

There is little empirical evidence on measuring the environmental productivity growth in swine production in developing countries. This study applied the work of Ball, et al. (2004) to swine production. Ball, et al.,(2004) calculated a series of environmentally sensitive Malmquist productivity indexes on output aggregates of crops and livestock and inputs of materials, labor, and capital in 48 adjoining US states for the period 1960-1996. Ball, et al. (2004) included 2 environmental indicators represented by risks to human health from being exposed to pesticide run-off and pesticide leaching and 2 other environmental indicators represented by risks to aquatic life from being exposed to pesticide leaching and pesticide run-off. This dissertation extended the approach of Mugera & Featherstone (2008) who employed a Data Envelopment Analysis (DEA) and bootstrapping on the original data set of Costales, et al. (2003) of 127 smallholder swine farms in the Philippines to derive technical and scale efficiency but suggested panel data and comparative analysis with commercial producers. Mugera & Featherstone (2008) did not include environmental performance variables which this study did using panel data but on a much smaller number of observations and for only two periods, 2002 and 2015 - for reasons that are explained in detail in Chapter 3.

The empirical literature relating green growth and swine production is limited. While the OECD has come up with 4 green growth indicators, by which to evaluate developing countries' progress on moving toward green growth (OECD, 2014), there is still lack of empirical studies that investigate on these green growth indicators. This dissertation contributes empirical evidence on two of these indicators.

There are constraints in mainstreaming green growth to improve the environmental productivity growth of smallholder swine farms in developing countries but these are not much studied. This dissertation provided more information on this research gap. Potential solutions for resolving these constraints were likewise examined taking the Philippines as a case in point. It discussed why a transition to green growth is necessary for the development of smallholder swine farms in developing countries who tend to be ignored.

1.4 Organization of the Dissertation

This dissertation has seven chapters.

Chapter 1 presents background of the study which underlies the formulation of problem statements and the objectives of this study. The significance of this dissertation as well as the overall framework is also stated in this Chapter.

Chapter 2 expounds on the literature and research materials so far in relation to the environmental impacts that are generated from swine production. The Chapter also reviews the relevant literature on green growth concept and its framework, measurement of environmental productivity, factors that affect environmental productivity in swine production, and constraints and potential solutions to mainstreaming green growth in swine production.

Chapter 3 presents the features of swine production in the Philippines with topics of interest related to green growth that include production trends, production system, feeds, breeds, and waste management and disposal.

Chapter 4 covers the results and discussion that pertain to the first objective of determining the environmental productivity growth of swine farms. Using the panel data for 2002 and 2015 of 40 sample swine farms, the Conventional and Environmentally Sensitive Malmquist Productivity Indexes are estimated in order to determine the environmental productivity growth of the 40 sample swine farms.

Chapter 5 is devoted to the achievement of the second objective. Changing structure in swine production include size and production arrangement. The results of the nutrient mass balance approach and BOD loading are used to evaluate two of four OECD-proposed green growth indicators, i.e., environmental and resource productivity of the economy and the natural asset base. The results of the Random effects model regressions clarify the effects of changing structure in swine production and green technology such as waste treatment facilities on these two green growth indicators.

Chapter 6 discusses a spectrum of constraints to mainstreaming green growth in smallholder swine farms. In order to achieve the third objective of this study, key informant interviews of a number of institutions and stakeholders and an impact pathway approach are used to trace the possible routes and the likely constraints that environmental regulatory policies that increase the environmental productivity of smallholder swine farms would have to hurdle in their implementation. Then, potential solutions to overcome constraints are recommended.

Chapter 7 presents the conclusions and recommendations based on the findings and discusses areas for future study.

Chapter 2

Literature Review

2.1 Environmental Impacts of Swine Production

Livestock production is identified as the major environmentally damaging business accounting for 18 percent of the world's greenhouse gases (GHG) in terms of CO_2 equivalent between 1995 and 2005. For the same period, it was responsible for "65 percent of human-related nitrous oxide, which has 296 times the Global Warming Potential of CO_2, and 37 percent of all human-induced methane (23 times as warming as CO_2)" (Steinfeld, et al. 2006). The average world agricultural GHG emission for 2014 was 5.2 gigatonnes of CO_2 equivalent, almost doubled its level in 1961 at 2.8 gigatonnes of CO_2 equivalent. Between 1961 and 2014, the livestock-related global GHG emission was responsible for about 62 percent of the global agricultural GHG emission (FAOSTAT, 2017). Beef and cattle milk production accounted for 41 percent and 19 percent of the global livestock sector's GHG emission, respectively, while swine meat and poultry meat and eggs accounted for 9 percent and 8 percent of the sector's emission, respectively (FAO, 2013).

Besides producing GHG emission, livestock production causes water pollution and eutrophication from excess nutrient loadings of nitrogen (N) and phosphorus (P) (Gerber, et al. 2012) and much of this is associated with poor feeding and manure management systems (Han, et al., 2014).

Other negative externalities brought about by swine production such as foul odors, flies that are vectors of diseases, and surface water pollution arising from ill-disposed and untreated swine waste and wastewater that eventually enter water courses can impact on public health. The literature documents these (Catelo, et al., 2003; Costales, et al., 2007; Gerber, et al., 2012).

In the case of the Philippines, Figure 2.1 shows that rice cultivation was responsible for almost two-thirds (61 percent) of agricultural GHG emission for the period 1990-2014 and livestock-related emission accounted for more than a quarter (28 percent).

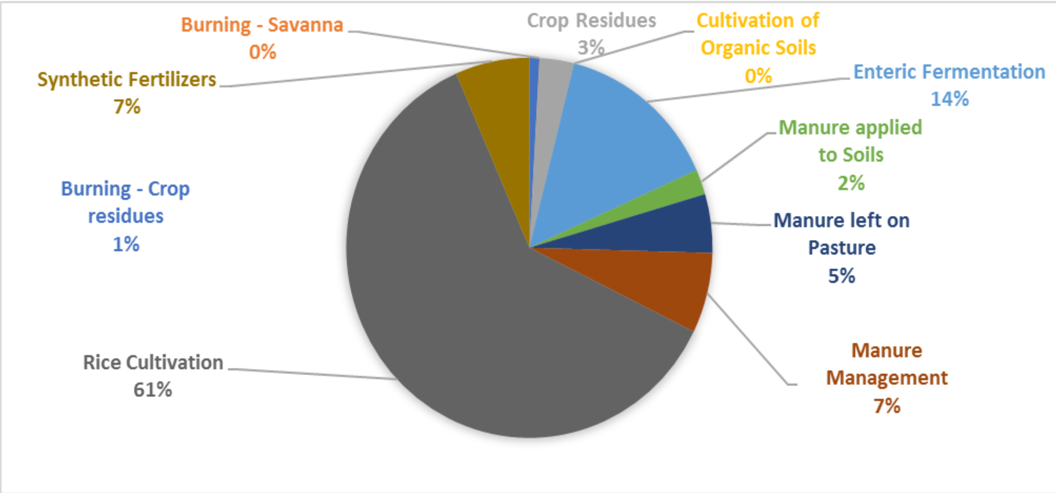


Figure 2.1 Share of GHG emission in Philippine agriculture, 1990-2014

Source: FAOSTAT (2017)

The sources of agricultural GHG emission attributed to livestock are enteric fermentation (14 percent), manure management (7 percent), manure left on pasture (5 percent), and manure applied to farms (2 percent). Enteric fermentation is made by ruminants – cattle, carabao, goats, and some sheep. The dominant manure applied to soils comes from poultry. Manure left on pasture would likely be from ruminants. The contribution of swine production would likely come from manure management, and that would constitute only around 25 percent of total livestock GHG emission.

The literature also identifies ruminants as the largest contributor of GHG emission in livestock. But that may be because in other countries and regions of the world, the population of ruminants is larger than that of swine. In the Philippines, given the significant number of swine in the livestock sector, its contribution in Figure 2.1 may be underestimated. On the other hand, if shares in GHG emission in Philippine agriculture in Figure 2.1 are credible, then it is asserted that the adverse environmental impacts of swine production should be traced to water pollution and other contaminations, rather than on GHG emission.

GHG emission in Philippine agriculture had been steadily increasing from 38,000 gigagrams of CO_2 equivalent in 1990 to more than 51,000 gigagrams in 2016 (Figure 2.2). However, although livestock production is a significant emitter of GHG, FAO (2013) claims that the livestock sector can also contribute significantly to its reduction, in fact, by as much as 30 percent. This can be achieved through technologies and practices that boost production efficiency of animals and herds such as "better feeding practices, animal husbandry, and health management". Other ways to reduce GHG emission of the livestock sector include manure management practices that recover and recycle nutrients and energy.

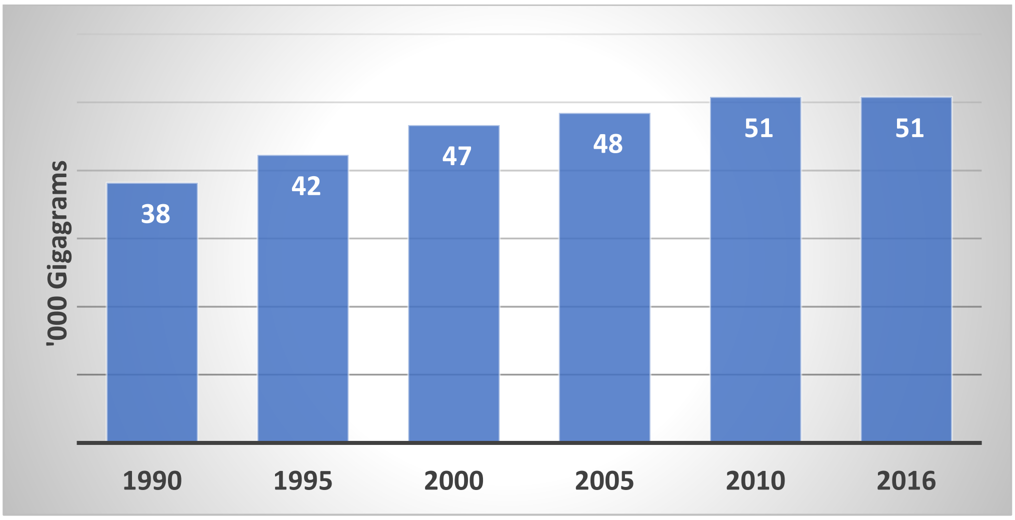


Figure 2.2 GHG emission in Philippine agriculture, 1990-2016 (CO_2 equivalent)

Source: FAOSTAT (2017)

2.2 Concept and Characteristics of Green Growth

The continuous and fast-paced growth being exhibited by developing countries has brought about concerns on environmental and natural resource management, as well as the goal of achieving sustainable development. Given the scarcity of resources, the concept of **green economy** and **green growth** have emerged. **Green growth** is collectively defined by a network of international institutions as one that *"seeks to fuse sustainable development's economic and environmental pillars into a single intellectual and policy planning process, thereby recasting the very essence of the development model so that it is capable of producing strong and sustainable growth simultaneously"* (Samans, 2013 p. 3). On the other hand, the United Nations Environment Programme (UNEP) simply defines **green economy** as low carbon pollution, resource efficiency, and social inclusion. It is a situation where increases in income and employment are driven by public and private sector investments which then work to decrease pollution and carbon emission, improve resource and energy efficiency, and deter losses of biodiversity and ecosystem services (OECD, 2012; UNEP, 2012; World Bank, 2012).

The social inclusion aspect of green growth refers to growth that generates employment, reduces poverty (UNEP, 2012), and enhances human development and conditions for poor and vulnerable groups of society (GGGI, 2013). Green growth is a strategic initiative towards achieving sustainable development and inclusive growth. Main drivers were global fuel, food, and financial crises (2008-2010) which gave the impetus for heads of state and government and high-level representatives to reconsider traditional growth models (UNEP, 2012).

In 2012, the UN Conference on Sustainable Development ("Rio+20") recognized the need for global commitment to steer away from 'business-as-usual approach', shift toward green growth path, and move to "green economy in the context of sustainable development and poverty eradication".

Green growth identifies environmental resource protection and conservation as a way of achieving national and global economic progress. However, to achieve such goals, political economy of change as well as environmental consequences of current economic development patterns must be faced (Stevens, 2011). Policies to be implemented must be geared towards economic growth and job creation that will create value-added from the environment.

Green growth aims to transform production and consumption patterns into eco-efficient and low-carbon systems although much effort is still needed to decouple growth from environmental degradation (Stevens, 2011).

Sectoral green growth progress is being measured through its ability to contribute to social well-being. Inasmuch as agriculture remains and will continue to remain to be an important growth sector in many developing countries, the goal towards transitioning to low-carbon, resource-efficient, and socially inclusive economies will require long-term policies and adjustment strategies that are coherent across economic, environmental, and sectoral interventions. To demonstrate the specific relationship between agriculture and green growth, Stevens (2011) presented the possible synergistic and conflicting effects between the two (Table 2.1).

The main diagonal in Table 2.1 presents the mutually reinforcing factors between green growth and agriculture. Those below the diagonal show the conflicting effects on each other particularly in the short-term while those above the diagonal present paired interventions that may be mutually enhancing (Stevens, 2011).

Economic, environmental, and social contributions of both agriculture and green growth can be summed up below (Stevens, 2011):

Table 2.1 Agriculture and green growth: complementarities (+) and differences (-)

	Economic Contribution of Agriculture to Green Growth	**Environmental Contribution of Agriculture to Green Growth**	**Social Contribution of Agriculture to Green Growth**
Economic Contribution of Green Growth to Agriculture	Agriculture is the basis of economic development while Green Growth can improve agricultural performance **(+)**	Green labels and eco-services can contribute to economic returns in agriculture **(+)**	Green jobs and activities can diversify and contribute to rural development **(+)**
Environmental Contribution of Green Growth to Agriculture	Environmental measures may slow agricultural growth in the short-term **(-)**	Green Growth will yield environmental co-benefits in agriculture through resource conservation and carbon sequestration **(+)**	Reform of supports to relieve environmental stress can promote more equitable farm incomes **(+)**
Social Contribution of Green Growth to Agriculture	Green Growth may detract from efforts to improve food security in the short-term **(-)**	Green Growth will necessitate structural adjustment measures in transition periods **(-)**	Food security, poverty reduction, and rural development will be enhanced through Green Growth **(+)**

Source: Stevens (2011)

2.2.1 Agriculture to Green Growth

Economic: Food Security. Green growth would highly depend on agricultural investments and farm viability to ensure future food production. For the sector to be able to feed the world population by 2050, with scarce resources, economic efficiency and productivity is vital.

Environmental: Environmental and Ecosystem Services. Though agriculture accounts for 10 percent of global direct GHG emission, the sector still has the potential to offset these from other sectors (e.g., energy and industry sectors) through carbon sequestration in soil and vegetation sinks which can offset around 20 percent of global fossil fuel emission. Agriculture can also contribute to the preservation of ecosystems by managing land and water resources, habitat protection, flood control, biodiversity maintenance, and shaping and protection of landscapes.

Social: Nourishing the Growing Population. Agriculture has been the key source of livelihood for rural population and, therefore, been the basis of poverty reduction and improved well-being by providing them with employment and income.

2.2.2 Green Growth to Agriculture

Economic: Green Tools and Techniques. One of green growth's main agenda is to improve agriculture's capacity to internalize environmental externalities in its production processes. Green tools and techniques can help farmers increase their economic returns through efficient inputs use and enhanced resource management.

Environmental: Environmental Investments. There is an evidence that environmental investments from both farmers and business have improved the overall performance of agricultural indicators. The achievement of green growth will also result to lesser environmental risks (i.e., diseases, weather conditions, and climate change) and lower expenditures as it can lessen the pressure on scarce environmental resources.

Social: Enhanced Social Welfare. Through green growth, there is a potential for more sound management of agricultural resources which can be a source of increased viability of rural economies and enhanced social welfare for farm households.

While green growth initiative is hoped to be a game-changing strategy because it offers some sort of panacea to the oftentimes conflicting relationship between economic development and the environment, debates on whether green growth will really work in emerging and developing countries (Macmillan, 2012) still continue. On the one hand, there is the belief that developing countries are the "key to achieving global green growth" since they can still do something to address environmental concerns when they make their decisions of meeting infrastructure and agricultural development needs unlike developed countries who are now constrained to move along a more sustainable growth path because they are already "locked into their investment and sunk capital from previous decades" (OECD, 2015). On the other hand, there is a serious doubt on whether green growth can deliver its promised benefits to developing countries of both "greenery and prosperity" especially because green growth has not yet been mainstreamed into these countries' economies and challenges and barriers of doing so are huge (OECD, 2015).

2.3 Measuring Productivity Growth

The past thirty years have seen the evolution of traditional methods of measuring efficiency and productivity whereby adjustments to the typical parametric and non-parametric efficiency and productivity analysis methods have been made in various forms. These adjustments have been conducted so that the environmental efficiency or environmental impacts of economic activities, which have become a pivotal issue in policymaking, can be taken into consideration (Bampatsou, et al., 2017; Lansink and Wall, 2014; Hoang and Coelli, 2009; Graham, 2004; Ball, et al., 2004; Färe et al., 1998; Diewert et al., 1982). Modifications in modelling have largely dealt with identifying, measuring, transforming, and incorporating environmental impacts of economic activities in general, although agricultural production activities seem to be a dominant area where these modifications in modelling are applied.

Lansink & Wall (2014) asserted the continued importance of environmental performance assessments in light of the increasingly challenging environmental problems that have been besetting the global community. They provided a comprehensive synopsis of frontier models that evaluate, in particular, the environmental efficiency[7] of agricultural production activities. They also chronologically traced four general methodological approaches to

[7] Reinhard, et al. (1999) as cited by Graham (2004) defined environmental efficiency as the "ratio of minimum feasible to the observed use of an environmental detrimental input. Environmental efficiency is essentially one aspect of technical efficiency in that it focuses on one input which has negative environmental consequences".

measuring the environmental efficiency: the first is the standard Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) that have been adjusted for pollution; the second is the “frontier eco-efficiency” that “relate ecological and economic outcomes” instead of conventional inputs and outputs; the third is the materials balance approach which suggests that nutrients that do not become an inherent part of good outputs have the potential to become undesirable inputs that cause pollution as they revert to the environment and, therefore, must be incorporated into productivity analysis; the fourth is the exergy balance approach which refers to the “usefulness or value of any forms of mass and energy” and these also have to be included in the models. The reader is referred to Ancev, et al. (2017), Lansink & Wall (2014), Graham (2004), Ball, et al. (2004), and Grosskopf (2002) for more detailed account and theoretical development of these general frontier-based methods for measuring environmental efficiency.

Few published papers had taken the undesirable input effects into productivity change analysis particularly in the study of the livestock sector (Graham, 2009). The literature of using the Malmquist Total Factor Productivity (TFP) Index that is adjusted for environmental impacts in agricultural studies is relatively limited, although it has been fairly recently extended and applied in other fields (Choi & Roberts, 2015; Yu-Ying Lin, et al., 2013; Shen, et al., 2010; Halkos & Tzeremes ,2002). Ball, et al. (2004) and Hoang & Coelli (2009) gave highlights of the studies done in the literature on the use of this particular approach tracing significant efforts that have been done[8]. Ball, et al. (2004) investigated the effect of including four environmental impacts on productivity growth of US agricultural sector and derived a set of marginal

[8] Such as, among others, those of Caves, et al. (1982); Färe, et al. (1989); Diewert, et al. (1992); Ball, et al. (1994); Tyteca (1996); Chung, et al. (1997); and Scheel (2001).

abatement elasticities for these four environmental indicators[9]. They constructed an environmentally sensitive Malmquist TFP index because 'environmental impacts cannot be incorporated into the more commonly used Fisher productivity index or Törnqvist productivity index 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, Hoang & Coelli (2009) developed a new measure of TFP growth that satisfies the materials balance condition which, accordingly, was the main criticism against earlier studies that traditionally modelled environmental effects as 'either a bad output or an environmentally detrimental input in production models'. Hoang & Coelli (2009) constructed a nutrient-oriented TFP (TFNP) index which is a Malmquist productivity index that is adjusted for environmental impacts. They applied this to the agriculture sector of 28 OECD member countries for the years 1990 to 2003 using Data Envelopment Analysis (DEA) methods. They found the mean technical and nutrient-orientated efficiency of the 28 OECD countries to be 0.798 and 0.526, respectively. They also estimated the mean TFNP growth at 1.5 percent per year with 0.8 percent of this growth attributed to nutrient-orientated technological progress. On the other hand, Yang, et al. (2008) estimated the technical efficiency of and the impact of environmental regulations on 39 farrow-to-finishing swine farms in Taiwan with the inclusion of wastewater effluents that were treated as undesirable outputs. A DEA-based model was developed whereby these undesirable outputs were "transformed or controlled into desirable ones" with the use of pollution abatement technologies by swine farms in response to the presence of environmental regulations. Transformed desirable outputs were in terms of the quantity of pollutants removed by the pollution abatement technologies and the degree of compliance to environmental regulations.

[9] 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 runoff (Ball, et al., 2004).

Their results showed that larger-size swine farms were more technically-efficient than small-size swine farms, implying that scaling up could improve production performance and compliance to environmental regulations.

Alimohammadloua and Mohammadi (2016) citing Wang, et al. (2014) and Grifell-Tatjé & Lovell (1996) gave several advantages of the DEA as a productivity change method. One of these advantages is the ease with which the data can be sorted and analysed. Another advantage is that the DEA method can estimate productivity growth over time without requiring an assumption regarding productivity measurement. On the other hand, the Malmquist Productivity Index is observed to be widely used because, among other things, it does not put a limit to the number of inputs and outputs that can be used to explain productivity changes. It does not require a specification of the underlying technology with objectives for optimization and assigning fixed weights for inputs and outputs (Alimohammadloua & Mohammadi, 2016). Bampatsou, et al. (2017) stated that the Malmquist Productivity Index (MPI) allows for a comparative analysis of productivity gains or losses among economic units and this is considered an advantage of using this method. Another advantage is that the MPI can capture factors that contribute to these productivity gains or losses for both individuals and aggregate observations. The MPI could also be used as a tool for "preventive" environmental policy.

In the domestic arena, there are studies that have investigated the total factor productivity (TFP) growth in the Philippine agriculture sector. Teruel, et al. (2014) presented 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. On the other hand, Teruel & Dumagan (2014) estimated TFP growth in the Philippine agriculture sector using the Törnqvist index number approach. Cabanilla, et al. (2014) 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 study 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 biological oxygen demand (BOD) and nitrogen and phosphorus loadings from swine waste; 2) among the past domestic empirical studies that were reviewed, this study applies the input-oriented 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, i.e., 1) smallholder independent farms, 2) smallholder contract farms, 3) commercial independent farms, and 4) commercial contract farms.

Comparison of swine farms according to size and production arrangement[10] was not done in the domestic literature[11] but was suggested by Mugera & Featherstone (2008) and Cabanilla, et al. (2014) 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 Teruel, Briones, & Paredes (2014) 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

[10] A smallholder swine farm is defined by the Bureau of Agricultural Statistics (BAS) as one that holds not more than 20 heads 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 (Costales, et al. 2003). Thus, in the implementation of the survey, this study categorized smallholder 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.

[11] Cabailla, et al.(2014) attempted to estimate TFP in swine production using panel data but their results were rather inconclusive and did not include environmental impacts.

approach is desirable, there are constraints in the Philippine agricultural database systems (which may 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, Teruel, Briones, & Paredes (2014) claim that more researches are needed to fill this critical gap in the literature in order to provide scientific-based evidence to 'support the design of productivity-oriented strategy to rejuvenate Philippine agriculture'. This study, therefore, fills this research gap by using DEA-based Malmquist Productivity Index non-parametric approach that incorporated adverse environmental impacts that are associated with swine production. This study assumed CRS of the underlying true technology and made a decomposition only into efficiency change and technical change. The study did not further decompose efficiency change into pure efficiency change and scale efficiency for the primary reason that there are only two time periods involved, 2002 and 2015.

2.4 Green Growth Indicators in Swine Production

The OECD (2014) provided a set of indicators, by which the move toward green growth can be measured and monitored. They included the following: 1) environmental and resource productivity of the economy which looked into the quantities of residuals from economic production such as pollutants vis-à-vis conventional output quantities, 2) flows and stocks of the natural asset base that mirrored the degree to which the asset base was affected by activities of economic agents, 3) environmental dimension of the quality of life which reflected how pollution and changes in environmental services impact on communities and people's lives and resources, and 4) economic opportunities and policy responses which assess the response of policy and decision-makers in terms of setting up and implementing economic, fiscal, environmental instruments as well as technology, research, and innovation programs in relation to the promotion of green growth concept and strategy. These indicators are used in this study to the extent that available and appropriate data would allow.

In relation to green growth, an improvement in the efficiency, by which feed is utilized in producing the final output, will certainly contribute to increasing the productivity of swine farm. Herrero, et al. (2013) stated that, although there may be huge variances among animal production systems and animal output, efficiency in the use of feed is an important aspect of productivity, resource use, and greenhouse gas emission. Improvements in feed efficiency (FE) also impact on the competitive position of swine farms since higher feed efficiency would mean lesser quantity of feed inputs used to achieve the desired quantity of the output, and, therefore, lower costs of production. A higher feed efficiency gives swine farms a comparative cost advantage (Herrero, et al. 2013) and higher profitability which can be related to the social inclusion aspect of green growth. Higher feed efficiency will also lessen the demand for feed resources and, thus, will create positive environmental implications.

Feed efficiency is expressed in a number of ways although these ways are still debatable (Patience, et al. 2015). Traditional approach of measuring FE is to calculate the ratio of feed intake to weight gain of the swine animals (McBride & Key 2014). Patience, et al. (2015) pointed out that this particular approach can be misleading specially if swine animal diets that contain higher fiber is used and the variances in dressing rates are not considered. Instead, they argued that the ratio of feed intake to carcass weight gain is now more commonly used in the Midwest-USA. In contrast, DiPietre (2014) noted the fact that typical swine farms in the USA do not really measure the individual swine animal consumption and weight of swine animals particularly while these swine animals are still on the farm. Moreover, those who do calculate the FE for the carcass constituted mere 17 percent of surveyed USA swine farms. A third approach to measure FE in swine production was offered by Knap & Wang (2012) and Patience, et al. (2015) who proposed the use of residual feed intake (RFI). RFI, as defined by Cai, et al.

(2008), is the ratio of “actual intake of feed by the swine animals and what it should have consumed given its growth rate and carcass fat content”. As feed efficiency indicator, a low RFI is ideal but the trade-off with improving RFI oftentimes came at the expense of slower growth rate of swine animals (Cai, et al. 2008). Other approaches to measure FE were also available but Patience, et al. (2015) was quick to point out that whichever feed efficiency indicator was adopted, the net income or profitability goal of swine production should not be left out.

This study employed the traditional approach used by McBride & Key (2014) to measure FE but it was modified by dividing the total weight (in kg) of the final output sold and the animals in inventory by the total weight (in kg) of feed used per production cycle per year. This modification was done due to the fact that smallholder swine farms in the Philippines did not practice farm record keeping. Thus, while it may be ideal to use the kilogram feed per kilogram carcass gain or the residual feed intake (RFI) as feed efficiency indicator, it was problematic to get this information under such considerations. Patience, et al. (2015) also confirmed the difficulty in measuring FE due to potential errors in measuring feed consumed and weight gained by the animals. Moreover, not all swine farms in the Philippines engaged in a single type of output or in an all-in, all-out type of swine production system like the grow-to-finishing which would have made the calculation of FE using the traditional approach relatively easier. The final output of swine farms may either be a weanling that can be fattened or a finishing pig (Psilos, 2010). Commercial swine farms sell their output as either live animals or as carcass. None of the smallholder swine farms sell their output as carcass. Thus, it would be problematic to apply the measurement of FE in terms of carcass output. This study, therefore, cannot use the RFI to measure FE but it used the approach of McBride & Key (2014) and modified it accordingly as explained above.

2.5 Changing Structure of Swine Production and Adoption of Innovation and Technology

There are studies that investigated the impacts of changing structure of swine production on the agriculture sector with particular attention on productivity (Krüger, 2008a) of the livestock sector. Fang, et al. (2000) revealed that changing structure of China's swine industry generally involved the shift to commercial size farms and has resulted in improved feed efficiency and substantial increases in the aggregate output through adoption of innovation and technology. Similar positive outcomes on the total factor productivity and efficiency of the USA swine sector were found by the investigations of McBride & Key (2014), MacDonald & McBride (2009), and Key et al. (2008) as arising from the scaling up of swine production and the proliferation of production contracts. However, MacDonald and McBride (2009) and McBride & Key (2014) cited negative impacts of the shift to commercial size farms on the environment as well as on the feasibility of smallholder farms. Such findings are shared by Catelo, et al. (2008).

The National Research Council (2002) of the USA posits that the adoption of innovation and technology may be affected by several structural characteristics of farms and their operations. As a consequence, depending on the extent and nature of the innovation and technology adoption, differential impacts on farms will result. For instance, farm size affects technology and innovation adoption. In the general case, commercial farms, which usually have economies of size, are able to purchase and adopt bulky or indivisible technology but smallholder farms will be constrained to do the same. More scale-neutral technologies are those that are divisible although the effect of size can also be overcome or eliminated by institutional arrangements. On the other hand, contractual arrangements also impact on the adoption of innovation and technology, although the literature has a larger number of citations on the effect of tenurial arrangements in croplands (Feder et al. 1985 cited by National Research Council, 2002) than that of production arrangements in swine or livestock production. Tenants with short term contracts are less likely to adopt innovation and technology. Besides this changing structure of swine production, the other determinants of the adoption of an innovation or technology pertain to farmer's characteristics such as education, age, and training experience. Public extension service is also cited as a very important determinant of innovation or technology adoption.

In view of the foregoing literature on contractual arrangements, this study asserts that the results on impacts of the length of tenurial arrangements in crop production on adoption of innovation and technology may not directly apply to livestock production in the Philippines. What one can look at are characteristics of contracts in swine production and investigate their differential effects on innovation and technology adoption. What is important might not be the length, but the strength of contracts and the incentives that they create in terms of a more equitable distribution of the income (or net income). Some contracts themselves may already contain (or require the adoption of) the application of innovation and technology, while other contracts do not. This would also be true in the case of innovation in swine waste management and utilization. This study looked into this particular gap in the literature.

2.6 Mainstreaming Green Growth in Swine Production of Developing Countries

Mainstreaming green growth in development plans of developing countries is imperative on two major grounds (OECD, 2012) : 1) the vulnerability of developing countries to environmental degradation and climate change impacts on the natural sector, on which most of their poor population depend, can also undermine their socio-economic-health development; and 2) though their current GHG emission relative to those of OECD and emerging economies are much lower, developing countries will soon achieve heightened levels of economic progress and growth. Consequently, they will eventually increase their GHG emission to levels that could mimic the same environmentally damaging path that developed countries had forged. Hence, advantages could be found in developing along green growth path to avoid finding themselves locked in inefficient technologies and unsustainable predicaments in investments undertaken.

Mainstreaming green growth may include the use of the following (OECD, 2012): 1) Public Environmental Expenditure Review (PEER) which looks into the efficiency and effectiveness of the allocation of funds by the public sector for environmental priorities; 2) Strategic Environmental Assessment (SEA) that aims to evaluate, at the policy and institutional levels, trade-offs, probable effectiveness on development, and sustainability of integrating environmental-social-economic objectives into policies, plans, and programmes; 3) Councils for Sustainable Development (CSDs) which can ease the incorporation of various dimensions of sustainable development into planning and formulation of strategies and policies, implementing, monitoring, and evaluation of programmes, as well as transitioning of various interest groups and stakeholders to green growth; and 4) Green Accounting and Alternative Development Measures (GAADM) which involves assimilation of environmental and social information into national economic accounts systems with the objective of providing a more precise depiction of the government and economic growth and development. The World Bank's partnership project on Wealth Accounting and Valuation of Ecosystem Services (WAVES) is a work in progress toward this end.

Mainstreaming green growth remains to be a huge challenge even as the pursuit of green growth is declared a priority of their governments. Nevertheless, five-member states of the Association of Southeast Asian Nations (ASEAN) - Thailand, Viet Nam, Indonesia, Cambodia, and the Philippines - have adopted green growth concept and are now members of the Global

Green Growth Institute (GGGI). They are also collaborating with other international agencies such as the United Nations Development Programme (UNDP). These five countries are vulnerable to climate change impacts and are now working toward mainstreaming green growth in their long-term development plans for the period 2011-2020 and up to 2030. Thailand is said to be the leading country in ASEAN in its commitment to mainstream green growth. It has started to implement its plans of greening low- and middle-income housing and constructing and retrofitting government buildings to make them energy- and water- efficient and help reduce GHG emission. Thailand projects to reduce its annual GHG emission by 304 kilotonnes of carbon dioxide equivalent (kt CO_{2e}) through the greening of housing and by 1.6 kilotonnes carbon dioxide equivalent (kt CO_{2e}) through the greening of government buildings (Md Staff 2018). In recent years, Thailand embarked on the use of biogas digester systems at the small, medium, and commercial size swine production levels to reduce environmental damages from swine production. Its Channel Digester Plus project between 2008-2011 treated the waste of 240,000 swine animals and was able to reduce GHG emission by 98 kilotonnes of CO_{2e} annually (Chaiyakul, 2014).

Likewise, Viet Nam, whose economic progress in recent years was tremendous but caused serious environmental damages, developed a Green Growth Action Plan across its economic sectors in order to reduce GHG emission and promote a low-carbon economy (Chamberlain, 2017). Along the same vein, Indonesia formulated plans for mainstreaming adoption of green growth strategy through the development of policies, instruments, and tools and coordinating with government agencies such as the Ministry of Energy and Mineral Resources, the Ministry of Environment and Forestry, the Ministry of Economic Affairs, and the Ministry of National Development Planning. Priority is given to the promotion of resource efficient technologies and environmentally sound practices particularly in renewable energy, transport, forestry, and agriculture sectors. Macroeconomic fiscal and investment policies toward the achievement of green growth in special economic zones are also being formulated (Global Green Growth Institute Indonesia, 2012).

In the case of the Philippines, the country submitted its Intended Nationally Determined Contributions (INDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) that expressed the Philippines' goal to decrease GHG (CO_2) emission by 70 percent by 2030 vis-a-vis its projected business-as-usual (BAU) GHG emission[12]. The Philippine Development Plan for 2017-2022 likewise provides for Low Emission Strategies with potential projects that will promote low carbon use in the Public Investment Program. Part of the Low Carbon Strategies for Agriculture are to 1) heighten the capacity of smallholder farmers to adopt improved and innovative technologies and to 2) strengthen the extension system for the promotion of good farming practices (PDP, 2017-2022). Moreover, the Global Green Growth Institute Philippines (GGGI, 2013) is working with the National Economic and Development Authority (NEDA) and selected National Government Agencies (NGAs). NEDA's National Long-Term Vision or Ambisyon Natin 2040 is used as point of entry to come up with guidelines for planning and tools of analysis toward achieving green growth. The Department of Environment and Natural Resources (DENR, 2011) suggested that green growth would be mainstreamed through stricter implementation of various environmental laws and regulations. The relevant environmental laws and regulations to mainstream green growth in swine production are enacted through Republic Act (RA) or Executive Order (EO). These are the Clean Air Act of 1999 (RA 8749), Clean Water Act of 2004 (RA 9275), Biofuels Act of 2006 (RA 9367) Renewable Energy Act of 2008 (RA 9513), Climate Change Act of 2009 (RA 9279)

[12] For more details, see http://www4.unfccc.int/submissions/INDC/Published%20Documents/Philippines/1/Philippines%20-%20Final%20INDC%20submission.pdf

and the Philippine Energy Plan 2017-2040 (EO No. 30). Furthermore, mainstreaming green growth in swine production can be also coursed through Clean Development Mechanism (CDM) projects such as the National Animal Waste Resources and Management Program (NAWRMP) project and the installation of anaerobic digesters in swine farms that can capture methane and mitigate animal waste/effluent-related GHG (DENR, 2011).

2.6.1 Constraints to Innovation, Adoption, and Dissemination of Green Technology

Green growth is important for the sustainable development of developing economies because green growth can lead to significant social and economic benefits that include those for the poor (OECD, 2013). However, catching up with green growth, especially by developing economies, remains debatable (Jacobs, 2013; Dercon, 2012, and Huberty, et al. 2011 as cited by Scott, et al. 2013) due to many constraints with respect to innovation, adoption, and dissemination of green technology. The use of green technology is one way to catch up with green growth (OECD, 2013).

Constraints to innovation, adoption, and dissemination of green technology such as the installation of biogas digester, lagoon, and other waste management and manure treatment facilities were identified and grouped in the literature (Haas, et al., 2018; Mittal, et al., 2018; Mengistu, et al., 2015; Resnick, et al., 2012 as cited by Scott, et al., 2013; Hallding, et al., 2012; Hazel, et al., 2007) according to these commonly broad categories: 1) economic and financial constraints; 2) market constraints; 3) social and cultural constraints; 4) regulatory and institutional constraints; 5) technical and infrastructural constraints; and 6) information constraints. Liu, et al. (2018) cited farmers' characteristics and farmers' risk preference as additional constraints although these were still debatable. Hazel, et al. (2007) mentioned lack of information on farmers' intent and behavior toward institutional innovation. The World Bank (2012) claimed that the constraints are more political, behavioral, and financial in nature.

Economic and financial constraints are the lack of financing mechanism and access to credit to finance the high initial investment cost of the green technology (Mittal, et al., 2018; Hallding, et al., 2012). Market constraints refer to those that have only a few suppliers of the green technology, and thus, these markets are considered as still immaturely developed and will not provide an economically sustainable environment for participating players. Highly concentrated markets and distant demand and supply centers can also serve as market constraints (Haas, et al., 2018). Social and cultural constraints are caused by biases of the communities against the use of methane gas for cooking which come from the anaerobic digestion process of swine waste (Mittal, et al., 2018; Hallding, et al., 2012). On the other hand, regulatory and institutional constraints refer to the usual top-down policy approach coupled with the lack of coordination among different stockholders particularly local government units. Inconsistent and irregular monitoring of compliance to environmental regulations is also a constraint (Hallding, et al. 2012; Scott, et al. 2013). Technical and infrastructural constraints are the lack of technical skills and services to operate, maintain, and repair the green technology (Mittal, et al., 2018; Liu, et al., 2018). Information constraint is the lack or low level of awareness about the policies, green technology, and their benefits. It also refers to the lack of training program for setting up, installing, and repair of the green technology (Liu, et al., 2018; Mittal, et al., 2018; Haas, et al., 2018; Hallding, et al., 2012).

Mittal, et al. (2008) reviewed 10 relevant articles from their literature, interviewed 10 experts from government, academe, foreign consultants, and financial institution, and used decomposition and logical problem tools in order to identify, categorize, and analyze constraints to rural and urban biogas systems dissemination in India. Haas, et al. (2018) used similar approaches to identify constraints to solar technologies in Chile but interviewed 50 experts who were comprised of technology providers, research institutes, and regulators.

In the Philippines, green growth mainstreaming process is proving to be quite challenging as a number of constraints have to be hurdled both at the national and local levels. For one, there is the discontinuity of government priorities that is largely attributed to election cycles. Second, there is the inadequate capacity of local government units to explicitly include green growth in their development planning activities (GGGI, 2012). Other cited factors that may constrain green growth mainstreaming process are as follows: 1) the failure to strike a balance between opportunities of expanding economic activities and exploiting the natural environment; 2) acceding to the designs of special business interests at the expense of environmental common goods; 3) inability of the government to strictly implement environmental laws; 4) graft and corruption; and 5) a scarcity of experts and professional opportunities (DENR, 2011).

The Thailand model of the introduction of Biogas Digester Systems to smallholder, medium size commercial, and large size commercial swine farms appears attractive. However, the greater proportion of Thailand's swine farms are large size commercial farms and medium size commercial farms which makes it relatively easier to deal with them regarding the introduction and adoption of innovation and technology in swine waste disposal and management. The problem of smallholder swine farms can then be subsumed in the strategy, but not an overwhelming problem. However, it is not known whether the Thailand approach involved large government subsidies, in the manner that it also provided large subsidies to milk production farms and companies toward the achievement of milk self-sufficiency (or lesser import dependency). The Thai public sector had quite large financial resources, so large that it was able to finance the famous Rice Farm Subsidy scheme during the rule of former Prime Minister Yingluck Shinawatra (2011-2014), which resulted in the bankruptcy for the concerned Thai government agency, valued at billions of US dollars. In the case that large subsidies are required to implement the biogas digester schemes, it remains a question whether the large size commercial and medium size commercial swine farms really need the subsidy, or whether they could do it on their own, with just a stricter enforcement of environmental laws and regulations pertaining to swine waste disposal and management. For the small segment of the smallholders, the subsidy may be justifiable. The Thai model, while doable there, may not be replicable in the Philippines with the large number of smallholder swine farms to deal with. Could the dispersion of biogas technology be achieved without government subsidy? If it requires subsidy, will it also be given to large size commercial and medium size commercial swine farms? And if it is also to spread to smallholder swine farms, would there be subsidy sufficient to cover them?

2.6.2 Potential Solutions

The potential solutions that were suggested in the literature in order to overcome the economic, financial, and market constraints were many but the often cited solutions included providing access to credit, granting of targeted subsidies and interest-free loans through microfinance, giving tax incentives to suppliers and adopters of green technology, and engaging in public-private partnerships (PPP) in order to increase investments in the waste-to-energy sector (Liu, et al., 2018; Haas, et al., 2018; Mittal, et al., 2018; Mengistu, et al., 2015; Hallding, et al., 2012).

For regulatory and institutional constraints, a strong and forceful implementation of environmental regulatory policies and monitoring compliance to them were proposed. Furthermore, a strong and coordinated local government leadership in terms of prioritizing funds for green technology and enhancing administrative capacities, supervision, and control was needed (Hallding, et al,. 2012; Mittal, et al., 2018). Hazel, et al. (2007) added public-private sector cooperation on initiating institutional innovation as a potential solution.

Active promotion of short term and long-term benefits of clean energy and green technology to a wider spectrum of policymakers, project developers, and stakeholders is proposed as a potential solution to address the information constraint (Mittal, et al. 2008; Haas, et al. 2018). More researches on farmers' risk preferences, environmental attitudes, preferred technologies and practices, and potential behavior in response to adoption of green technology are deemed as potential solutions to information constraint (Liu, et al., 2018 citing Stuart & Gillon, 2013).

For technical and infrastructural constraints, targeted subsidies for training and certification of technology extension staff are suggested as a potential solution (Hallding, et al., 2012). Green technology projects that are location-specific based on approved feasibility studies for each location and that are backed up by annual government investment spending are also suggested to address technical and infrastructural constraints.

2.7 Conclusion

Based on the literature covered by this study, there appears to be research gaps to livestock production in general, and swine production in particular on determining the environmental productivity of swine farms which refers to productivity that includes the adverse environmental impacts of swine production. Moreover, the impacts of changing structure of swine production on innovation and technology adoption are not much investigated.

The weakest link of the literature is to mainstream green growth in developing countries. There are not a lot of case studies, or cross-country studies on which particular technologies and approaches hold promise, and which ones not to attempt to do at all. The costs to mainstreaming are not yet specified, nor are there estimates at the country level, unless the tasks are specifically identified, and what these tasks are specifically aimed at, and what the expected benefits would likely be. Although the constraints to mainstreaming green growth in terms of the innovation, adoption, and dissemination of green technology have been looked into by some studies, these constraints were not examined in an integrated manner. Thus, this study's contribution is to integrate a spectrum of constraints to mainstreaming green growth in swine production in developing countries using the case of the Philippines.

Chapter 3

Features of Swine Production in the Philippines

The Bureau of Animal Industry (BAI) of the Department of Agriculture envisions the Philippine swine industry to be sustainable and globally-competitive by the year 2027. It has drafted an industry road map for 2017-2027 toward achieving this vision. Increasing farm productivity, reducing cost of feed inputs, and improving animal health status are three of the seven goals of the industry road map that relate to seeking green growth in Philippine swine production.

The succeeding sections present the features of swine production in the Philippines that are relevant to green growth. Specifically, the sections expound on production system, production trends, size of production, production arrangement, breeds, feeds, and animal health.

3.1 Production System

Swine farms are engaged in different kinds of production system and tend to produce multiple output. Farrow-to-wean (FW), also known as farrow-to-feeder production operation is a production system in which swine farms raise sows to produce weanlings (~20 - 25 kg in liveweight) as the main output. These weanlings are then sold to other swine farms. Grow-to-finishing (GF) operation is a production system that does not have sows in the herd since swine farms only purchase or acquire weanlings that they will raise until the growing (~40 - 60 kg) stage or more commonly until the finishing (~90 - 110 kg) stage. Finishing pigs or fatteners are the main output of GF production system.

The GF production system is common under the contract growing scheme[13]. Farrow-to-finishing (FF) production system is similar to FW in terms of having sows in the herd but the main output is finishing (or growing) pigs or fatteners instead of weanlings. Other swine farms engage in a combination of FW and FF or GF and FF. Unfortunately, there is no available comprehensive and longitudinal database that will show various kinds of swine production systems and changes in these production systems that have occurred over time. Nevertheless, using the national database on animal inventory kept by farms/ holdings based on age of swine animals (PSA, 2018), it can be seen from Figure 3.1 that over time, there has been a marked increase in the share of finishers or fatteners from 25 percent in 2001 to 29 percent in 2017. Growers had an increase in share from 26 percent in 2001 to 29 percent in 2017. However, there has been a significant decrease in the share of other swine animals (i.e., piglets, weanlings, and boars) by 8 percent. With almost unchanged shares of sows and gilts, it is conjectured that the swine production system has been shifting to becoming either the grow-to-finishing (GF) type of production system or the farrow-to-finishing (FF) type of production system. Similar to the conjectured profile of national swine animal inventory based on age in Figure 3.1, Costales, et al. (2003) found that the predominant production system in 2002 for the 207 sample swine farms in the top swine-producing regions of Central Luzon, CALABARZON[14], and Northern Mindanao, was farrow-to-finishing (FF) at 40 percent and grow-to-finishing (GF) at 29 percent. The more lucrative business of swine production is in these types of production systems.

[13] Contract growing is a scheme where swine farms who enter into contracts with integrators supply the facilities, labor, and skills while the integrators provide the piglets, feeds, veterinary medicines, and services. Integrators are large multinational or national corporations or even local feed millers that typically engage in activities that are vertically coordinated. These activities may involve feed milling, breeding, meat processing or a combination of some or all of these activities. On the other hand, independent growers solely bear all the costs and risks that go with the swine production activity and take all the profits as well. (Costales, et al. 2003).

[14] CALABARZON is an acronym for the provinces that are covered by this region, namely, Cavite-Laguna-Batangas-Rizal-Quezon.

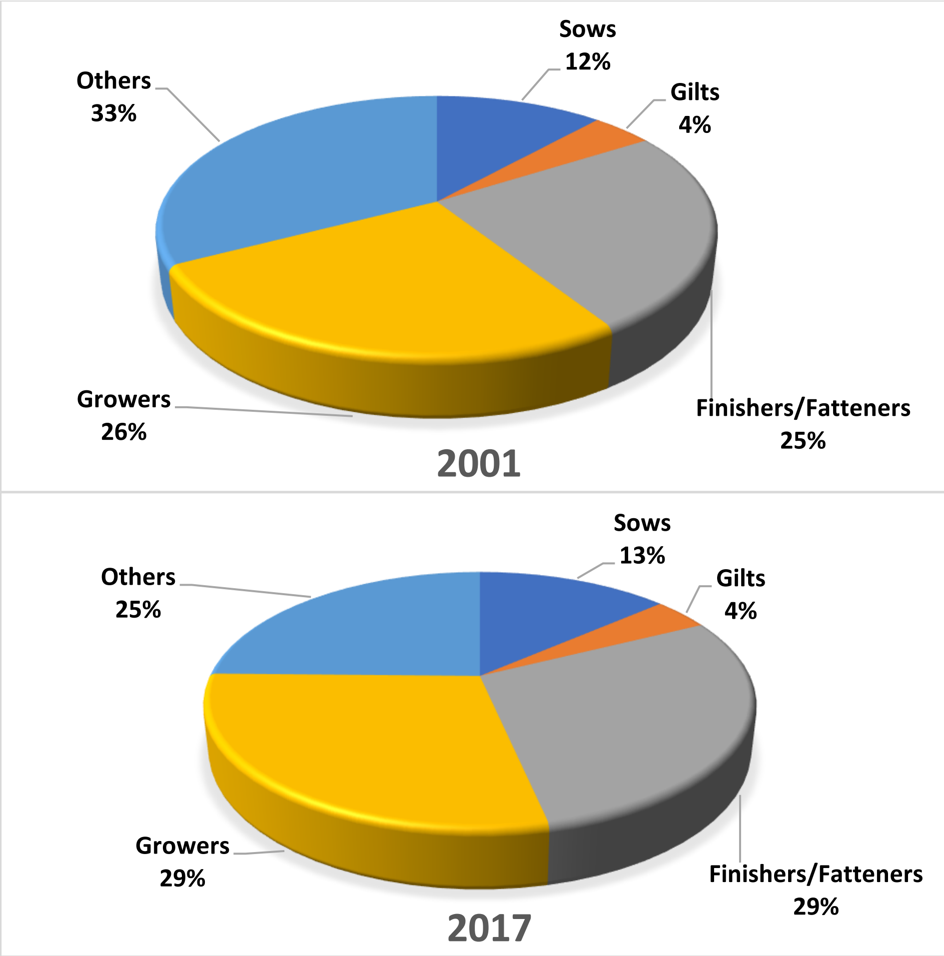


Figure 3.1 Distribution of swine animals by age, Philippines, 2001 and 2017

Source: PSA (2018)

Farrow-to-wean (FW) production system is the domain of smallholders because of the relatively low level of capital investment required in starting the business and the much shorter time that it takes to recoup the investment.

On the other hand, Aspile (2015) found that the more dominant production system for the 71 sample swine farms in San Jose Del Monte, Bulacan was farrow-to-wean (FW). Bulacan is the top swine-producing province in Central Luzon Region. Seventy-four percent of the 71 sample swine farms in San Jose Del Monte, Bulacan were smallholders in size. But for the 74 sample swine farms in Sta. Maria, Bulacan where 66 percent were commercial in size, the more dominant production system was grow-to-finishing (GF) (58 percent).

Lambon (2018) found that 89 percent of the 91 sample smallholder swine farms in Calamba City, San Pablo City, and the municipality of Pila in Laguna, CALABARZON were engaged in grow-to-finishing (GF) production system.

For the 40 sample swine farms in the panel data of this study, for the periods 2002 and 2015, Table 3.1 shows a different shift in production system that has occurred. Farrow-to-finishing (FF) and grow-to-finishing (GF) used to be the predominant production system in 2002 but 13 years later, in 2015, farrow-to-wean (FW) seems to have become the more dominant production system, followed by farrow-to-finishing (FF) production system.

Table 3.1 Production system of 40 sample swine farms, 2002 and 2015

Production System	**2002**	**2015**
	% (*N*=40)	**% (*N*=40)**
Farrow-to-Wean (FW)	20	40
Farrow-to-Finishing (FF)	35	28
Grow-to-Finishing (GF)	20	10
Combination (FW+FF/GF+FF)	26	23

Source: Costales, et al. (2003); survey by Author (2015)

3.2 Production Trends, 1995-2017

The Census of Agriculture and Fisheries [15] provides evidence that swine production is a significant economic activity in the Philippines (Table 3.2). It is, in fact, the second to chicken

[15] This census is done every 10 years. There appear to be some discrepancies between the absolute numbers in the Census of Agriculture and Fisheries and in the Bureau of Agricultural Statistics (BAS) Semestral Livestock Surveys. Such discrepancies can arise from probable differences in sampling frames. However, the changes in the numbers between the 2002 and 2012 censuses would be indicative of the relative magnitudes that were taking place over the period covered. The ratio of the number of farms/holdings by type of livestock to the total number of farms/holdings is referred to as percent of farms/holdings.

Table 3.2 Farms/holdings engaged in swine production in the Philippines, 2002 and 2012

Livestock	No. of Farms/Holdings		No. of Animals (Head)		No. of Animals/ Farm/Holdings (Head)		% of Farms/ Holdings	
	2002	**2012**	**2002**	**2012**	**2002**	**2012**	**2002**	**2012**
Chicken	3,465,232	4,590,716	126,705,576	146,584,468	36.6	31.9	71.9	82.5
Swine	2,058,951	1,549,127	8,572,977	7,709,082	4.2	5.0	42.7	27.8
Carabao	1,525,195	1,160,889	2,805,941	1,801,791	1.8	1.6	31.6	20.9
Cattle	924,628	882,108	2,329,383	1,995,841	2.5	2.3	19.2	15.9
Goat	695,772	693,854	2,106,768	2,336,325	3.0	3.4	14.4	12.5
Duck	429,700	638,902	11,171,949	8,937,198	26.0	14.0	8.9	11.5
TOTAL	4,822,739	5,563,138	153,692,594	169,364,705				

Source: Census of Agriculture and Fisheries (2002; 2012)

production. In 2002, out of the 4.82 million farms/holdings[16], close to 43 percent were engaged in swine production.

In 2012, with 5.56 million farms/holdings, swine production remained as the second most important undertaking although a decline of about 15 percent had occurred and presumably shifted to chicken production. Except for 11 percent increase in the number of farms/holdings engaged in chicken production, the number of farms/holdings engaged in livestock production decreased. It is important to note, however, that despite the decrease in number of farms/holdings engaged in swine production between 2002 and 2012, the average number of animals held per farm/holding increased from 4.2 heads to 5 heads or by close to 20 percent. This depicts an intensification of swine production which reflects a form of structural change and yet, the smallholder swine production has continued to predominate.

In the period of 1995-2017, total swine inventory grew at an average annual rate of 1.8 percent, reaching 12.52 million heads in 2017 (Figure 3.2). The share of smallholder swine farms steadily decreased from 80 percent in 1995 to only 64 percent in 2017 (Figure 3.3).

[16] A farm/holding is any piece of land used wholly or partly for any agricultural production involved in raising crops, livestock, poultry and other agricultural activities under single management, and operated as one technical unit by one person alone or with others, regardless of title, legal form, size or location (https://psa.gov.ph / content/special-report-highlights-2012-census-agriculture-2012-ca).

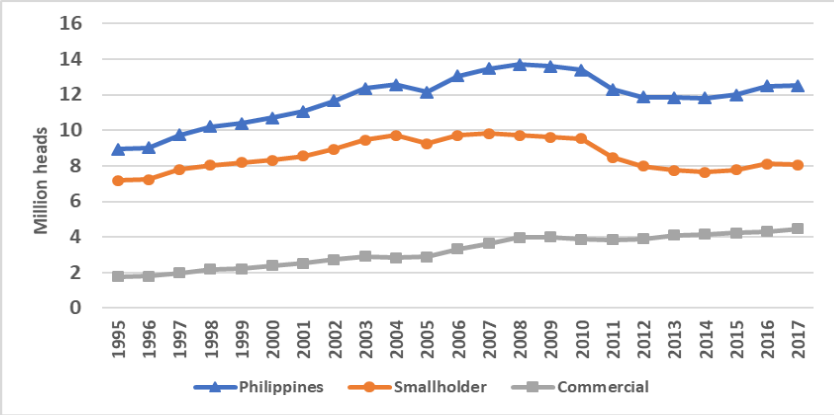


Figure 3.2 Swine animal inventory by size[17] of production, Philippines, 1995 to 2017

Source: PSA (2018)

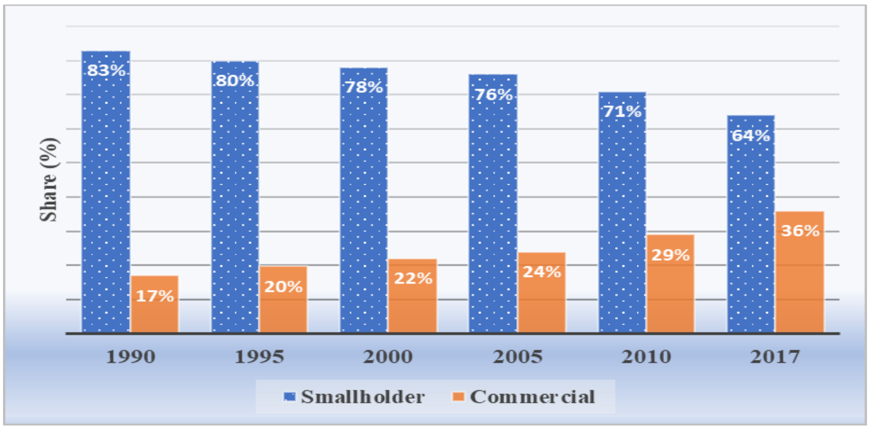


Figure 3.3 Share of smallholder and commercial swine farms in total animal inventory in the Philippines, 1990 to 2017

Source: PSA (2018)

Despite a declining trend in the annual growth rate in animal inventory, commercial swine farms grew at an average annual rate of 7 percent between 1995 and 2017 and 2.4 percent between 2011 and 2017 (Table 3.3).

[17] In 2017, the Philippine Statistics Authority (PSA) came out with a standardized definition of livestock farms according to size of production. A smallholder or backyard farm is "any farm or household whether farming or non-farming raising at least one head of animal and does not qualify as a commercial farm." On the other hand, PSA (2017) defines a large size or commercial farm as any livestock farm which satisfies at least one of the following conditions: 1) tending at least 21 heads of adult and zero head of young; 2) tending at least 41 heads of young animals; and 3) tending at least 10 heads of adult and 22 heads of young. Costales, et al. (2003) classified commercial farms as small (21-99 heads), medium (100-999 heads) and large (>999 heads).

Table 3.3 Growth rates in total swine inventory by size of production, 1995 to 2017, Philippines

Size	Growth Rate (%)				
	1995-2017	1995-2000	2001-2005	2006-2010	2011-2017
Philippines	1.8	3.3	1.9	0.5	0.3
Smallholder	0.5	2.7	1.7	-0.4	-0.7
Commercial	7.0	5.9	2.9	3.2	2.4

Source: PSA (2018)

In contrast, the growth in animal inventory in smallholder swine farms barely increased at an average annual rate of 0.5 percent between 1995 and 2017. The highest average annual growth rate in animal inventory of smallholder swine farms was at 2.7 percent between 1995 and 2000. After 2000, however, the average annual growth rate in animal inventory in smallholder swine farms started to decline and posted a negative 0.7 percent average annual growth between 2011 and 2017 (Table 3.3). But despite these decreasing growth trends which can somehow be attributed to the entry and exit of smallholder swine farms in each period, these trends also imply their resiliency.

Figure 3.3 shows that the movement of smallholder swine farms out of the sector in almost three decades between 1990 and 2017 has been relatively slow. In other words, there has been the persistence of smallholder swine farms in the agricultural scene over time. It means that they will stay and continue producing swine animals in the foreseeable future. Thus, from the viewpoint of green growth, they have to be supported especially in terms of increasing their productivity.

In terms of geographical distribution, Figure 3.4 and Figure 3.5 show the change in regional concentration of the total swine animal inventory in the Philippines over a span of almost two decades between 2002 and 2017 although the top two swine-producing regions have been essentially the same. In 2002, of 12.36 million heads of swine animal inventory, almost one-third (31 percent) were accounted for by the top two regions of Southern Tagalog (currently known as CALABARZON) and Central Luzon. The top five swine-producing regions in 2002 were Western Visayas, Southern Mindanao, and Central Visayas with almost equal shares of 7-8 percent. These top five regions already accounted for more than half (53 percent) of the total swine animal inventory in the country.

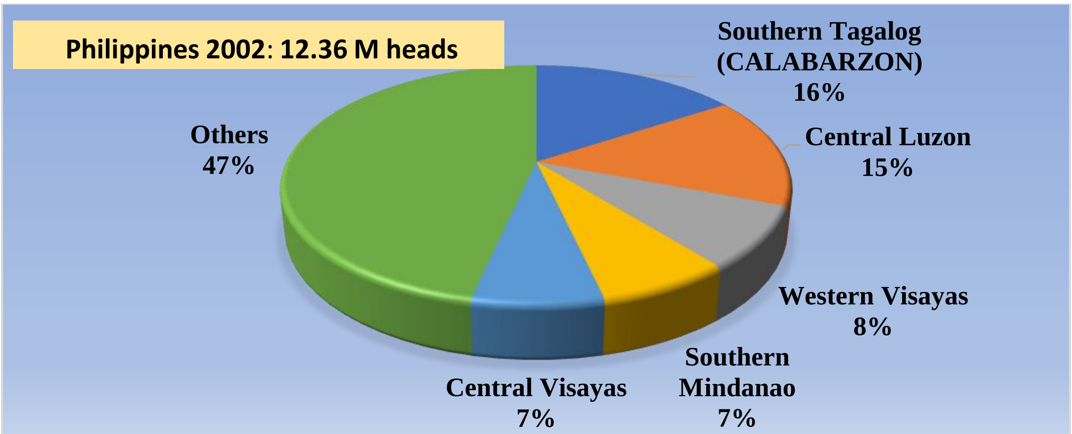


Figure 3.4 Total swine animal inventory in the Philippines by region, 2002

Source: PSA (2018)

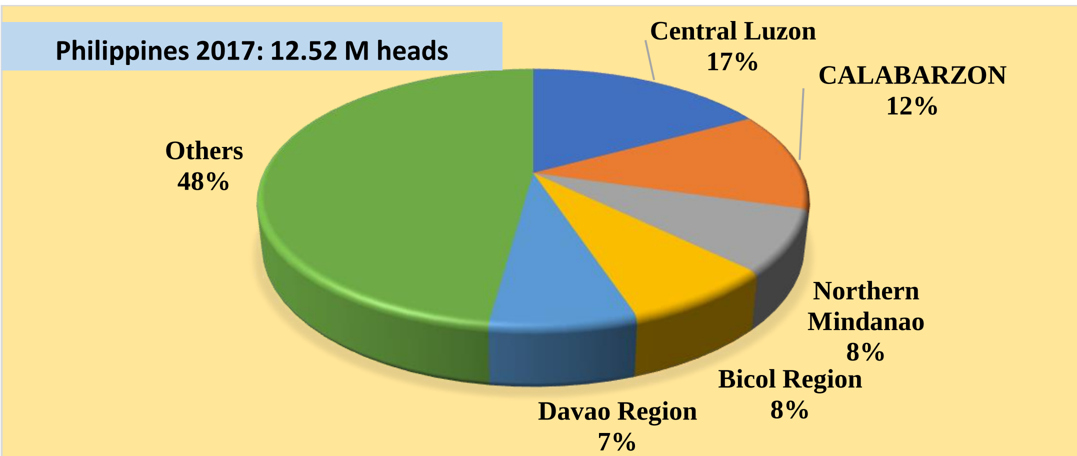


Figure 3.5 Total swine animal inventory in the Philippines by region, 2017

Source: PSA (2018)

After 15 years, in 2017, the top two swine-producing regions are still Central Luzon and CALABARZON. These two regions still maintained almost one-third share (29 percent) of the total swine animal inventory. However, there has been a change in the list that completes the top five: Northern Mindanao (8 percent), Bicol Region (8 percent), and Davao Region (7 percent) (Figure 3.5).

In terms of size of production, there are also changes in the configuration of the top swine producing regions between 2002 and 2017. For the year 2002, smallholder swine animal inventory was concentrated in the top five regions of Western Visayas, CALABARZON, Central Luzon, Southern Mindanao, and Central Visayas with a combined share of 42.5 percent (Figure 3.6). For the year 2017, however, only Western Visayas remained in the top five regions and Bicol Region was now the first on the list with other new top smallholder swine-producing regions. The combined share of the top five regions was 42.4 percent (Figure 3.7).

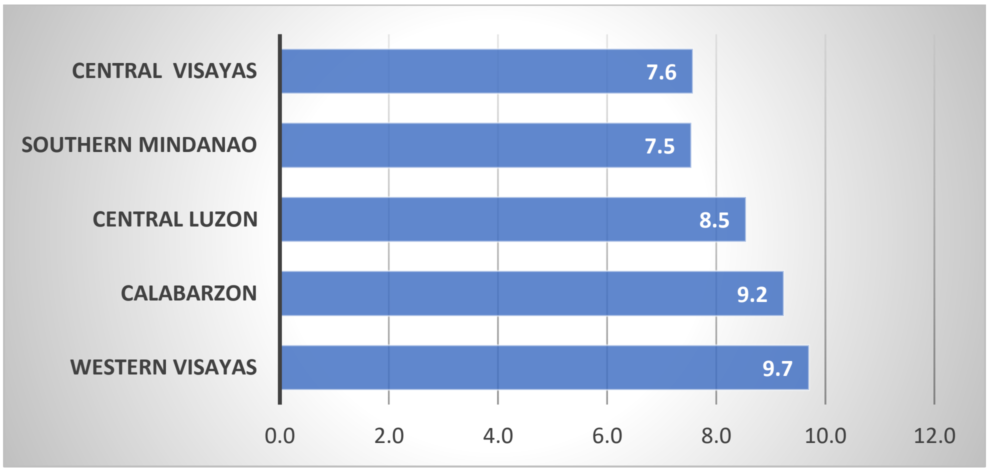


Figure 3.6 Share (%) of top 5 regions in smallholder swine animal inventory, 2002

Source: PSA (2018)

On the other hand, commercial swine animal inventory in 2002 was highly concentrated in Central Luzon and CALABRZON with each region accounting for a share of more than one-third. Their combined share is 73 percent (Figure 3.8).

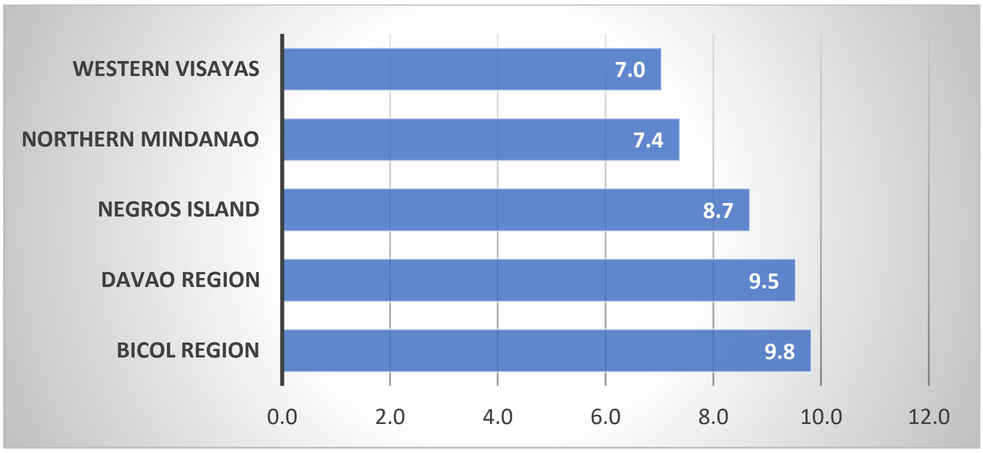


Figure 3.7 Share (%) of top 5 regions in smallholder swine animal inventory, 2017

Source: PSA (2018)

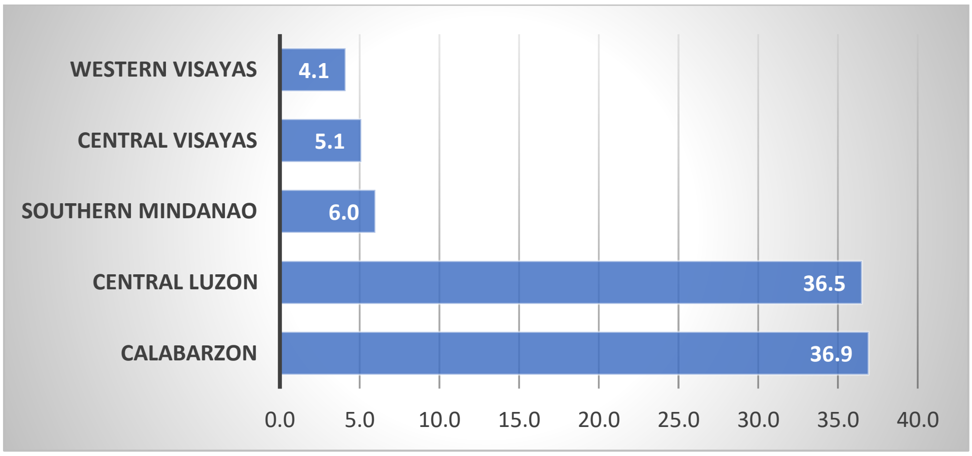


Figure 3.8 Share (%) of top 5 regions in commercial swine animal inventory, 2002

Source: PSA (2018)

In 2017, commercial swine animal inventory was still highly concentrated in these two regions (62 percent) but it was only Central Luzon that maintained its 2002 share level of 36 percent because CALABARZON's share decreased by 10 percentage points (Figure 3.9). The implication of these geographical concentrations of smallholder and commercial swine farms and having new regions in this top five list is that attention accorded to the aspect of green growth needs to be expanded.

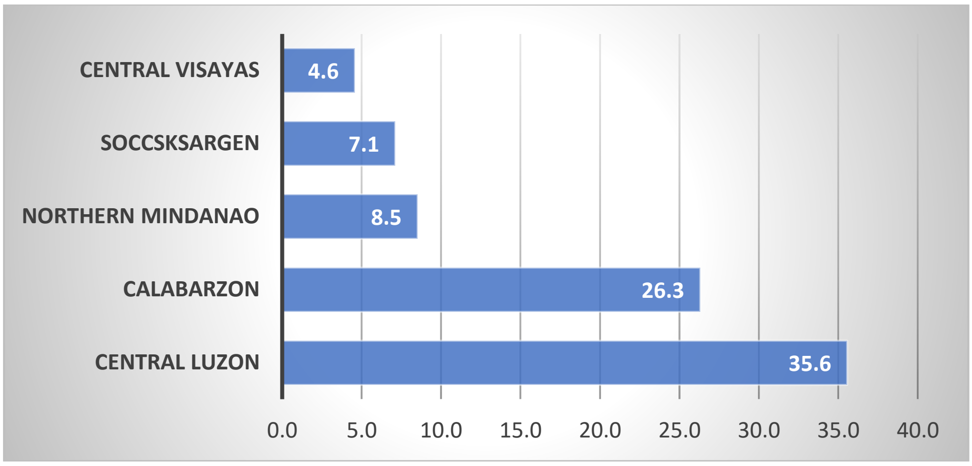


Figure 3.9 Share (%) of top 5 regions in commercial swine animal inventory, 2017

Source: PSA (2018)

3.3 Size of Production and Production Arrangement

According to the 2012 Census of Agriculture and Fisheries (see Table3.2), the estimated national average number of animals per swine farm was about five heads. Unfortunately, there is no national-level data on the actual number of swine farms, much less at the disaggregated levels by region and by production arrangement. What is available is only data on the national swine animal inventory that is disaggregated by region and by province. Therefore, the discussion on size of production and production arrangement in this Section is limited to field survey data that were done and made available by individual research projects over time.

Based on 207 swine farms, Costales, et al. (2003) found that in the top swine- producing regions of Central Luzon, Southern Luzon (now CALABARZON), and Northern Mindanao, smallholder independent swine farms had average size of animal holdings of about 33 heads while for smallholder contract farms, the average size of animal holdings was 36 heads (Figure 3.10). Furthermore, commercial independent swine farms and commercial contract swine farms had average farm sizes that were about eight to 53 times larger than those of smallholder swine farms. Aspile (2015) found similar inventory configuration (Figure 3.11).

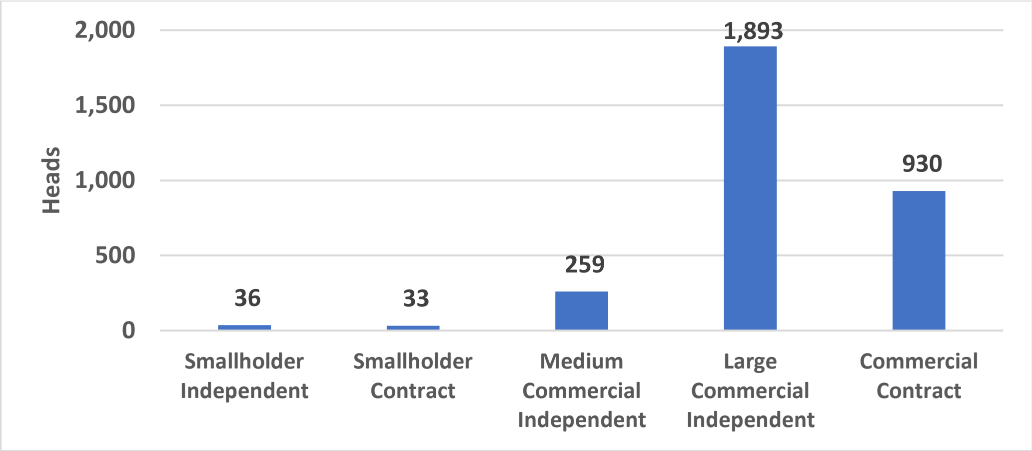


Figure 3.10 Average size of animal holdings in 207 sample swine farms, 2002

Source: Costales, et al. (2003)

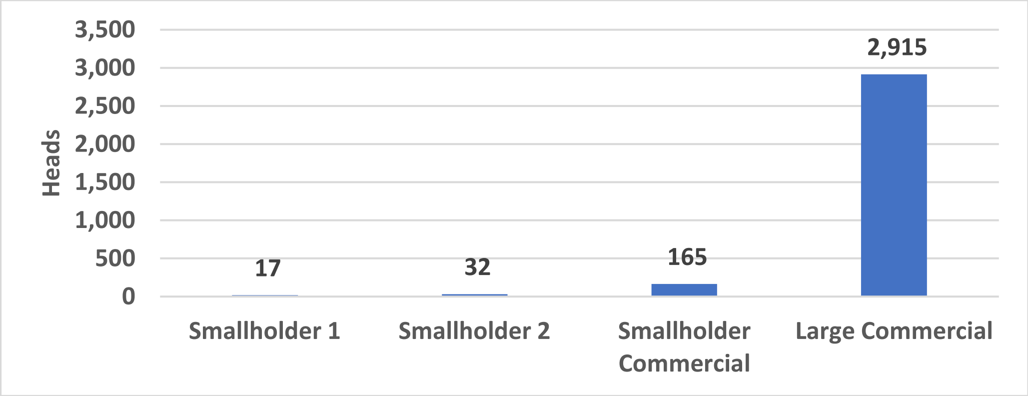


Figure 3.11 Average size of animal holdings in 145 sample swine farms, 2015

Source: Aspile (2015)

For the 40 sample swine farms in this study, smallholder independent and smallholder contract swine farms had average size of animal holdings of 41 and 35 heads, respectively in 2002. Commercial independent and commercial contract swine farms had 14 times and 7 times larger than these size levels. In 2015, the average size of animal holdings decreased by about 50 percent across production arrangements (Figure 3.12). Sample smallholder contract farms in 2002 expanded their farm sizes in 2015 and have become commercial contract farms. These trends in farm size and production arrangement imply an association between them. Contract growing requires swine farms to enlarge the size of their animal holdings over time.

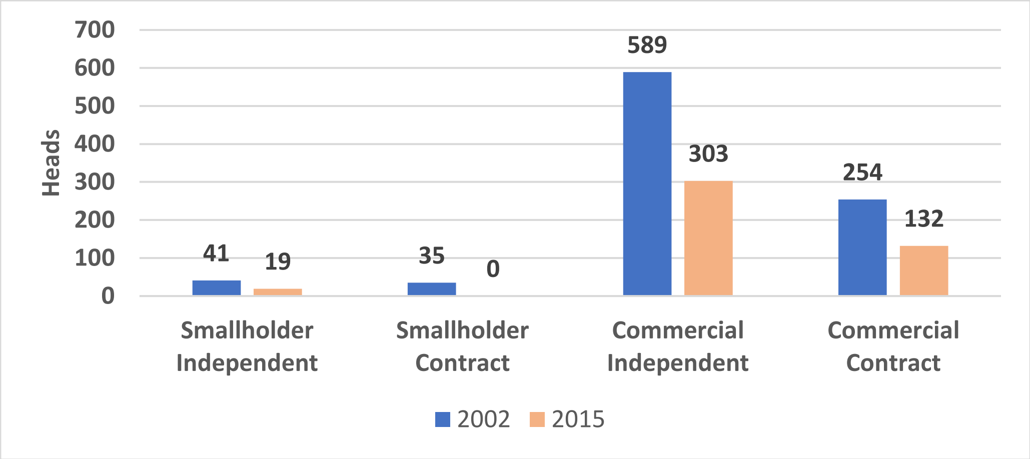


Figure 3.12 Average size of animal holdings in 40 sample swine farms, 2002 and 2015

Source: Costales, et al. (2003); survey by Author (2015)

3.4 Breeds, Feeds, and Animal Health

3.4.1 Breeds

The genetic makeup of swine breeds is very important in production because it can influence the efficiency to which feed is converted to meat, and because genetics also impact on the mortality characteristics of swine. Thus, in relation to the resource efficiency aspect of green growth, the kind of breeds used by swine farms is important. The more commonly used swine (*Sus scrofa domesticus)* breeds in the Philippines are Landrace, Large White, and Duroc. Others also use crossbreeds of Pietrain (Gonzales et al., 2012). In general, these particular breeds are preferred because they are relatively more adapted to the climate and environment and even in confinement conditions in the Philippines, can grow faster with their comparatively better feed efficiency, and can produce larger litter18 size of higher growth quality. They

[18] Litter size usually refers to the number of piglets born alive but others define it as the number of piglets born alive including stillborn but excluding mummified piglets (Vallet et al. 2006)

produce offspring with superior carcass quality when crossbred (BAR 2012). These breeds are imported and foreign companies usually supply parent stocks to commercial swine farms and breeder farms. Some of these foreign companies include PIC (UK), ACMC (UK), Topigs (The Netherlands), Hypor (The Netherlands), and CEFN (Australia).

Among local breeder farms that are accredited by the Bureau of Animal Industry (BAI), the top five companies are International Swine Genetics, Inc. (ISGI-Infarmco), Jaltas Agro Industrial Corp., Jhon and Jhon Farms, Luz Farms, and Jaro Development Corporation. These companies belong to the Accredited Swine Breeders Association of the Philippines (ASBAP) which has 37 members as of 2017[19] They also supply parent stocks to commercial swine farms.

For the 40 sample swine farms in this study, the dominant breeds that were used in 2002 are similar to the three aforementioned commonly used breeds in the country. Thirteen years later, in 2015, these 40 sample swine farms still used the same breeds but the Duroc seems not as popular as before. Landrace and Large White continued to be the dominant swine breeds, and crossbreeds such as Hypor, New Dalland, and Seghers are now also being used (Table 3.4).

By size of animal holdings, Table 3.5 shows that a relatively higher proportion of smallholder swine farms in the sample used Large White breed in 2002. For the commercial swine farms, it can be observed that their animal inventory in 2002 consisted more of combination of Large White, Landrace, and Duroc and also of Crossbreeds. However, in 2015, a higher number of commercial swine farms in the sample used Crossbreeds as well as Landrace and Large White. Crossbreeds are progenies of a pure bred female swine with a pure bred male swine of a different species. Crossbreeding is done in order to take advantage of improved genetic characteristics (Pellier, 1976).

[19] https://accreditedswinebreeders.wordpress.com/

Table 3.4 Average inventory of major swine breeds used by 40 sample swine farms, 2002 and 2015

Breed	2002		2015	
	% (*N*=40)	No. of heads in inventory	% (*N*=40)	No. of heads in inventory
Large White (LW)	10.0	121	15.0	63
Landrace (LD)	2.5	27	10.0	790
Duroc (D)	2.5	35	2.5	226
LW+LD	12.5	254	10.0	107
LW+D	5.0	115	2.5	77
LD+D	15.0	28	2.5	0
LW+LD+D	7.5	140	0.0	0
Crossbreeds	45.0	297	57.5	140

Source: Costales, et al. (2003); survey by Author (2015)

Table 3.5 Distribution of 40 sample swine farms by size of production and major swine breeds, 2002 and 2015

Breed	2002		2015	
	Smallholder % (*N*=40)	Commercial % (*N*=40)	Smallholder % (*N*=40)	Commercial % (*N*=40)
Large White (LW)	12	7	21	10
Landrace (LD)	4	0	5	14
Duroc (D)	4	0	0	5
LW+LD+D	32	53	5	24
Crossbreeds	48	40	68	48

Source: Costales, et al. (2003); survey by Author (2015)

In terms of average inventory, what can be observed is that some commercial swine farms (14 percent as seen in Table 3.5) in the sample seemed to specialize in raising Landrace breed in 2015, and it had the highest average inventory. This was not so in 2002. About 5 percent of commercial swine farms also seemed to specialize in using Duroc breed in 2015. While there had been an increase in the proportion of sample swine farms that used Crossbreeds between 2002 and 2015, the average inventory for both commercial and smallholder swine farms decreased remarkably in 2015 (Table 3.6).

Table 3.6 Average inventory of major swine breeds used by 40 sample swine farms, by size of production, 2002 and 2015

Breed	2002		2015	
	Smallholder	Commercial	Smallholder	Commercial
Large White (LW)	56	315	20	148
Landrace (LD)	27	0	67	1,031
Duroc (D)	35	0	0	226
LW+LD+D	66	552	47	165
Crossbreeds	63	1,002	33	284

Source: Costales, et al. (2003); survey by Author (2015)

3.4.2 Feeds

Feed always plays a crucial role as a swine production input. Feed is a very important input that is used in all types of swine production systems. It constitutes about 60-80 percent of swine production cost (Pierozan, et al., 2016 citing van Heugten , 2010; Aspile, 2015; Patience, et al., 2015; Gonzales, et al. 2012; Hinrichs & Steinfeld 2007; Costales, et al. 2003; Catelo, et al. 2003). Feed cost is the most important cost in swine production and is predicted to continue to increase in the future. Thus, feed efficiency is a critical aspect of swine production[20]**.** To reiterate, an improvement in the efficiency by which feed is utilized in producing the final output, will contribute to increasing the productivity of the swine farm and at the same time, lessen the waste of unutilized feed that will be released to the natural environment.

This dissertation employs the traditional approach used by McBride & Key (2014) to measure feed efficiency but it is modified by dividing the total weight (in kg) of the final output sold and the animals in inventory by the total weight (in kg) of feed used per production cycle per year. The reasons for this modification have been elucidated on earlier in Chapter 2.

[20] Since feed costs are the major contributor to swine production cost, efficient utilization of feed is essential to achieving higher economic profit. https://topigsnorsvin.com/ about/total-feed-efficiency/

Unfortunately, national level data on feed efficiency in swine production in the Philippines is not available. Therefore, besides the survey data from the 40 sample swine farms for 2002 and 2015, data from other sources are presented.

Details about the average feed efficiency with respect to size, production arrangement, and production system for the 40 sample swine farms in 2002 and 2015 are shown in Table 3.7. For example, an average feed efficiency of 0.44 for smallholder swine farms in 2002 means that one kilogram of feed was able to produce 0.44 kilogram of output. On the other hand, an average feed efficiency of 0.60 for smallholder swine farms in 2015 means that one kilogram of feed was able to produce 0.60 kilogram of output. Therefore, a higher average feed efficiency is preferred since it reflects a higher input efficiency that, in turn, can lead to a potential increase in productivity. The results of t-tests across time period and by structural change variables are likewise shown in Table 3.7.

Table 3.7 Average feed efficiency and changing structure variables, 2002 and 2015

Changing Structure Variable	2002	2015	Difference
1. Size of Production			
Smallholder (*n*=16)	0.44	0.60	0.16*
Commercial (*n*= 12)	0.55	0.56	0.01
Changed: Smallholder to Commercial (*n*=9)	0.45	0.38	-0.07
Changed: Commercial to Smallholder (*n*=3)	0.30	0.46	0.16*
2. Production Arrangement			
Independent (*n*=25)	0.47	0.49	0.02
Contract (*n*=3)	0.46	0.41	-0.05
Changed: Independent to Contract (*n*=3)	0.40	0.42	0.02
Changed: Contract to Independent (*n*=9)	0.47	0.70	0.23 *
3. Production System			
Farrow-to-Finishing (FF) (*n*=9)	0.49	0.60	0.11
Non-Farrow-to-Finishing (NonFF) (*n*=25)	0.47	0.50	0.03
Changed: FF to NonFF (*n*= 5)	0.42	0.57	0.14
Changed: NonFF to FF (*n*=1)	0.21	0.42	N/A
4. Over-all	0.46	0.53	0.07

Source: Costales, et al. (2003); survey by Author (2015)

Note: * denotes statistical significance (p value $\leq .05$)

In general, an increase in average feed efficiency can be seen in swine farms that are smallholder, independent, and engaged in any type of production system in 2002 and 2015. The only statistically significant difference in average feed efficiency can be found among smallholder swine farms that did not change their size level in 2002 and 2015 and those that engaged in a change of production arrangement. Such increases in the average feed efficiency across production systems are not significant.

In relation to green growth, the use of pelleted feed is introduced as an innovation which can reduce feed waste by five percent relative to mash or crumble feed form (Patience, et al. 2015). However, for the 40 sample swine farms in this study, only 13 percent of them used pelleted feeds in 2002 and this further decreased to only 8 percent in 2015 (Table 3.8).

Table 3.8 Feed form used by 40 sample swine farms in 2002 and 2015

	2002	**2005**
Feed Form	**% (*N*=40)**	**% (*N*=40)**
Mash/Crumble	88	93
Pellet	13	7
Total	100	100

Source: Costales, et al. (2003); survey by Author (2015)

Over a span of two decades, the share of feed cost to the total cost of swine production has remained within 60-80 percent share, depending on the production system and output as well as on whether the operator/family labour is included as a non-cash cost in the case of smallholder swine farms or as a cash cost for hired labor in the case of commercial swine farms (Costales, et al. 2003). Figure 3.13 shows that feed cost accounts for about 80 percent of the total cash cost of operating a farrow-to-wean production system at one-sow level and for one production cycle. If non-cash costs such as operator and/or family labor cost is included, then the share of feed cost in the total cost of production decreases to 62 percent but this is still a huge share particularly in the smallholder swine production cost (Figure 3.14). A detailed account of the cash and non-cash costs for operating a farrow-to-wean production system at one-sow level and for one production cycle is given by Appendix A.

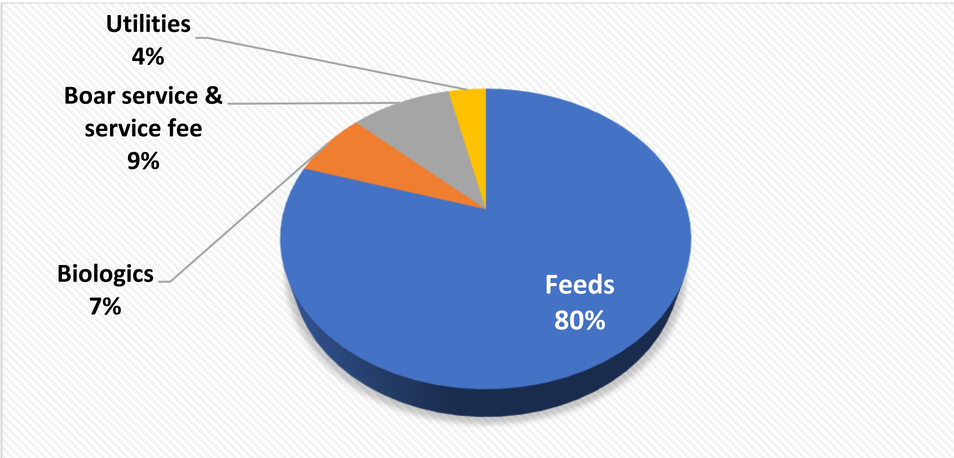


Figure 3.13 Cash costs of farrow-to-wean production system, one sow-level and one cycle, 2016

Source: PB Livestock Business (2016)

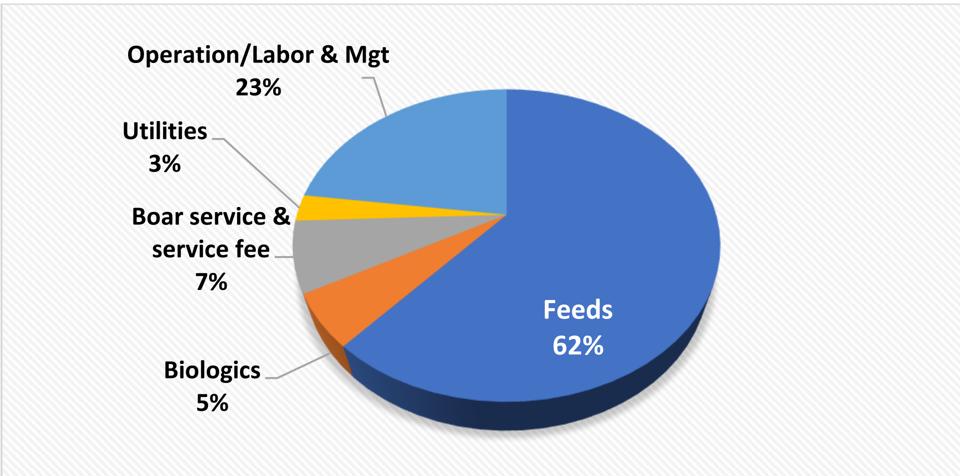


Figure 3.14 Cash and non-cash costs of farrow-to-wean production system

Source: PB Livestock Business (2016)

Corn or its substitute protein, feed wheat, remains to be the main ingredient (50 percent to 60 percent of feed) particularly for commercial swine feed. The other feed ingredients are soybean meal (20 percent to 25 percent) and fish meal (Vasquez, 2010 as cited by Gonzales, et al., 2012). Most of these ingredients are imported, although local feed mills also use local corn especially when the prices of local corn are lower than the prices of imported feeds. In fact, swine production in the Philippines is said to consume 60 percent of local feed production. There are about 700 feed mills that are registered in the country and majority of them (74 percent) are in Luzon and they are usually located near corn-growing areas. The top five feed mill companies in the country are San Miguel Foods, Cargill Philippines, Swift Foods, Inc., General Milling Corporation, and Vitarich Corporation (Gonzales, et al., 2012).

3.4.3 Animal Health

Healthy breeds of swine mean profitable business and in relation to green growth, healthy animals also imply lesser mortalities, lower risk of infecting the herd, and higher resource efficiency. When a disease breaks out, this decreases or even worsens the production efficiency of the animals, makes the work load heavier, and lowers the farm profitability. Biosecurity procedures are very important in preventing diseases to enter and infect swine farms. However, while commercial swine farms, in general, are able to put up biosecurity[21] procedures such as controlled entry to the farms, installation of disinfection foot and wheel baths, immunization and vaccination of the swine animals, etc., the same cannot be expected from smallholder swine farms who, besides lacking the financial capital to do these extra procedures, may also lack the technical know-how and information to apply biosecurity procedures. Thus, size of production matters in implementing biosecurity procedures.

In terms of animal inventory, many of the 40 sample swine farms in this study,

[21] Biosecurity measures are "specific procedures for all swine farms to follow to help reduce the risk to farming operations of disease entering a property, spreading through livestock and/or being passed to surrounding livestock operations". (Source: www.farmbiosecurity.com.au/)

particularly in Central Luzon, have downsized their herd by 33 percent to almost 100 percent (Figure 3.15). The main reasons for downsizing were the escalating feed prices in 2014 and disease outbreaks such as the Porcine Epidemic Diarrhea Syndrome (PEDS)[22], Porcine Reproductive and Respiratory Syndrome (PRRS), Transmissible Gastro Enteritis (TGE), Hog Cholera, and Swine Flu that occurred sometime in 2006 and 2009 not only in the study areas but also in other parts of the country. These diseases resulted in high rates of morbidities and mortalities in all sizes of swine farms. Huge losses in slaughter swine production were also incurred. As a loss-minimizing response to the disease scare and drop in output market price, swine farms immediately sold their animals and avoided herd expansion. The exception to this downsizing occurred for the 9 swine farms in Southern Luzon that actually increased their production from smallholder to commercial size. Their average inventory significantly increased from 70 heads in 2002 to as many as 170 heads in 2015.

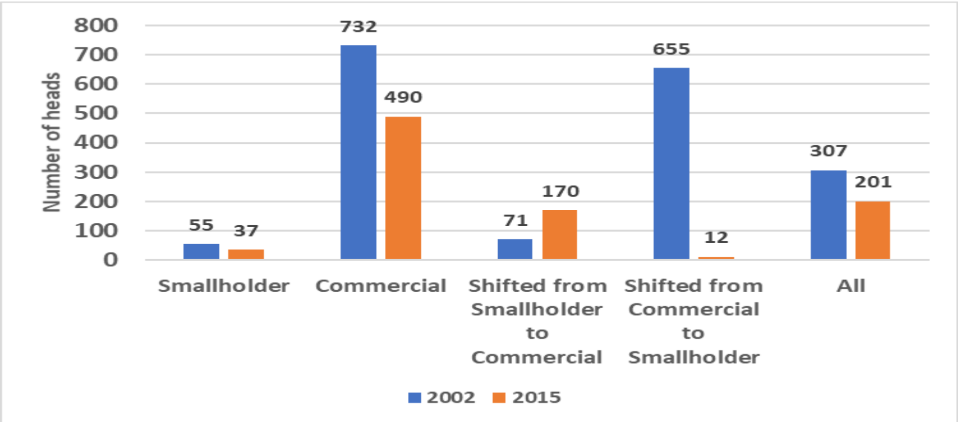


Figure 3.15 Average inventory of 40 sample swine farms by size, 2002 and 2015

Source: Costales, et al. (2003); survey by Author (2015)

Note: T-test was done to compare the animal inventories kept by swine farms according to size of production and across time periods. The reduction in the average animal inventory for swine farms was significant at the $p \leq 0.05$ level while the increase in the animal inventory for swine farms who changed their size of production from small to commercial was significant at $p \leq 0.01$ level.

[22] http://nationalhogfarmer.com/news/Porcine_disease_epidemic; http://www.ansci.wisc.edu/jjp1/pig_ case/ html/ library/Swine%20Diseases%20in%20Philippines.pdf

Swine production in the country has always been challenged by the incidences of these diseases, some of which have been recurring but others have been controlled or eradicated like the Foot and Mouth Disease (FMD). Swine diseases pose threats to the animal population. Table 3.9 lists the occurrences of swine diseases in the Philippines but this list is by no means exhaustive. Green growth aspect of increasing productivity is related to recent government interventions and innovations in swine production such as reducing mortality and increasing reproduction and productivity through the use of 1) portable diagnostic test kits for early detection of key diseases in swine like the Transmissible Gastro Enteritis and 2) genomics or gene markers that develop protocols to identify certain traits that are carried by the swine animals in the herd:

> *"Sixteen (16) gene marker protocols associated to high litter size, fast growth rate and meat qualities as well as seven markers for screening of genetic defects and disease resistance were optimized. The application of gene marker was developed by the Philippine Carabao Center (PCC) and Bureau of Animal Industry (BAI) in partnership with the Accredited Swine Breeders Association of the Philippines (ASBAP). The adoption of the gene marker technology by the swine breeder farms is expected to increase productivity and efficiency in terms of number of pigs weaned and liveweight produced per sow per year. The R&D initiatives for swine aim to increase pigs produced per sow per year by 4.6 piglets, which is equivalent to an additional 460 kilograms of hog liveweight or a 25 - 30 percent increase in pork production without increasing the breeder pig population."*

-DOST-PCAARRD[23], 2016 p.1

3.4.4 Waste Management and Disposal

Proper waste management and disposal prevents the occurrence and spread of diseases and decreases the risk of environmental pollution. Swine farms have to manage, treat, and dispose of manure, wastewater, and dead animals or mortalities.

[23] DOST-PCAARRD refers to the Department of Science and Technology-Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development.

Table 3.9 Swine diseases and occurrences in the Philippines

Swine Disease	Year Disease Occurred	Causes and Symptoms	Mortality and Morbidity Rates /Impacts	Places/Farms Affected	Treatment	Source
Porcine Epidemic Diarrhea Syndrome (PEDS)	2006-2010; recurring	Acute diarrheal disease caused by corona virus; Airborne Symptoms in adult pigs: anorexia, lethargy and diarrhea; in young pigs: vomiting and watery diarrhea.	100 percent in nursing pigs; ≥50 percent in piglets; 60,000 pigs killed (Batangas)	Batangas, Bulacan	Electrolyte replacements; biosecurity measures like quarantine of farm personnel	National hog farmer.com; CLSU n.d.
Porcine Reproductive and Respiratory Syndrome (PRRS)	2006-2009; recurring	Viral; Respiratory signs characterized by dyspnea, tachypnea and deaths are usually seen in infected piglets and grower-finishers while reproductive signs characterized by acute illness with sluggishness and anorexia are seen in sows	Affects all stages of swine, causing high morbidity and mortality, poor herd performance; 15 abortions per month for affected farms; farrowing rates were only 50-65 percent; high piglet mortalities	Commercial and smallholder swine farms in Pampanga, Bulacan, Quezon and Luzon	Mass vaccination of breeding herd followed by vaccination of piglets	Ducusin, et al,. 2015 citing various authors. CLSU n.d.; Manabat 2010
Transmissible Gastro Enteritis (TGE)	2006-2009; recurring	Caused by Coronavirus or TGEV; vomiting often is the initial sign, followed by profuse watery diarrhea, dehydration, and excessive thirst. Feces of nursing pigs often contain curds of undigested milk.	Affects all classes of pigs, including breeder stocks. Mortality is nearly 100 percent in piglets <1 wk old, whereas pigs >1 month old seldom die.	20 percent loss in value of swine production	Vaccination	CLSU n.d.
Hog Cholera or Classic Swine Fever (CSF)	2007; recurring	Highly contagious viral disease of swine that is characterized by high fever, severe depression, reluctance to eat, multiple superficial and internal hemorrhages.	Outbreak affected 3,000-5,000 sows or about 0.29 percent of total swine population	Pampanga and Bulacan	Mass vaccination; inoculation program	PigProgress 2007

Table 3.9 continued…

Swine Disease	Year Disease Occurred	Causes and Symptoms	Mortality and Morbidity Rates /Impacts	Places/Farms Affected	Treatment	Source
Foot and Mouth Disease (FMD)	1954; 1955-1959; 1965-1966; 1975;1976; 1980; 1988; 1990; 1995;1999-2005; country was declared FMD-free without vaccination in 2011 by OIE	Acute infectious viral disease of livestock causing fever, followed by the development of vesicles (blisters) chiefly in the mouth and on the feet. Causes lameness.	1 commercial farm (150 sows), 1 stock yard and 2 smallholder farms in 1976; massive outbreak in 1995 with 1,553 cases and 98,000 swine animals affected; smallholder farms in 2002-2003	27 provinces in Luzon in 1995; Panay Island; Visayas; Mindanao	National FMD Control and Eradication Plan was developed and used four components: surveillance, public awareness campaign, animal movement management, and vaccination	USDA, 1999; Abao, 2013; PigProgress 2010
Porcine Circovirus Type 2 (PCV2)	2004; New and emerging disease	Rapid weight loss in early finishing with reduced water consumption, pneumonia, diarrhea, enlarged lymph nodes, high mortality, abortion and weak born pigs	Commercial and smallholder swine farms; slaughter-houses	Pampanga, Quezon, Luzon	Vaccination	Thacker, 2013 cited by Ducusin, et al. 2015

Source: http://www.nationalhogfarmer.com/news/Porcine_disease_epidemic

Note: OIE is Office Internationale des Epizooties or Animal Health Organization

However, the majority of smallholder swine farms in the Philippines do not practice proper waste disposal and they do not have waste treatment facilities installed in their farms to treat the waste and wastewater. The market for swine waste, unlike poultry waste which is generally applied on agricultural lands as soil fertilizer, has not yet been well established in the country. The more common way to dispose of swine waste is to dump this into canals and waterways. Mortalities or dead animals are usually buried within the farm while others are burned or incinerated although the latter is not a common disposal practice (Delgado, et al., 2008; Costales, et al., 2003; Catelo, et al., 2003).

Table 3.10 shows the manner of disposing dead animals in 207 swine farms in Central Luzon, Southern Luzon, and Northern Mindanao as examined by Costales, et al. (2003). The practice of 90 percent of the smallholder independent swine farms was to bury dead animals. The majority of commercial swine farms, on the other hand, disposed dead animals by burying or incinerating them or by using open and closed pits. Burying animal mortalities within the farm premises seems to pose no serious environmental problem occurring in these farms. Swine farms are apparently aware of the environmental degradation that can possibly result with improper disposal of dead animals. On the other hand, they could be actually exercising preventive measures to protect their own inventories from contracting diseases if dead animals are not properly dealt with.

For the 40 sample swine farms in this study, the most common practice to dispose dead animals in 2002 was to bury them within the farm. This practice has been maintained in 2015 (Table 3.11). Aspile (2015) also found that burying dead animals in the farm was the most common method of disposal practiced by 94 percent of the 145 swine farms in Bulacan, Central Luzon.

Table 3.10 Manner of disposing dead animals in 207 swine farms, by size of production, Philippines, 2002.

Manner of Disposing Dead Animals	Smallholder Independent (%)	Smallholder Contract (%)	Medium Commercial (%)	Large Commercial (%)	Commercial Contract (%)
On Farm					
Buried	92	100	80	77	71
Incineration	1	0	6	6	7
Open Pit	0	0	9	2	23
Closed Pit	4	0	0	13	0
Dog feed	2	0	1	1	0
Fish feed	0	0	1	0	0
Off Farm					
Dumped in river	1	0	0	0	0
Sold as feed	0	0	2	1	0
Total	100	100	100	100	100

Source: Costales, et al. (2003)

Table 3.11 Manner of disposing dead animals in 40 sample swine farms, 2002 and 2015

Manner of Disposing Dead Animals	2002 (%)	2015 (%)
On Farm		
Buried	95	85
Incineration	1	15
Closed Pit	4	0
Total	100	100

Source: Costales, et al. (2003); survey by Author (2015)

Table 3.12 presents information on the manner of disposal of swine manure by 207 swine farms in Central Luzon, Southern Luzon, and Northern Mindanao. Costales, et al. (2003) found that only 67 percent of the sample farms cleaned up their waste through the use of impounding structures such as biogas digester, lagoon, or septic tank. Thirty-four percent of the sample swine farms disposed the manure directly into rivers and creeks by flushing it out when cleaning the pens. Others simply let the manure to dry on the ground. A few of the sample

Table 3.12 Manner of disposing swine manure in 207 swine farms, by size of production, Philippines, 2002

Manner of Disposing Swine Manure	Smallholder Independent (%)	Smallholder Contract (%)	Medium Independent (%)	Large Independent (%)	Commercial Contract (%)
On Farm					
Crops	21	4	23	23	23
Biogas	7	4	9	7	5
Off Farm					
Sold	1	0	1	3	5
Used Both On Farm and Off	1	0	4	3	2
Non-economic use					
Thrown in canal/river	3	9	0	0	0
Laid on ground	15	13	0	0	0
Open pit	20	30	0	0	0
Lagoon	20	30	62	63	65
Septic tank	13	9	1	1	0
No response	0	0	0	0	5
Total	100	100	100	100	100

Source: Costales, et al. (2003)

swine farms applied the manure on their croplands as fertilizer. Since the market for swine manure as soil fertilizer has not been established unlike in the case of poultry manure, only three percent of the sample swine farms were able to sell it.

Similar evidence on swine manure disposal is provided by old and recent studies in Southern Luzon and Central Luzon regions. Catelo, et al. (2003) found that 80 percent of the 82 farms swine farms in Majayjay, Laguna in Southern Luzon dumped the swine manure into rivers and creeks. Darvin (2005) revealed that of the 82 smallholder swine farms in three municipalities in Laguna, 20 percent flushed out swine manure into water bodies, 40 percent put it in open pits and 20 percent used it on croplands. In Bulacan province in Central Luzon, Aspile (2015) found that 10 percent of the 145 sample swine farms had biogas digesters and lagoons and less than 20 percent either sold swine manure as fertilizer or used it on their own croplands. About 20 percent had septic tanks but more than 50 percent disposed it into water bodies or on public lands. Lambon (2018)[24] did a survey in the same areas as Darvin's (2005). Of the 91 smallholder swine farms surveyed, she found that 40 percent of them disposed the swine manure directly into water bodies while 53 percent put it in open pits.

For the 40 sample swine farms in this study, more than half of them installed waste treatment facilities such as biogas digesters and lagoons (Table 3.13). In 2002, 50 percent of them installed lagoons, 5 percent put up biogas digesters, and another 5 percent installed both lagoons and biogas digesters. In 2015, the proportion of sample swine farms that installed lagoons slightly decreased to 45 percent, those who put up both lagoons and biogas digesters slightly increased to 8 percent. The other swine farms disposed the manure in 2002 and 2015 either by applying it on croplands (10 percent), throwing it into open pits (13 percent -18 percent), or flushing it out into canals and rivers (18 percent - 20 percent).

Table 3.13 Manner of disposing swine manure in 40 sample swine farms, 2002 and 2015

Manner of Disposing Swine Manure	2002 (%)	2015 (%)
On Farm		
Crops	10	10
Biogas only	5	0
Off Farm		
Sold	0	0
Used Both On Farm and Off	0	0
Non-economic use		
Thrown in canal/river	18	20
Laid on ground	0	0
Open pit	13	18
Lagoon only	50	45
Septic tank	0	0
Biogas + Lagoon	5	8
Total	100	100

Source: Costales, et al. (2003); survey by Author (2015)

[24] The research studies made by Lambon (2018) and Darvin (2005) were supervised by the Author.

It is unfortunate that between 2002 and 2015, after thirteen years, there has not been much improvement in the manner of disposing swine waste. This has implications on green growth because of the likely impacts of ill-disposed and untreated swine waste on the natural environment or on the natural asset base. Swine farms may have found it difficult to install waste treatment facilities because the cost of installing lagoons and biogas digesters is not really cheap. Smallholder swine farms spent about Php 2,000 to Php 30,000 or an average of Php 6,640 on these waste treatment facilities in 2002 (Table 3.14).

Table 3.14 Average cost of biogas digesters and lagoons, 40 sample swine farms, 2002 and 2015

Size	2002 (Php)	2015 (Php)
Smallholder		
Min	2,000	1,000
Max	30,000	25,000
Ave	6,640	4,158
Commercial		
Min	2,000	10,000
Max	150,000	200,000
Ave	28,473	36,250

Source: Costales, et al. (2003); survey by Author (2015)

Commercial swine farms, on the other hand, spent from Php 2,000 to Php 150,000 or an average of Php 28,473 on these waste treatment facilities in 2002. In 2015, smallholder and commercial swine farms also incurred relatively huge costs in putting up these waste treatment facilities. The costs of these waste treatment facilities primarily depend on the size and capacity of facilities and materials that are used to construct them. However, Table 3.15 shows that the cost of constructing a biogas digester in the Philippines seems to be relatively more expensive than what it costs in other Asian countries. Assuming a similar capacity of 4 cubic meters (4 m^3) and similar materials used to construct a biogas digester, it will cost twice as much in the

Table 3.15 Comparative cost of a 4 m^3 biogas digester in Asia, 2010

Country	Investment Cost Php	Local Currency	
Philippines, HDPED	55,000	55,000	Php
Philippines, Stacked dome	60,000	60,000	Php
Nepal	28,589	42,673	NPR
Viet Nam	24,046	8,000,000	VND
Cambodia	25,915	2,052,650	KHR
Bangladesh	21,138	26,000	BDT
Laos	26,076	4,232,000	LAK
Pakistan	28,487	43,351	PKR

Source: Feasibility Study of a National Biogas Programme on Domestic Biogas in the Philippines, SNV and Winrock International, 2010

Note: HPDED is High Density Polyethylene Digester.

Philippines than in any other Asian country that is listed in Table 3.15. The Department of Science and Technology (DOST) and the Department of Environment and Natural Resources (DENR) have been promoting the use of biogas digester (Baron, n.d.) and DOST has come up with different prototypes that have the flexibility to be sized according to preferred size by users (Appendix B).

Private firms that manufacture biogas digesters have also cheaper prototypes for micro users such as smallholder swine farms (Appendix C). Whether smallholder swine farms have access to information on this kind of waste treatment facility through government extension workers or any other source is uncertain.

In the period of 2002 to 2015, smallholder swine farms have not improved much in properly disposing swine manure or in treating it. They might not have also the incentive to do so probably because: 1) they lack the financial capability to install impounding structures like lagoons and biogas digesters; 2) they do not have access to information about waste treatment technologies and waste reduction/ minimization practices on how to better manage the swine waste; and 3) it is not easy to spot them since they are small in size and geographically dispersed unlike commercial swine farms that are easily pinpointed as the source of wastewater pollution because of their larger size. Thus, since environmental regulators or regulatory agencies[25] have difficulty attributing wastewater pollution to smallholder swine farms, the latter do not have incentive to adopt waste treatment facilities.

3.5 Conclusion

The trend in production system over the past two decades somehow indicates that swine production could be moving more toward farrow-to-finishing (FF) and grow-to-finishing (GF) types of production systems. On the other hand, the trend in animal inventory shows a scaling up or intensification[26] of production with the increasing share of commercial swine farms (36 percent) and the decreasing share of smallholder swine farms (64 percent) in the total swine population. Contract farming has emerged to be an institutional innovation with respect to production arrangement. All these changing structures in swine production have implications on the challenges for achieving green growth because of the intensity in inputs and the increase in waste that will be generated with the increase in animal population. Breeds used by swine farms over the past two decades have not changed much. But from the point of view of green growth and the aspects of resource efficiency and productivity, it is important, especially for smallholder swine farms, to be able to source out quality breeds with good genetic makeup that will ensure higher prolificacy and feed efficiency and lower mortalities. Higher feed efficiency is vital for better nutrition and disease resistance as well as for production cost reduction since feed cost still accounts for 60 percent to 80 percent of the total production cost. In terms of swine waste disposal and treatment, there is an evidence that only 50 percent to 60 percent of

[25] Environmental regulators may be government agencies such as the Laguna Lake Development Authority (LLDA) in CALABARZON Region, the Department of Environment and Natural Resources (DENR) and its regional offices and local government units (LGUs) that implement rules, regulations, and policies for safeguarding the environment from the polluting behavior of economic activities within their jurisdiction.

[26] Intensification of swine production means significantly increasing the size of animal inventory.

swine farms then and now have installed biogas digesters and lagoons because these waste treatment facilities are costly, swine farms may not have access to information regarding cheaper waste reduction/minimization[27] and waste treatment facilities, or environmental regulations are not strictly implemented and so swine farms do not have the incentive to adopt technologies to reduce or minimize waste. In relation to green growth, the environmental and resource productivity aspect of swine farms can increase if they practice waste reduction/minimization activities and are able to adopt waste treatment technologies.

[27] Refers to activities/techniques employed to minimize the generation of both liquid and solid wastes in swine farms. Waste reduction/minimization may also involve the modification of standard mechanisms applied in swine farms to reduce or minimize water usage such as the use of mechanical drinkers, etc. See Catelo, et al., (2003) for details.

Chapter 4

Determining Environmental Productivity Growth in Philippine Swine Production

4.1 Introduction

To reiterate from Chapter 1, in order to assess if smallholder swine farms can catch up with green growth, it is necessary to examine first if their productivity is increasing or if they are experiencing productivity growth because this is essential for sustainable growth and significant poverty reduction particularly in developing countries such as the Philippines. Furthermore, since negative environmental impacts are associated with swine production, this productivity growth has to be green or has to incorporate such environmental impacts so as not to produce misleading results in the productivity growth analysis. In other words, smallholder swine farms have to experience environmental productivity growth.

This chapter presents a measurement of the productivity growth of the 40 sample swine farms in the periods of 2002 and 2015. The conventional productivity growth as well as the environmental productivity growth which includes undesirable environmental impacts of swine production are estimated.

4.2 Sampling and Data Collection

In the Philippines, there are data series on swine production output but data series on swine production inputs and environmental impacts attributable to swine production are not available. So far, the only systematic and comprehensive data set on swine production that has been collected is the survey in 2002 on 100 backyard (smallholder swine farms) and commercial swine farms in the top two swine-producing regions in the Philippines: Central Luzon and South

Luzon[28]. In order to measure the environmental productivity growth of swine farms over two periods, which is the focus of the first objective of this study, a verification survey on the continued existence of swine farms 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 swine farms in Central Luzon and South Luzon swine farms were still around and still raising pigs. Twenty-nine (29) of the original sample swine farms 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 sample swine farms in period 1 (2002) and period 2 (2015) now form the balanced panel data set of this study.

4.3 Data Analysis Method

In order to achieve the first objective of this study, the focus is to measure the environmental productivity growth in swine production. The original intent of this study was to use the parametric approach. This is in recognition of the advantage of econometric methods over non-parametric approaches in terms of allowing for statistical inference, hypothesis testing, calculation of confidence levels, and the imposition of fewer restrictions regarding the assumptions about the technology. The parametric empirical approach also allows for the derivation of productivity measurement and its causal factors using only a one-step procedure that typically involves fitting parameters into a system of equations (Teruel, et al. 2014). However, the parametric approach is very strict with respect to data requirements as compared

[28] This survey was part of a collaborative project (see Delgado, et al. 2008) of the International Food Policy Research Institute (IFPRI), the Food and Agriculture Organization (FAO) of the UN, and the University of the Philippines Los Baños entitled, "Livestock Industrialization, Trade and Social-Health-Environment Impacts in Developing Countries". The project was funded by the Department for International Development (DFID-UK) through the Livestock, Environment, and Development (LEAD) initiative at FAO. The author was a co-collaborator of this project.

to non-parametric approaches. As Cabailla, et al. (2014) also point out, there are no time series data on farm inputs for swine production in the Philippines that could complement the time series data on output, both of which could be used for productivity growth estimation. The balanced panel data set of 40 sample swine farms that was mentioned in Section 4.2 for two periods may not be sufficient for a parametric approach to measuring and explaining productivity growth. Thus, the best alternative is to estimate the environmental productivity growth over two periods using non-parametric frontier methods. The use of non-parametric frontier methods such as index number methods is resorted to so that output and input indexes could be constructed which will then allow for the construction of productivity index numbers (Rao, et al., 2004). Moreover, the true production frontier is not commonly known in practice and it is generally estimated if there is sufficient data (Rao, et al., 2004). But if data is not sufficient, as in the case of swine production in the Philippines, the use of non-parametric frontier methods has the advantage of being more flexible than other productivity-estimating techniques (e.g., Stochastic Production Frontier or SPF) because there is no *a priori* technology function required, no limitations on the returns to inputs, inefficiency in production can be captured, and a standard baseline for comparison can be provided (Barros & Managi 2009 as cited by Yu-Ying Lin, et al., 2013; Coelli, et al., 2003).

Among non-parametric frontier approaches available, the more commonly used Törnqvist productivity index is a superlative index and provides computational convenience for decomposing the sources of productivity growth (Dumagan & Ball 2009) of economic sectors. However, it requires price data and cannot include environmental impacts that usually are non-marketed and non-priced (Ball, et al., 2004). Hence, this study makes use of the Malmquist Productivity Index (MPI).

4.3.1 Basic Concepts of Efficiency Change and Technical Change

The Malmquist Productivity Index (MPI) measures changes or growth in productivity over time. When panel data is available, MPI can be decomposed into its components which indicate efficiency change (EC) and technical change (TC) as shown by Färe, et al. (1998). But before focusing on the MPI, it is important to explain the basic concepts of efficiency change and technical change since they provide insights as to the possible causes of productivity change.

Production frontiers have customarily been used to measure efficiency change, technical change, and change in productivity (Worthington, 2000). Following Färe, et al. (1998), Figure 4.1 presents production frontiers (PF) for two periods, *t* and *t*+1 for the simple case of a one-input, and one-output technology.

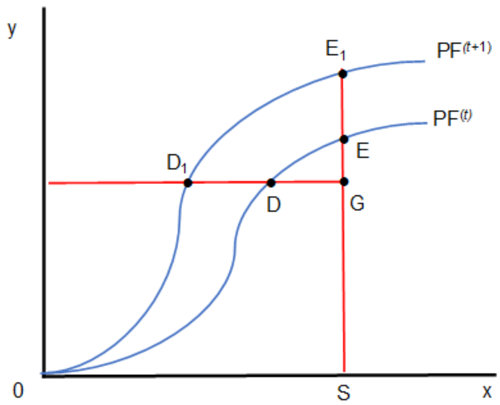


Figure 4.1 Efficiency change and technical change

Source: Modified from Rao, et al. (2004)

The production frontier is a locus of points illustrating the efficient level of output (*y*) that can be potentially produced by a given level of input (*x*). As applied to swine production, for any given swine farm in period *t*, efficiency refers to the ability of a swine farm to use minimal amount of input in order to produce a given level of output, relative to best practice which is defined by the production frontier. A swine farm that is able to achieve an input-output combination that lies on its production frontier is said to be technically efficient but if its input-output combination falls below or beneath the production frontier, it is said to be technically inefficient.

For example, using $PF^{(t)}$ as reference, for a given input level S, the distance SE shows the maximum output level that can technically be produced using period *t* technology. If the actual production of a swine farm is at a level given by SG, then an output-oriented measure of efficiency (Farrell, 1957) for this swine farm can be inferred by the vertical distance ratio SG/SE whose value will be between zero and one, with one indicating efficiency. On the other hand, an input-oriented measure of efficiency (Farrell, 1957) for this swine farm is given by the horizontal distance ratio 0D/0G which implies the level of input reduction that is feasible to enable this swine farm to produce the same output level and achieve efficiency at time *t*. Under the assumption that the underlying technology (frontier) exhibits constant returns to scale (CRS), the input-oriented and output-oriented measures of efficiency will coincide (Bampatsou, et al., 2017; Ball, et al., 2004; Rao, et al., 2004; Umetsu, et al. 2003; Worthington, 2000; Caves, et al., 1982).

Over time, the level of output that a swine farm can produce may increase due to improvements in technology that can affect the swine farm's ability to combine outputs and inputs in an optimal manner. These technological improvements can shift the production frontier upward from $PF^{(t)}$ in period *t* to $PF^{(t+1)}$ in period *t*+1. This additional source of possible improvements in productivity is known as technical change and is measured by the shift in the production frontiers. Technical change measurement will vary depending on the input (or output) level at which it is measured. For example, in Figure 4.1, an output-oriented technical change measure is given by the vertical distance ratio SE_1/SE whose value is greater than one which implies technical progress. On the other hand, an input-oriented technical change measure is given by the horizontal distance ratio $0D/0D_1$. Thus, for any swine farm, the two sources of productivity change or growth may be either efficiency change (EC) or technical change (TC).

4.3.2 Input-oriented Distance Function

The Malmquist Productivity Index (MPI) evaluates productivity change or productivity growth by means of ratios of multiplicative distance functions which have to be computed. The formulation of multiplicative distance functions to production theory is attributed to Shephard (1953, 1970)[29]. The use of multiplicative distance functions enables the description of a multi-input, multi-output production technology without the need for specifying whether the behavioral objective of swine farms is to minimize cost or maximize profit (Rao, et al., 2004). An input-oriented distance function considers a minimal proportional reduction of the input vector, within the context of a given output vector. It implicitly assumes cost-minimizing behavior of swine farms. On the other hand, an output-oriented distance function considers a maximal proportional expansion of the output vector, within the context of a given input vector. It implicitly assumes a revenue-maximizing behavior of swine farms. This dissertation considers an input-oriented distance function because it seems more plausible to assume that swine farmers have budget constraint and would, thus, minimize costs.

The starting point in expressing the Malmquist Productivity Index (MPI) in terms of distance functions is to represent the true but essentially unknown production technology of swine farms as the set of all feasible input and output vectors for time period *t*. This production

[29] For a comprehensive review of distance functions and efficiency measurement, see Pastor & Aparicio (2010). They cited Russel (1998) who claimed that the formulation of distance functions was actually started by Debreu (1951) but because he was unable to develop a duality which Shephard (1953) did, it was Shepard who became recognized for distance functions. Malmquist (1953) introduced the same notion to consumer theory (Pastor & Aparicio, 2010).

set is built from the data and it derives from the observations that appear to be the "best" in the data set (Deprins and Simar, 1983). Let $\mathbf{x}^t = (x_1^t, x_2^t, \ldots, x_N^t)$ be an input vector in period t with $i = 1,\ldots, N$ inputs and $\mathbf{y}^t = (y_1^t, y_2^t, \ldots, y_M^t)$ be an output vector in period t with $j = 1,\ldots, M$ outputs where $\mathbf{x}^t \in \Re_+^N$, and $\mathbf{y}^t \in \Re_+^M$. Thus, the production set at period t in which productivity change is calculated and which contains all feasible output-input vectors in period t may be represented by Q^t where:

$$Q^t = \{(\mathbf{x}^t, \mathbf{y}^t): \mathbf{x}^t \text{ can produce } \mathbf{y}^t\} \qquad \text{(Equation 4.1)}$$

Furthermore, the input set associated with Q^t which gives all the feasible input vectors, $\mathbf{x}^t \in \Re^N_+$ that can produce the output vector, $\mathbf{y}^t \in \Re^M_+$ is expressed as

$$L^t(\mathbf{y}^t) = \{\mathbf{x}^t : (\mathbf{x}^t, \mathbf{y}^t) \in Q^t\}, \qquad t = 1, \ldots, T \qquad \text{(Equation 4.2)}$$

The input set is assumed to be closed, bounded, convex, and with strong disposability of inputs and outputs[30]. Constant returns to scale (CRS) is also assumed and that Q^t satisfies other axioms specified by Shephard (1970) for the construction of meaningful input distance functions.

Shephard (1970) described isoquants in terms of input-oriented distance functions[31] in period t as:

$$D_I^t(\mathbf{y}^t,\mathbf{x}^t) = [\mathbf{min}\{\lambda: (\mathbf{x}^t/\lambda) \in L^t(\mathbf{y}^t)\}]^{-1} \quad t = 1, \ldots, T \qquad \text{(Equation 4.3)}$$

where $D_I^t(\mathbf{y}^t,\mathbf{x}^t)$ estimates the maximum possible contraction of $\mathbf{x}^t$ that the production unit should realize to produce same output $\mathbf{y}^t$ in an efficient way. The maximum input deflation factor is denoted by λ. The input orientation of the distance function is denoted by the subscript I. The input-oriented distance function takes a value greater than or equal to 1 for $(\mathbf{x}^t,\mathbf{y}^t) \in L^t$.

[30] Strong disposability of inputs and outputs means that disposal of excess or surplus inputs and outputs is free. But Grosskopf (2002) claims that this assumption can be relaxed.

[31] Shephard (1970) also described isoquants in terms of output-oriented distance functions but the focus of this dissertation is only on input-oriented distance functions.

Farrell's (1957) input-oriented measure of efficiency, which varies between zero and 1, is actually the inverse of Shephard's input-oriented distance function and is expressed as

$$F_I^t\,(\mathbf{y}^t, \mathbf{x}^t) = \ \mathbf{min}\{\lambda\text{: } \lambda\mathbf{x}^t \in L^t(\mathbf{y}^t)\} \quad t = 1, \ldots, T \qquad \text{(Equation 4.4)}$$

where F_I^t ($\mathbf{y}^t$,$\mathbf{x}^t$) estimates the minimum possible expansion of $\mathbf{x}^t$ that the production unit should realize to produce same output $\mathbf{y}^t$ in an efficient way. The minimum input inflation factor is denoted by λ. F_I^t ($\mathbf{y}^t$, $\mathbf{x}^t$) is a radial measure of the distance between a unit ($\mathbf{y}^t$, $\mathbf{x}^t$) and L^t ($\mathbf{y}^t$). It requires information on input and output but does not require input prices nor does it require behavioral assumptions on swine farmers.

Figure 4.2 is used to illustrate the input-oriented Farrell measure of efficiency and Shephard's input-oriented distance function for a two-input case. L^t($\mathbf{y}^t$) is a piecewise linear isoquant that represents the frontier technology in period *t*. Assuming constant returns to scale, swine farms producing at points G and B are efficient but swine farm producing at point g is not efficient since g lies inside the input requirement set. Farrell input-oriented measure of efficiency in period *t*, in terms of distance, is given by 0b/0g and Shephard's input-oriented

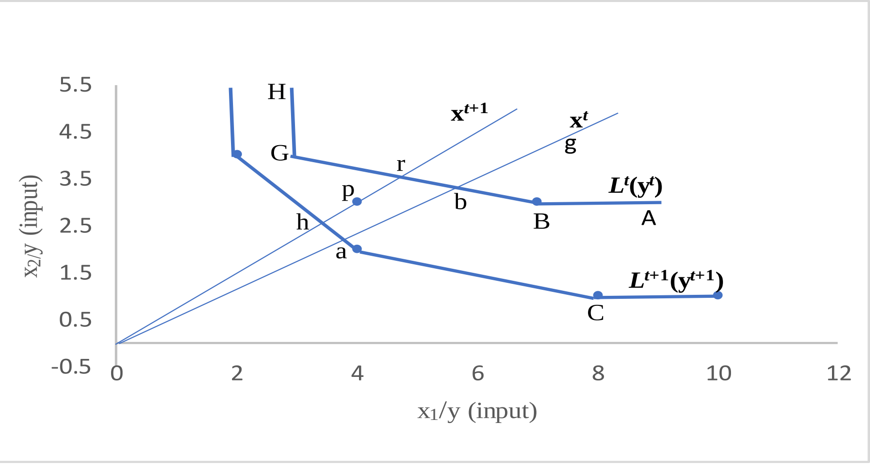


Figure 4.2 Input-oriented distance function and the Malmquist Productivity Index

Source: Modified from Umetsu, et al. (2003)

distance function is the inverse which is given by 0g/0b. Linear programming technique (Färe, et al., 1998; Charnes, et al., 1978) may be used to evaluate observations (i.e., swine farms) in period t relative to the reference (frontier) technology, $L^t(\mathbf{y}^t)$, in period t.

4.3.3 Malmquist Productivity Index

To reiterate from Section 4.3.2, the Malmquist Productivity Index (MPI), which is defined using multiplicative distance functions, measures the change in productivity between two data points (e.g., those of swine farms in two time periods). The ratio of the distances of each data point relative to a reference (frontier) technology is calculated. Following Färe, et al. (1998), and assuming CRS, in order to estimate the MPI from period t to t+1, additional input-oriented distance functions have to be calculated and this implies solving the following additional linear programming problems[32]:

$$D_I^t(\mathbf{y}^{t+1}, \mathbf{x}^{t+1}) = \mathbf{max}\{\lambda: (\mathbf{x}^{t+1}/\lambda) \in L^t(\mathbf{y}^{t+1})\} \quad \text{(Equation 4.5)}$$

$$D_I^{t+1}(\mathbf{y}^t, \mathbf{x}^t) = \mathbf{max}\{\lambda: (\mathbf{x}^t/\lambda) \in L^{t+1}(\mathbf{y}^t)\} \quad \text{(Equation 4.6)}$$

$$D_I^{t+1}(\mathbf{y}^{t+1}, \mathbf{x}^{t+1}) = \mathbf{max}\{\lambda: (\mathbf{x}^{t+1}/\lambda) \in L^{t+1}(\mathbf{y}^{t+1})\} \quad \text{(Equation 4.7)}$$

The distance function $D_I^{t+1}(\mathbf{y}^{t+1}, \mathbf{x}^{t+1})$ measures the efficiency of the observation at period t+1 relative to the frontier technology at period t. On the other hand, the distance function $D_I^{t+1}(\mathbf{y}^t, \mathbf{x}^t)$ measures the efficiency of the observation at period t relative to the frontier technology at period t+1. These two distance functions are termed as mixed or cross-period distance functions and can take values of less than, more than, or equal to 1 (Umetsu, et al. 2003). Referring to Figure 4.2, the input requirement set for period t+1 is shown by $L^{t+1}(\mathbf{y}^{t+1})$. $D_I^t(\mathbf{y}^{t+1}, \mathbf{x}^{t+1})$ is given by 0p/0r and $D_I^{t+1}(\mathbf{y}^t, \mathbf{x}^t)$ is given by 0g/0a. $D_i^{t+1}(\mathbf{y}^{t+1}, \mathbf{x}^{t+1})$ is 0p/0h.

[32] Details of these additional linear programming problems can be seen from Umetsu, et al. (2003); Rao, et al. (2004).

Following Färe, et al. (1998), and given the four input-oriented distance functions above, the input-oriented Malmquist Productivity Index between period *t* and *t*+1 can now be defined as:

$$MPI_I{}^{t+1}(\mathbf{y}^{t+1},\mathbf{x}^{t+1},\ \mathbf{y}^{t},\mathbf{x}^{t}) = \left[\frac{D_I^t(\mathbf{y}^{t+1},\mathbf{x}^{t+1})}{D_I^t(\mathbf{y}^{t},\mathbf{x}^{t})} \cdot \frac{D_I^{t+1}(\mathbf{y}^{t+1},\mathbf{x}^{t+1})}{D_I^{t+1}(\mathbf{y}^{t},\mathbf{x}^{t})}\right]^{1/2}$$

(Equation 4.8)

The first ratio represents the Malmquist Productivity Index for period *t*, which indicates the production point for the first period using period *t* as the benchmark technology and measuring productivity change from period *t* to period *t*+1. The second ratio represents the Malmquist Productivity Index for period *t*+1 and indicates the most recent production point ($\mathbf{x}^{t+1}$, $\mathbf{y}^{t+1}$) using period *t*+1 technology. It measures productivity changes from period *t* to period *t*+1 using technology level at period *t*+1 as benchmark.

The Malmquist Productivity Index can also be decomposed into efficiency change and technical change.

$$MPI_I{}^{t+1}(\mathbf{y}^{t+1},\mathbf{x}^{t+1},\ \mathbf{y}^{t},\mathbf{x}^{t}) = \frac{D_I^{t+1}(\mathbf{y}^{t+1},\mathbf{x}^{t+1})}{D_I^t(\mathbf{y}^{t},\mathbf{x}^{t})} \cdot \left[\frac{D_I^t(\mathbf{y}^{t+1},\mathbf{x}^{t+1})}{D_I^{t+1}(\mathbf{y}^{t+1},\mathbf{x}^{t+1})} \cdot \frac{D_I^t(\mathbf{y}^{t},\mathbf{x}^{t})}{D_I^{t+1}(\mathbf{y}^{t},\mathbf{x}^{t})}\right]^{1/2}$$

(Equation 4.9)

The first term indicates the efficiency change from period *t* to *t*+1. The second term indicates the technical change or a shift in the frontier from period *t* to period *t*+1. The second term is actually the geometric mean of the two distance functions indexes. The geometric mean is a type of average that is usually used for growth rates. For example, to find the geometric mean of two values, the product of these two values are calculated and then the square root of the product is taken since there are only two values. The advantage of using the geometric mean over the arithmetic mean is that it makes the ratios of two values equal. MPI is the product of efficiency change and technical change.

When the values of the MPI are less than 1, more than 1, or equal to 1, then these values are interpreted as deterioration in productivity, growth in productivity, or stagnant productivity, respectively. The values of the MPI can be explained by the values of the efficiency change and technical change.

For the first objective of this dissertation, two types of MPIs are estimated: Conventional MPI (CMPI) and the Environmentally Sensitive MPI (ESMPI). Details of the CMPI and ESMPI are discussed in the next section.

4.3.4 Data Envelopment Analysis (DEA), CMPI, and ESMPI

Data Envelopment Analysis (DEA) is a non-parametric programming technique that was developed by Charnes, et al. (1978). DEA is used to evaluate the performance of swine farms. A main advantage of DEA over other approaches is that it can work with both multiple inputs and multiple outputs even without specifying whether swine farms aim for cost minimization or profit maximization' (Rao, et al. 2004). Thus, it is suitable for analysis of multiple swine output (i.e., weanlings, growers, finishing pigs) produced from different production systems as discussed in Chapter 3 of this dissertation. Moreover, there is no need to impose a specific functional form on the model for the production process (Rao, et al., 2004) unlike in the use of parametric approaches like the Stochastic Production Frontier approach which would require it.

For this study, the Data Envelopment Analysis (DEA)-based CMPI involves the construction of an efficiency frontier with respect to the technology of the initial period and uses input and output data over the whole panel data of 40 sample swine farms who 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 (period t) and for the year 2015 (period t+1). All DMUs are compared with the best performing DMUs. The ratio of the respective distance functions gives the CMPI. Moreover, in order to avoid problems in choosing the benchmark, the CMPI is specified as the geometric mean of the two distance function indexes (Ball, et al., 2004).

Applying Equation 4.8 onto Equation 4.10, CMPI is the input-oriented Conventional Malmquist Productivity Index of the 2015 production point (*t*+1) relative to the 2002 production point (*t*); **y** is the vector of output; **x** is the vector of inputs; and $D_I^t(\mathbf{y}^t, \mathbf{x}^t)$ and $D_I^t(\mathbf{y}^{t+1}, \mathbf{x}^{t+1})$ are the input-oriented distance functions. The input orientation of CMPI is denoted by the subscript I.

The first ratio of Equation 4.10 represents the Malmquist Productivity Index for the first period (*t*) or 2002, which indicates the production point ($\mathbf{y}^t$, $\mathbf{x}^t$) for the first period using period *t* as the benchmark technology and measuring conventional productivity change from 2002 to 2015. The second ratio of Equation 4.10 represents the Malmquist Productivity Index for period *t*+1 or 2015 and indicates the most recent production point ($\mathbf{y}^{t+1}$, $\mathbf{x}^{t+1}$) using period *t*+1 technology. It measures conventional productivity change from period *t* to period *t*+1 using technology level at period *t*+1 as benchmark.

$$CMPI_I{}^{t+1}(\mathbf{y}^{t+1}, \mathbf{x}^{t+1},\ \mathbf{y}^t, \mathbf{x}^t\ ) = \left[\frac{D_I^t(\mathbf{y}^{t+1}, \mathbf{x}^{t+1})}{D_I^t(\mathbf{y}^t, \mathbf{x}^t)} \cdot \frac{D_I^{t+1}(\mathbf{y}^{t+1}, \mathbf{x}^{t+1})}{D_I^{t+1}(\mathbf{y}^t, \mathbf{x}^t)}\right]^{1/2}$$

(Equation 4.10)

Similar to Equation 4.9, CMPI can be decomposed into efficiency change and technical change as presented in Equation 4.11:

$$CMPI_I(\mathbf{y}^{t+1}, \mathbf{x}^{t+1},\ \mathbf{y}^t, \mathbf{x}^t\ ) = \frac{D_I^{t+1}(\mathbf{y}^{t+1}, \mathbf{x}^{t+1})}{D_I^t(\mathbf{y}^t, \mathbf{x}^t)} \cdot \left[\frac{D_I^t(\mathbf{y}^{t+1}, \mathbf{x}^{t+1})}{D_I^{t+1}(\mathbf{y}^{t+1}, \mathbf{x}^{t+1})} \cdot \frac{D_I^t(\mathbf{y}^t, \mathbf{x}^t)}{D_I^{t+1}(\mathbf{y}^t, \mathbf{x}^t)}\right]^{1/2}$$

(Equation 4.11)

On the right-hand side of Equation 4.11, the first term outside the square brackets is a measure of efficiency change (CEC) between the two periods (*t* and *t*+1), while the second term in square bracket measures the technical change (CTC). Thus, the Conventional Malmquist Productivity Index (CMPI) is also the product of Conventional Efficiency Change (CEC) and Conventional Technical Change (CTC).

Conventional Efficiency Change (CEC) reflects the capability of swine farms in 'catching up' with efficient ones between the periods 2002 and 2015. It measures whether swine farms have gotten closer to or farther away from the frontier over time. Conventional Technical Change (CTC) 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 (Briones 2014). The first ratio inside the CTC bracket evaluates the shift in the frontier at the data observed in period t+1 (2015) while the second ratio inside the CTC bracket captures the shift in the frontier evaluated at the data observed in period t (2002). If CEC > CTC, then productivity gains are primarily the result of an improvement in efficiency. If CEC < CTC, then productivity gains are primarily the result of technological progress (Charnes, et al. 1978).

If CMPI >1, this implies that the swine farm is efficient, increasing its productivity over time. If CMPI < 1, then productivity of the swine farm 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.

For estimating the Environmentally Sensitive Malmquist Productivity Index (ESMPI), the environmental impacts arising from swine production are incorporated and treated as additional input vectors, $\mathbf{z}^t$ for period t and $\mathbf{z}^{t+1}$ for period t+1 since the environment is asserted to serve as waste sink into which swine farms dispose of the non-marketed environmental by-products. As such, the conventional input-oriented distance functions are modified to reflect the addition of these environmental impact vectors. Furthermore, the modified conventional input-oriented distance functions now correspond to the environmentally sensitive input-oriented distance functions from which the Environmentally Sensitive Malmquist Productivity Index (ESMPI) can be derived.

ESMPI is similar to CMPI but with the inclusion of the input vectors of environmental impacts, $\mathbf{z}^t$ and $\mathbf{z}^{t+1}$, as follows:

$$ESMPI_I(\mathbf{y}^{t+1}, \mathbf{x}^{t+1}, \mathbf{z}^{t+1}\ \ \mathbf{y}^t, \mathbf{x}^t, \mathbf{z}^t)$$

$$= \frac{D_I^{t+1}(\mathbf{y}^{t+1},\mathbf{x}^{t+1},\mathbf{z}^{t+1})}{D_I^{t}(\mathbf{y}^{t},\mathbf{x}^{t},\mathbf{z}^{t})} \cdot \left[\frac{D_I^{t}(\mathbf{y}^{t+1},\mathbf{x}^{t+1},\mathbf{z}^{t+1})}{D_I^{t+1}(\mathbf{y}^{t+1},\mathbf{x}^{t+1},\mathbf{z}^{t+1})} \cdot \frac{D_I^{t}(\mathbf{y}^{t},\mathbf{x}^{t},\mathbf{z}^{t})}{D_I^{t+1}(\mathbf{y}^{t},\mathbf{x}^{t},\mathbf{z}^{t})}\right]^{1/2} \quad \text{(Equation 4.12)}$$

Input vectors of environmental impacts for period *t* and period *t*+1 consist of nitrogen (N), phosphorus (P), and BOD loading which are considered as undesirable inputs since they serve as pollutants to soil and water.

On the right-hand side of Equation 4.12, the first term is a measure of the Environment Efficiency Change (EEC) between the two periods (*t* and *t*+1), while the second term in square bracket measures the Environment Technical Change (ETC). Thus, the Environmentally Sensitive Malmquist Productivity Index (ESMPI) is also the product of Environment Efficiency Change and Environment Technical Change.

Environment Efficiency Change (EEC) reflects the capability of swine farms in 'catching up' with efficient ones in the period of 2002 to 2015 in terms of adopting waste treatment facilities. It measures whether swine farms have gotten closer to or farther away from the frontier over time. Environment Technical Change (ETC) measures the shift in the technology frontier in the periods of 2002 and 2015 that may come from technology improvements in waste treatment facilities which in turn can arise from increased public investments in agricultural research, development, and extension (Briones 2014). The first ratio inside the ETC bracket evaluates the shift in the frontier at the data observed in period *t*+1

(2015) while the second ratio inside the ETC bracket captures the shift in the frontier evaluated at the data observed in period *t* (2002). If EEC > ETC, then productivity gains are primarily the result of an improvement in efficiency. If EEC < ETC, then productivity gains are primarily the result of technological progress (Charnes, et al. 1978).

If the value of ESMPI is >, =, or < 1, then it implies that between the two periods, there has been increasing, stagnating, or decreasing productivity, respectively, inclusive of environmental impacts. Increasing productivity can also come from increased innovation through the adoption of waste treatment technologies that contract environmental impacts along with purchased inputs and expand marketed outputs.

The CMPI and ESMPI and their respective components of efficiency change and technical change for each of the 40 sample swine farms are then compared in order to determine whether the CMPI of each swine farm is overstated or understated. CMPI is overstated if its value is less than that of the corresponding ESMPI and vice-versa.

Table 4.1 presents output, inputs, and environmental impact variables used to construct CMPI and ESMPI in the study. Appendix C gives the details and assumptions of the computations of the variables.

Table 4.1 Description of variables used for CMPI and ESMPI

Variable	Description
Output ($\mathbf{y}_i$)	Total weight of swine sold and unsold (kg/cycle)
Inputs ($\mathbf{x}_i$)	
Feeds	Feeds purchased (kg/cycle)
Labor	Sum of hired, operator, and family labor/cycle)
Water	Liter/cycle
Capital	
Housing	Animal housing and storage facilities (m^2)
Waste Treatment Facilities	Biogas digesters and lagoons (m^2)
Land	Size of cropland for swine manure application (hectare)
Environmental Impact Variables ($\mathbf{z}_i$)	
BOD Loading	Biological Oxygen Demand (kg/cycle)
Nitrogen Loading	Net nitrogen loading from swine waste (kg/ha)
Phosphorus Loading	Net phosphorus loading from swine waste (kg/ha)

Source: Author (2019)

4.4 Results and Discussion

4.4.1 Descriptive Statistics

Table 4.2 shows that 32 out of the 40 sample swine farms were managed by independent swine farms and only 8 sample swine farms were contract swine farms. Size-wise, the proportion of small swine farms (52 percent) was almost equal to that of large or commercial swine farms (48 percent) in the sample. The results of the analysis of variance (ANOVA) tests indicated significant differences in the means of output and input variables among the 4 categories of swine farms particularly for the period 2015. In the previous section, the Malmquist Productivity Indexes were defined relative to a reference technology in the period of 2002 to 2015 and also adjusted for environmental impacts. With this information, the measurement of productivity growth over the two periods was decomposed into efficiency change (the ‘catching-up’ effect) and technical change (the ‘frontier shift’ effect). Table 4.2.

Table 4.2 Data summary statistics of output and input variables, by category of swine farms

Variables	Smallholder Independent (*n*=19)	Smallholder Contract (*n*=2)	Commercial Independent (*n*=13)	Commercial Contract (*n*=6)	Average (*n*=40)	ANOVA F-Value
Output (kg) 2002	5,591	4,528	12,322	21,587	10,125	1.40^{ns}
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^{ns}
Feeds (kg) 2015	1,518	7,198	13,883	35,190	10,871	6.78^{*}
Labor (person) 2002	4	5	8	5	5	2.24^{ns}
Labor (person) 2015	2	1	8	4	4	9.05^{*}
Water (liter) 2002	27,612	14,783	32,003	65,201	34,036	0.62^{ns}
Water (liter) 2015	2,277	10,797	20,824	52,785	16,307	6.78^{*}
Housing (m^2) 2002	333	68	872	314	492	0.72^{ns}
Housing (m^2) 2015	34	899	1,183	384	503	4.34^{*}
Land (ha.) 2002	0.37	0.88	0.75	0.41	0.52	1.34^{ns}
Land (ha.) 2015	0.47	1.25	1.37	2.66	1.13	9.05^{*}
Waste Treatment Facility (m^2) 2002	15	9	83	193	64	1.28^{ns}
Waste Treatment Facility (m^2) 2015	13	9	107	74	53	3.00^{*}

Source: Author’s computations (2019)
Note: * denotes statistical significance (*p* value $\leq .05$), ns - not significant

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 farms. In general, marketed output and important inputs such as feeds, labor, and water had decreased in the period of 2002 to 2015. Consequently, it is expected that a conventional productivity index would show decrease in productivity growth at the aggregate level. This aggregation, may not show an inter-farm variation and some farms may actually exhibit a productivity growth.

On the other hand, Table 4.3 shows the generally declining trend of the three environmental impact indicators at the aggregate level. However, there was a divergent path of the environmental impact indicators among swine farm categories which made it difficult to establish an expected relationship between the Conventional Malmquist Productivity Index and the Environmentally Sensitive Malmquist Productivity Index.

Table 4.3 Environmental indicators in 2002 and 2015 by category of swine farms

Environmental Indicator	Smallholder Independent (*n* =19)	Smallholder Contract (*n* =2)	Commercial Independent (*n* = 13)	Commercial Contract (n=6)	Average (*n* =40)	ANOVA F-Value
BOD Loading (kg) 2002	2,662	557	7,652	4,150	4,402	1.17^{ns}
BOD Loading (kg) 2015	696	9,018	5,636	3,632	3,158	6.64^{*}
Nitrogen Loading (kg ha^{-1}) 2002	861	605	2,210	1,329	1,357	1.85^{ns}
Nitrogen Loading (kg ha^{-1}) 2015	356	501	2,158	1,293	1,089	5.27^{*}
Phosphorus Loading (kg ha^{-1}) 2002	383	287	1,110	430	622	1.42^{ns}
Phosphorus Loading (kg ha^{-1}) 2015	95	276	1,017	1,212	571	4.08^{*}

Source: Author's estimations (2019)

Note: * denotes statistical significance (p value $\leq .05$), ns - not significant

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

This study estimated an Environmentally Sensitive Malmquist Productivity Index (ESMPI) for swine production and then compared it with an estimated Conventional Malmquist Productivity Index (CMPI) so that the influence of incorporating environmental impacts on measured productivity growth in swine production could be determined. The nature and extent of productivity growth and efficiency in swine production can be also determined from the comparison of the results of the ESMPI and CMPI estimations. In general, if CMPI is greater than ESMPI, then the conventionally measured productivity growth is said to be overstated because environmental impacts such as increases in BOD level in the wastewater of swine farms as well as increases in nitrogen (N) and phosphorous (P) loadings from swine manure have not been included. If CMPI is less than ESMPI, this means that productivity growth is understated by CMPI since reductions in BOD level in the wastewater from sample swine farms and reductions in N and P loadings arising from the use of waste treatment facilities by sample swine farms have not been accounted for. Table 4.4 presents aggregate results of estimating productivity growth based on a panel data of 40 sample swine farms in the period of 2002 to 2015 using CMPI and ESMPI. The results are arranged in ascending order of CMPI. Over-

Table 4.4 CMPI and ESMPI, 40 sample swine farms, 2002 and 2005

Farm No.	Category of Swine Farm	Conventional MPI (CMPI)	Conventional Efficiency Change (CEC)	Conventional Technical Change (CTC)	Environment-ally Sensitive MPI (ESMPI)	Environment Efficiency Change (EEC)	Environment Technical Change (ETC)	Remarks on CMPI
1	Smallholder Independent	0.517	1.000	0.517	0.704	1.111	0.633	understated
2	Smallholder Independent	0.520	1.000	0.520	0.520	1.000	0.520	
3	Smallholder 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	Smallholder 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	Smallholder Independent	0.686	1.000	0.686	0.686	1.000	0.686	
9	Smallholder 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	Smallholder 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	Smallholder Independent	0.890	1.000	0.890	0.844	0.900	0.938	overstated
20	Smallholder Independent	0.891	1.000	0.891	0.938	1.106	0.847	understated
21	Smallholder 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	Smallholder 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	Smallholder Independent	0.970	1.000	0.970	1.022	1.111	0.920	understated
26	Smallholder 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	Smallholder Independent	0.999	1.000	0.999	0.999	1.000	0.999	
29	Smallholder 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	Smallholder Independent	1.061	1.000	1.061	1.118	1.111	1.007	understated
32	Smallholder 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	Smallholder 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	Smallholder 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	Smallholder Independent	1.283	1.111	1.154	1.157	1.111	1.041	overstated
39	Smallholder 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	0.880	1.000	0.880	0.870	1.000	0.870	
	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	

Source: Author's estimations (2019)

all geometric mean of CMPIs for the entire sample was only 0.88 which is less than 1.0. This implies that, on average, the conventional productivity growth of swine farms, as a group, had decreased in the period of 2002 to 2015. The average values of CMPIs by category of sample swine farms are presented in Table 4.5. The CMPIs were also decomposed into the Conventional Efficiency Change (CEC) and the Conventional Technical Change (CTC). Although there were absolute differences in the average levels of the CMPIs and their components, these differences were not statistically significant across the categories of swine farms.

Table 4.5 Estimates of CMPI by category of swine farms

Category	CMPI	CEC	CTC
Smallholder Independent (*n*=19)	0.878	0.998	0.876
Smallholder 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

Source: Author’s estimations (2019)

At the individual swine farm level, however, the conventional productivity growth rates varied from a range of 0.1 percent to 52.3 percent but only 12 of the 40 sample swine farms (30 percent) had the conventional productivity growth in the period of 2002 to 2015. These were Farm Nos. 29 to 40 in Table 4.4. 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 sample swine farms would show significantly higher levels for the 12 swine farms (Table 4.6).

A further look into the salient characteristics of inputs and outputs of these top 12 swine farms that achieved conventional productivity growth show that of these farms,

Table 4.6 Difference in CMPI, CEC, and CTC between 12 swine farms that achieved increases in Conventional Productivity growth and those that did not

Category	CMPI	CEC	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

Source: Author's estimations (2019)

Note: * denotes statistical significance ($p \leq .05$)

Table 4.7 Characteristics of inputs and outputs of 12 swine farms that achieved increases in Conventional Productivity growth

Category	CEC	CTC	Output 2002	Output 2015	Feed 2002	Feed 2015	Land 2002	Land 2015	Labor 2002	Labor 2015
Smallholder Independent (*n*=5)	1.022	1.114	1,302	885	4,893	2,271	0.48	0.74	5	1
Smallholder 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

Source: Author's estimations (2019)

Note: * denotes statistical significance (p value $\leq .05$); ns-not significant

three (3) or 25 percent were commercial independent farms, two (2) were smallholder contract farms, and another two (2) were commercial contract farms (Table 4.7). Going back to Table 4.4, it can be seen that the highest CMPI of 1.523 (or 52.3 percent increase) was achieved by a commercial contract swine farm. In terms of output, the top 12 swine farms, as a group, had only 11 percent average decrease in output in the period of 2002 to 2015 as compared to the rest of the 40 sample swine farms which had an average decrease in output of almost 60 percent.

What is not shown in Table 4.7 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. 40 in Table 4.4) increased its output by 5 times (5x) in the period of 2002 to 2015. In terms of the important inputs such as feeds, Farm No. 40 increased its use of feed by 3 times (3x) between the periods 2002 and 2015. The general trend for the rest of the top 12 swine farms was also a reduction in the use of feed by an average of 53 percent, 27 percent, and 42 percent for small independent farms, smallholder contract farms, and commercial independent farms, respectively.

For the rest of the 40 sample swine farms, the decrease in the use of feed went down by as much as 66 percent on average. Use of labor also decreased for the top 12 swine farms with smallholder independent swine farms and smallholder contract swine farms having the largest decrease of about 77 percent on average. The rest of the 40 sample swine farms had the least reduction in labor of only 18 percent on average. As for the land input, the general trend for the top 12 swine farms was in the upward direction with commercial contract swine farms having the largest increase by 92 percent on average.

Since the change in 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 4.4, the increase in CEC ranged from 1.058 to 1.111 or an increase of 5.8 percent-11.1 percent. But only three (3) of the 40 swine farms achieved this growth - Farm Nos. 33, 35 and 38 in Table 4.4. which were categorized as commercial contract, commercial independent, and smallholder independent farms, respectively. The rest of the 40 sample swine farms did not achieve increases in CTC. Only 6 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 sample swine farms were able to catch up with each other in terms of Conventional Efficiency Change.

The other component of CMPI is Conventional Technical Change (CTC). Going back to Tables 4.4 to 4.7, the same top 12 swine farms that achieved conventional productivity growth also achieved the increase in CTC which ranged from 1.001 to 1.523 or an increase of 0.1 percent to 52.3 percent. In the previous discussion, it was seen that the variation in CEC of the 40 swine farms was not very large, ranging from 0.900 to 1.11. Thus, while CEC was an important component in increasing the conventional productivity growth of swine farms, it was CTC that caused more variation in the conventional productivity growth of these swine farms. For the top 12 swine farms, or the so-called ’leaders of the pack’, what differentiated them from the rest of the 40 sample swine farms were their much higher levels of CTC. The remaining 28 swine farms had CTCs ranging from as low as 0.517 (Farm No. 1 in Table 4.4) to 0.999 (Farm No. 28 in Table 4.4). Table 4.6 shows that the average CTC of 1.155 for the top 12 swine farms was significantly much higher than average CTC of 0.805 achieved by the rest of the 40 sample swine farms. This implies then that the majority of the swine farms were not able to take advantage of or were constrained access to the technological innovations that could increase the technical change component of their conventional productivity growth. It can also imply that there may not be any technology available to them, especially to small independent farms and commercial independent farms who constituted the majority of those with the lower level 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 ESMPI are given in Table 4.4. The over-all geometric mean of ESMPI for the entire sample was only 0.87 which was less than 1.0. This implies that, on average, the environmentally sensitive productivity growth of swine farms, as a group, had decreased in the period of 2002 to 2015. Table 4.8 presents the average value of ESMPI by category of swine farms. The ESMPIs were also decomposed into Environment Efficiency Change (EEC) and the Environment Technical Change (ETC). Absolute differences in the mean levels of the ESMPIs and EEC components across categories of swine farms were not statistically significant but the differences in the ETCs were marginally significant (*p* value = 0.06).

Table 4.8 Estimates of ESMPI by category of swine farms

Category	Mean ESMPI	Mean EEC	Mean ETC
Smallholder Independent (*n*=19)	0.85	1.00	0.85
Smallholder Contract (*n*=2)	1.14	0.95	1.21
Commercial Independent (*n*=13)	0.89	1.01	0.88
Commercial Contract (*n*=6)	1.00	1.01	0.98
ANOVA F-value	1.53^{ns}	0.47^{ns}	2.63^{ns}
p value	0.22	0.70	0.06

Source: Author’s estimations (2019)

Note: ns - not significant

As in the case of CMPI, only 12 swine farms (30 percent) had achieved environmentally sensitive productivity growth. Eleven (11) of these swine farms were the same swine farms that attained conventional productivity growth except for Farm No. 34 (in Table 4.4), but including Farm No. 25 (in Table 4.4), both of which were smallholder independent farms. The value of Farm No. 34’s ESMPI was 0.813 which was lower than its CMPI level of 1.155. This implies that CMPI was overstated and misleading since it did not consider the environmental impacts of swine production that are now considered in estimating ESMPI. Relative to the productivity frontier, what seemed to be an increase in conventional productivity growth of 15.5 percent was actually a decrease in productivity growth of about 18.7 percent [i.e., (1-0.813) x 100] when environmental effects were taken into consideration. On the other hand, Farm No. 25’s CMPI value of 0.970, which was interpreted as a decrease in conventional productivity growth, was understated because it was lower than ESMPI estimate of 1.022 which implies a 2.2 percent increase in productivity growth after including the environmental effects of swine production.

Table 4.9 presents ESMPI, EEC, and ETC estimates of the top 12 swine farms. The range of ESMPIs was from 1.001 to 1.642 with a mean of 1.151. This implies an increase in the environmentally sensitive productivity growth in the period of 2002 to 2015 from 0.1 percent to 64.2 percent with an average of 15.1 percent. When compared to ESMPIs of the rest of the 40 sample swine farms, the differences at the means were highly statistically significant. With regard to EEC of ESMPI, Table 4.4 reveals that there were 11 swine farms that achieved increases in EEC. EEC values of these 11 swine farms ranged from 1.012 to 1.111 with a mean of 1.028 (Table 4.9). The additional swine farms with increases in EEC were mostly commercial in size. When compared to the average of the EECs of the rest of the 40 sample swine farms (i.e., 0.991), there were no significant differences between them. Similar to the case of CEC, this implies that there was not much variation in the EEC of swine farms when environmental effects were considered.

Table 4.9 Difference in ESMPI, EEC, and ETC between 12 swine farms that achieved increases in Environmentally Sensitive Productivity growth and those that did not

Category	ESMPI	EEC	ETC
12 Swine Farms			
Min	1.001	1.012	1.001
Max	1.642	1.111	1.478
Mean	1.151	1.028	1.119
Other Swine Farms (Mean)	0.792	0.991	0.798
Difference (Mean)	0.359^{*}	0.037^{ns}	0.321^{*}
T-test *p* value	0.000	0.153	0.000

Source: Author’s estimations (2019)

Note: * denotes statistical significance (p value $\leq .05$); ns-not significant

While the efficiency change component of the ESMPI certainly makes an important contribution toward increasing the environmentally sensitive productivity growth of swine farms, Table 4.4 and Table 4.9 would show that it is ETC that caused much of the variation in ESMPI. The ETCs of the top 11 swine farms ranged from 1.001 to 1.478 with an average of 1.119. This means that there were increases in technical change of about 0.1 percent to 47.8 percent at the individual farm level. Table 4.9 shows that there was highly significant difference between the mean ETC of the 11 swine farms and that of the rest of the 40-sample swine farms whose ETCs ranged from 0.520 to 0.999. The majority of these swine farms with low ETCs were smallholder independent swine farms. It can be inferred that there were again constraints faced by this particular group of swine farms with respect to having access to technological innovations that can reduce the environmental impacts that are by-products of swine production. Smallholder independent swine farms found difficulty in taking advantage of these technological innovations or, perhaps, these technological innovations may not be available at all.

Table 4.10 gives the environmental indicator characteristics of 12 swine farms that achieved increases in ESMPI relative to those swine farms that did not. In general, there was an increase in the size of waste treatment facilities that have been installed in the swine farms in the period of 2002 to 2015. In particular, commercial contract swine farms had increased the size of their waste treatment facilities by as much as 15 times in the period of 2002 to 2015. It has to be recalled from CMPI section that the output of these contract swine farms had also grown five times during this period.

This tremendous growth in waste treatment facilities suggests that commercial contract swine farms had relatively easier access to these technological innovations and were not constrained to use them. In terms of environmental indicators, there was, on average, an upward trend in BOD and nitrogen loading levels but a marked decrease in the phosphorus loading level. Thus, the question on the effectivity of the available technological innovations that can

Table 4.10 Environmental indicator characteristics of 12 swine farms that achieved increases in Environmentally Sensitive Productivity growth

Category	ESMPI	EEC	ETC	Waste Treatment Facility		BOD		Nitrogen		Phosphorus	
				2002	2015	2002	2015	2002	2015	2002	2015
Smallholder Independent (*n*=5)	1.058	1.024	1.030	8	14	1,156	1,382	188	400	51	157
Smallholder Contract (*n*=2)	1.143	0.950	1.210	9	9	557	9,018	605	501	287	276
Commercial Independent (*n*=3)	1.161	1.052	1.107	214	233	6,542	3,231	2,092	3,628	1,915	576
Commercial Contract (*n*=2)	1.376	1.081	1.266	2	35	1,954	5,536	2,355	543	597	94
Average of 12 Farms	1.151	1.028	1.119	59	72	2,536	3,809	1,095	1,248	648	271
Average of Other Farms	0.792	0.991	0.798	66	45	5,201	2,879	1,469	1,021	611	700

Source: Author's estimations (2019)

Table 4.11 Mean Environmentally Sensitive MPI of swine farms with waste treatment facility

Category	With Waste Treatment Facility	Size of Waste Treatment Facility (m^2)	ESMPI	EEC	ETC
Independent (*n*=21)	17	49.80	0.87	1.00	0.87
Smallholder (*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
Smallholder (*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

Source: Author's estimations (2019)

address the undesirable environmental impacts of swine production surfaces. Furthermore, Table 4.11 provides more details on the apparent relationship between installation/construction of waste treatment facilities and growth in the ESMPI. Of the 40 sample swine farms, 23 (58 percent) of them had installed waste treatment facilities to assimilate environmental impacts. Across production arrangements, 6 of the 8 contract swine farms installed larger waste facilities than that of the independent swine farms. In terms of size, the commercial swine farms had expectedly larger waste treatment facilities. Contract swine farms, regardless of size, had higher environmental productivity growth that was driven by both efficiency change and much higher levels of technical change as compared to independent swine farms.

4.5 Conclusion

In the period of 2002 to 2015, only one-third of the 40 sample swine farms experienced environmentally sensitive productivity growth at the frontier. This was largely the result of efficiency improvements rather than technological improvements or shifts in the production frontier. Thus, environmentally sensitive productivity growth in the swine sector had declined. As to characteristics of productivity growth in swine production, the CMPI actually tended to overstate the productivity growth of swine farms. However, incorporating three environmental impacts such as N and P loadings and BOD generally reduces the level of conventional 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 was about 0.900 to 1.111 which implies that swine farms were able to catch up with the best practice and their technical efficiency levels were not too far from the frontier.

On the other hand, the technical change (both CTC and ETC) was the main driver causing much variation in productivity growth. The range of CTC and ETC was wide from

0.512 to 1.64. Moreover, while there were 11 or 12 out of the 40 sample swine farms that achieved increases in productivity growth (both CMPI and ESMPI), particularly contract swine farms, the majority (70 percent) of the 40 sample swine farms, especially small independent swine farms, seemed 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 were 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 encourage or did not provide swine farms with sufficient incentive to adopt game-changing[33] technology. Particularly for small independent swine farms, who constituted the majority of the 40 swine farms, the past 13 years have not seen them investing in green technology as reflected by the relatively smaller size of their waste treatment facilities and increased levels of environmental indicators such as BOD and nitrogen and phosphorus loadings in the period of 2002 to 2015.

[33] Game-changing technology refers to one that has a "big effect on the conditions in an area such as in business." (http://dictionary.cambridge.org/us/dictionary/).

Chapter 5

Changing Structure of Philippine Swine Production and Green Growth

5.1 Introduction

Chapter 4 discussed the measurement of environmental productivity growth in swine production. It was found that only one-third of the 40 sample swine farms had environmental productivity growth in the period of 2002 to 2015 and that technical change was the main driver of such growth. Smallholder independent swine farms, unlike contract swine farms, seem to face difficulty in gaining access to available technological innovations that can increase the level of their productivity growth. This finding implies that the changing structure of swine production that has been occurring in recent decades in the Philippines and other Asian countries such as the shift to larger-size, specialized and highly integrated production systems (Delgado, et al., 2008) can affect the environmental and resource productivity of swine farms as well as the natural asset base on which swine production depends. In turn, this changing structure of swine production has important bearing on the capacity of swine farms to expand production in a sustainable manner that will promote green growth.

In Chapter 2, it was elucidated that swine production causes water pollution and eutrophication from excess nutrient loadings of nitrogen (N) and phosphorus (P) (Gerber, et al., 2012) and much of this is associated with poor feeding and manure management systems (Han, et al., 2001). A large part of N and P losses in feeding are caused by inefficiencies in digestion and metabolism and only about 20-50 percent of N and 20-60 percent of P consumed is retained in the body. (Korneygay & Harper 1997 as cited in Han, et al. 2001). Untreated and ill-disposed animal waste and wastewater will eventually enter water courses and increase BOD loading level as well. Thus, a major way for swine farms to achieve green growth is to improve their environmental and resource productivity and reduce environmental pollution by reducing N and P excretions and BOD loading to the environment through decreasing N and P intake by animals, increasing the efficiency of N and P utilization, or using green technology such as waste treatment facilities. Thus, it is important to assess the level of environmental pollution emitted or assimilated by swine production. Equally important is to be able to determine the factors that affect the level of environmental pollution and whether the changing structure of swine production is a contributing factor.

The main objectives of Chapter 5 are:

1. to estimate the mass balance of nitrogen (N) and phosphorus (P) and BOD loading from swine production; and
2. to examine factors that affect the mass balance of N and P and BOD loading.

5.2 Methodology

The second objective of this dissertation is to examine factors affecting environmental productivity in swine production. This is achieved by analyzing 2 of 4 OECD-proposed green growth indicators. The 4 indicators include: 1) environmental and resource productivity of the economy which looks into the quantities of residuals from economic production such as pollutants vis-à-vis conventional output quantities, 2) flows and stocks of the natural asset base that mirror the degree to which the asset base is affected by activities of economic agents, 3) environmental dimension of the quality of life which reflects how pollution and changes in environmental services impact on communities and people's lives and resources, and 4) economic opportunities and policy responses which assess the response of policy and decision-makers in terms of setting up and implementing economic, fiscal, environmental instruments as well as technology, research, and innovation programs in relation to the promotion of green growth strategy. Due to data limitations, the focus of this Chapter is only on the first two OECD indicators.

Environmental and resource productivity indicators are represented by nitrogen and phosphorus loadings from the wastewater of swine farms. Nutrient Mass Balance Calculation Approach (Delgado, et al., 2008) is used to estimate organic nitrogen (N) in kg/ha and phosphorus (P)[34] in kg/ha that can be potentially assimilated by swine farms through crop production. Positive values of nutrient mass balances are preferred because these would imply that swine farms have croplands that can assimilate the waste and, therefore, indicate higher environmental and resource productivity. On the other hand, for the natural asset base indicator, average values of Biological Oxygen Demand (BOD) loading (kg), BOD loading/swine output, and BOD concentration (mg/li) are estimated. A lower value is preferred because this would imply lower level of water pollution and lesser burden on the environment per unit output.

Factors that are hypothesized to affect the mass balance of N and P and BOD loading include 1) size of production, 2) production arrangement, 3) use of green technology or waste treatment facility such as biogas digester and lagoon, 4) number of livestock related trainings, 5) number of visits to swine farms by extension worker, and 6) interaction terms. Effects of these factors are analyzed through panel data model regressions.

[34] P_2O_5 is the empirical formula of phosphorus pentoxide which is an anhydride of phosphoric acid. The animal industry uses elemental phosphorus (P) in feed ration. Fertilizer industry uses the term P_2O_5 to mention the phosphorus (P) content of fertilizer materials. To convert P_2O_5 to P, multiply it by 0.44 (https:// www. agro ser vicesinternational.com/Education/Fert6.html)

5.2.1 Mass Balance Calculation Approach

5.2.1.1 Green Growth Indicator: Environmental and Resource Productivity of the Economy

The mass balance calculation approach (Delgado, et al. 2008) is used to estimate the organic nitrogen (N) and phosphorus (P) that can be potentially assimilated by swine farms through crop production.

Let $\mathbf{m}_t$ be a 2 × 1 vector representing the mass balance of the 2 nutrients N and P (in kg/ha) at year *t*, $\boldsymbol{\beta}$ a 2 ×1 vector representing the absorptive capacity of the nutrients per unit of land (in kg/ha), **a** the 40 ×1 vector representing the area (ha) of cropland of the households, and $\mathbf{T}_t$ a 2 × 40 matrix representing the total deposition of the nutrients (rows) by household (columns) at year *t*.

The mass balance can then be as expressed as:

$$\mathbf{m}_t = \boldsymbol{\beta}\mathbf{a}'\mathbf{1} - \mathbf{T}_t\mathbf{1}\ ,\ \ t = 2002, 2015 \qquad \text{(Equation 5.1)}$$

where **1** is a 40 × 1 vector of ones.

The total deposition by household *h* of nutrient *n* is expressed as follows:

$$\mathbf{T}_t = \boldsymbol{\alpha}\mathbf{u}_t' + \mathbf{F}_t + \mathbf{M}_t - \mathbf{S}_t \qquad \text{(Equation 5.2)}$$

where $\boldsymbol{\alpha}$ is a 2 × 1 vector representing the amount of nutrient produced per animal, $\mathbf{u}_t$ is a 40 × 1 vector representing the animal unit of swine per household at year *t*, $\mathbf{F}_t$ is a 2 × 40 matrix representing the amount of nutrient applied on cropland by household as inorganic fertilizer at year *t*, $\mathbf{M}_t$ is a 2 × 40 matrix representing the amount of manure (kg) per household purchased from other farms and applied as fertilizer on cropland at year *t*, and $\mathbf{S}_t$ is a 2 × 40 matrix representing the amount of manure (kg) per household sold off farm at year *t*.

Nutrient values from swine production were computed based on animal unit conversion (Kellog, et al. 2000 as cited by Delgado, et al. 2008), because different animal species produce varying levels of manure and consequently varying levels of N and P nutrients. Thus, 1 animal unit is equivalent to 5 sows with piglets and 1 animal unit of swine produces 150 pounds or 68 kg of N and 118 pounds or 54 kg of P excreted from the manure. In terms of nutrient uptake, it is assumed that for rice production in the Philippines, N uptake is 100 kg/ha and P uptake is 32 kg/ha (Delgado, et al., 2008; Costales, et al., 2007).

The total N and P nutrients deposited by each household is equal to the sum of organic N and P produced by animal units of swine in the respective household plus the inorganic forms of nutrients used by the household in terms of commercial fertilizer applied on cropland. If the household purchased manure from other farms as additional organic fertilizer, this is also included but if the household sold manure off farm, this amount is deducted.

To interpret the results, a positive mass balance implies that there is enough cropland that can potentially absorb the nutrient loading produced by the swine animals, while a negative mass balance implies otherwise.

5.2.2 Estimation of Potential BOD Loading

5.2.2.1 Green Growth Indicator: Natural Asset Base

Wastewater from swine production operations eventually find its way into surface and ground waters particularly if there are no impounding structures such as biogas digesters or lagoons that can process or treat wastewater. Wastewater contains organic pollutants, the most common indicator of which is the biological oxygen demand or biochemical oxygen demand (BOD) which refers to the amount of dissolved oxygen that aquatic life requires in order to break down micro-organisms.

To reflect the extent to which the quality of natural asset base is being affected by the operations of swine farms through water pollution, this dissertation estimated the potential biological oxygen demand (BOD) as a green growth indicator. However, in lieu of the expensive actual laboratory testing for the level of BOD loading in the wastewater from swine farms down to the final disposal repository, the daily BOD loading ranging from 0.032 kg/day for sucklings to 2.4 kg/day for the farrow-to-finish animals, as estimated by Hilborn & Debruyn (2004), was adopted (Table 5.1). Higher BOD loading would mean lower water quality and, therefore, higher negative impacts of swine production on the natural asset base.

Table 5.1 Daily BOD loading (kg) by type of livestock

Animal	Weight (kg)	Daily BOD Loading (kg)
Dairy	454	0.770
Beef	454	0.720
Swine	16	0.032
	29	0.059
	68	0.140
	91	0.180
Sow and Litter	170	0.450
Farrow to Finish (per sow)	n/a	2.400
Sheep	45	0.040
Poultry	21	0.006

Source: Hilborn & DeBruyn (2004)

BOD loading per kilogram of swine output is likewise calculated as an indicator of environmental and resource productivity. A lower value is preferred because this would imply lesser pollution burden on the environment per unit of output.

BOD concentration in milligram per liter (mg/li) is estimated and compared to the historical effluent wastewater standard for class C water set by the Philippine's Department of Environment and Natural Resources (DENR) at 50 mg/li. This was adjusted in 2016 to between 100-900 mg/li in consideration of establishments such as agricultural livestock that have influents of >3,000 mg/li. The BOD threshold value of effluents into surface water that is set by the EU is 25 mg/li (CEC, 1999).

It has to be noted, though, that while the OECD green growth indicator for the impact of swine production on the natural asset base ought to be flows and stock levels of BOD loading, the data used in this study allow for just the estimation of potential stock levels of BOD loading in the sample swine farms.

5.2.3 Descriptive Analysis

5.2.3.1 Green Growth Indicator: Environmental Dimension of the Quality of Life

The negative externalities brought about by swine production such as foul odors, flies that are vectors of diseases, and surface water pollution arising from ill-disposed and untreated swine waste can impact on public health and these are well documented in the literature (Catelo, et al., 2003; Costales, et al., 2007; Gerber, et al., 2012). This study gives a qualitative discussion for this particular indicator due to data limitations.

5.2.3.2 Green Growth Indicator: Economic Opportunities and Policy Responses

Information on the local research and development expenditures that are related to green growth and to swine production in particular is currently unavailable. However, a discussion of wastewater effluent standards and the environmental user fee system (EUFS) which is grounded on the "polluter pays principle" and other related regulations to abate pollution from swine production is presented in this study.

5.2.4 Factors Affecting Green Growth Indicators: N, P, and BOD Loading

Three panel data regressions were conducted to determine factors that may affect the levels of green growth indicators (i.e., N, P, and BOD loading). The dependent variables (y_{it}) are total *N* (kg), total *P* (kg), and total *BOD* loading (kg). In order to reduce the skewness in the residuals, their natural logarithms were taken. The dependent variables are, thus, *ln N*, *ln P*, and *ln BOD*. The explanatory variables are composed of factors pertaining to changing structure of swine production such as dummy variables for size of production (SIZE) and production arrangement (PA), technological factor represented by a dummy variable for adoption of waste treatment facility (WTF), and institutional factor which is an index that sums up the number of livestock related trainings attended by managers or decision-makers of the sample swine farms in the last 2 years prior to the survey and the number of times that extension workers visited the sample swine farms in the past 3 months prior to the survey. Interaction terms were included as explanatory variables in order to test conditional hypotheses or context conditionality. For example, for the variable SIZE, it is expected that commercial swine farms will generate relatively more waste and higher levels of N, P, and BOD loading as compared to smallholder swine farms due to the larger animal inventory of commercial swine farms. However, the effect of size of production on the green growth indicators of N, P, and BOD loading may actually be conditional on the value of one or more other variables particularly adoption of waste treatment facility (WTF).

Table 5.2 describes explanatory variables and their hypothesized relationship with dependent variables.

Table 5.2 Description of variables affecting green growth indicators in swine farms

Variable (x_{it})	**Description**	**Hypothesized relationship with *ln N* (total kg), *ln P* (total kg), and *ln BOD* (total kg) and expected sign of the coefficient**
SIZE	Size of Production Smallholder: 0; Commercial: 1	Commercial swine farms generate higher volumes of wastewater and manure; sign is (+)
PA	Production Arrangement Independent: 0; Contract: 1	Contract swine farms have information exchange with integrators on feed efficiency and manure management; sign is (−)
WTF	Waste Treatment Facility Without: 0; With: 1	Swine farms with waste treatment facility are better able to reduce wastewater and treat waste from manure; sign is (−)
TE	Number of livestock-related trainings attended in last 2 years and number of visits by extension workers in past quarter	Swine farms with managers or decision-makers who have more livestock-related trainings and are visited by extension workers have more knowledge on waste reduction and treatment; sign is (−)
SIZE x WTF	Interaction term for Size of Production and Adoption of Waste Treatment Facility	The presence of waste treatment facilities in commercial farms modifies the individual effect of commercial farms; sign is (−)
PA x WTF	Interaction term for Production Arrangement (PA) and Adoption of Waste Treatment Facility (WTF)	The presence of waste treatment facilities in contract swine farms reinforces the individual effect of contract farms; sign is (−)
TE x WTF	Interaction term for Training attended in last 2 years/ number of visits by extension workers in past quarter and Adoption of Waste Treatment Facility	The presence of waste treatment facilities in swine farms with managers or decision-makers who have more livestock-related trainings and are visited by extension workers (TE) reinforces the individual effect of TE; sign is (−).

Source: Author (2019)

5.2.5 Fixed Effects, Random Effects, and Pooled OLS Models

The main motivation for using panel data is to give solution to the problem of omitted variables (Wooldridge, 2012). Panel data are also termed as cross-sectional time series data. They may either be balanced where for all time periods, all individuals have been observed , i.e., $T_i = T$ for all i or they can be unbalanced which means that for some individuals, $T_i \neq T$. Data set may be a short panel which means there are few time periods and many individuals or a long panel with many time periods and few individuals. Model errors may be correlated over time for a given individual but independent over individual units (Cameron & Trivedi, 2002).

Furthermore, some panel data sets may have correlation across individuals. Because of these possible correlations, some corrections to ordinary least squares (Pooled OLS) model standard errors may be necessary and there can be efficiency gains in using generalized least squares (GLS). Panel data may have individual-specific effects which may be unobserved.

The two main approaches to fitting models using panel data are Fixed Effects Model (FEM) and Random Effects Model (REM). The key difference between FEM and REM is how the unobserved individual-specific effects are modelled.

The rationale behind using the FEM is that if an unobserved individual-specific farm *i* effect, α_i, remains fixed or does not change over time, then any change in the dependent variable, y_{it}, may be attributed to influences of factors other than these fixed characteristics. Time-invariant variables are absorbed by the intercept. FEM examines if intercepts vary across group or time period (Wooldridge, 2012).

The equation for the Fixed Effects Model is:

$$y_{it} = \alpha_i + \mathbf{x}'_{it}\boldsymbol{\beta} + u_{it}, \qquad i = 1, \dots N, \quad t = 1, \dots, T \qquad \text{(Equation 5.4)}$$

where y_{it} is the dependent variable, α_i is the unobserved individual-specific farm *i* effect that captures all time-constant factors that affect y_{it}, $\boldsymbol{\beta}$ is a *K* x 1 column vector of coefficients, $\mathbf{x}_{it}$ is a *K* x 1 column vector of explanatory variables, and u_{it} is an idiosyncratic error or time-varying error.

The underlying assumptions about the idiosyncratic error under the FEM are

1) $E(u_{it}) = 0$ (Equation 5.5)

2) $E(u_{it}u_{js}) = 0, \quad i \neq j, \; t \neq s$ (Equation 5.6)

3) $E(\alpha_i u_{it}) = 0$ (Equation 5.7)

4) $u_{it} \sim IN(0, \sigma_u^2)$ (Equation 5.8)

Assumption 1) is essential for consistent estimators of $\boldsymbol{\beta}$. This implies exogeneity of the explanatory variables. The expected value of the idiosyncratic error given the explanatory variables in all time periods and unobserved individual-specific effect is zero: $E(u_{it} | \mathbf{X}_i, \alpha_i) = 0$ where $\mathbf{X}_i = [\mathbf{x}_{i1}\, \mathbf{x}_{i2} \ldots \mathbf{x}_{iT}]$. Assumption 2) means that for all $t \neq s$, the idiosyncratic errors, u_{it}, are not correlated (conditional on all explanatory variables, $\mathbf{X}_i$, and α_i: Cov $(u_{it}, u_{is} | \mathbf{X}_i, \alpha_i) = 0$. Assumption 3) means that the idiosyncratic errors u_{it}, and unobserved individual-specific effect, α_i, are not correlated. Assumption 4) implies that the idiosyncratic error is independent and identically distributed as normal with mean zero and constant variance.

The FEM allows the unobserved individual-specific farm *i* effect, α_i, to be correlated with the explanatory variables, $\mathbf{X}_i$ (Wooldridge, 2012 p. 459), implying that a limited form of endogeneity is permitted. Thus, $\mathrm{E}[\alpha_i | \mathbf{X}_i] = \mathrm{g}(\mathbf{X}_i) = \text{constant}$, and $\mathrm{Cov}[\mathbf{X}_i, \alpha_i] \neq 0$.

On the other hand, the rationale behind the Random Effects Model (REM) is that it assumes that the variation across entities, (e.g., swine farms), u_{it}, is random and, therefore, is uncorrelated with the observed explanatory variables, x_{it}. This implies that time-invariant variables are included as explanatory variables. This variation across swine farms, u_{it}, is also assumed to affect the dependent variable, y_{it}. REM examines differences in error variance components across individuals or time period (Wooldridge 2012, p. 493).

The equation for the Random Effects Model is:

$$y_{it} = \alpha_i + \mathbf{x}'_{it}\boldsymbol{\beta} + u_{it} \qquad \text{(Equation 5.9)}$$

with the assumptions that:

1) $\mathrm{E}(\alpha_i) = 0$ (Equation 5.10)
2) $\mathrm{E}(\alpha_i^2) = \sigma_\alpha^2$ (Equation 5.11)
3) $\alpha_i \sim \mathrm{IID}(0, \sigma_\alpha^2)$ (Equation 5.12)
4) $u_{it} \sim \mathrm{IN}(0, \sigma_u^2)$ (Equation 5.13)

Assumption 1) means that α_i are random variables and the expected value of α_i given all explanatory variables is constant. This implies that there is no correlation between α_i and all elements of $\mathbf{X}_i$ and, thus, time-constant explanatory variables can be included. Assumption 2) means that the variance of α_i given all explanatory variables is constant and, therefore, non-zero: Var $(\alpha_i |\mathbf{X}_i) = \sigma^2_\alpha$. Homoscedasticity of α_i across individuals is imposed. Assumption 3) means that the α_i of different individuals are independent and identically distributed with constant mean and are homoscedastic across individuals. Assumption 4) means that the error term, u_{it} , is normally distributed with a mean of zero and constant variance, σ^2_u.

The REM essentially puts the unobserved individual-specific farm *i* effect (α_i) in the error term; u_{it} is the between-swine farm error and $v_{it} \equiv \alpha_i + u_{it}$ is the within-swine farm error. The intercept and slopes of explanatory variables are the same across individual swine farms. The difference among individual swine farms (or time periods) lies in their individual specific errors, not in their intercepts (Wooldridge 2012, p. 493).

Using the variable list in Table 5.2, the equation to be estimated to determine the factors affecting green growth indicators (y_{it}) - *ln N, ln P, ln BOD* - is shown by Equation 5.14 using $ln\, N_{it}$ as a sample dependent variable and using the Fixed Effects Model as a starting point:

$$ln\, N_{it} = \beta_0 + \beta_1 \mathrm{SIZE}_{it} + \beta_2 PA_{it} + \beta_3 TE_{it} + \beta_4 WTF_{it} + \beta_5 SIZE_{it} * WTF_{it} + \beta_6 PA_{it} * WTF_{it} + \beta_7 TE_{it} * WTF_{it} + \alpha_i + u_{it}$$

(Equation 5.14)

On the other hand, if a Random effects model should be used, Equation 5.14 becomes

$$ln\, N_{it} = \beta_0 + \beta_1 \mathrm{SIZE}_{it} + \beta_2 PA_{it} + \beta_3 TE_{it} + \beta_4 WTF_{it} + \beta_5 SIZE_{it} * WTF_{it} + \beta_6 PA_{it} * WTF_{it} + \beta_7 TE_{it} * WTF_{it} + v_{it}$$

(Equation 5.15)

where the individual-specific farm *i* effect, α_i, is not treated as a parameter but is considered as a random variable with constant mean and variance σ_{α}^2.

However, if no individual-specific effect exists over time and across cross-sectional entities, then ordinary least squares model (Pooled OLS Model) can be used. One reason for using independently pooled cross section data is to increase the sample size. Under Pooled OLS Model, the intercept and slope coefficients are constant across time and individual farms, and the error term, $u_{it,}$ capture differences over time and over individual farms.

Equation 5.16 gives the Pooled OLS Model

$$y_{it} = \alpha + \mathbf{x}'_{it}\boldsymbol{\beta} + u_{it} \qquad \text{(Equation 5.16)}$$

where α is an unknown constant.

5.2.6 Model Selection among Pooled OLS, Fixed Effects Model, and Random Effects Model

To determine which specific form of panel data model to estimate, the selection process generally involves three steps. The first is to use the F-test, which is based on the loss of goodness-of-fit and is employed in order to test for significant fixed group effects. The F-test contrasts the Fixed Effects Model with Pooled OLS Model. If the null hypothesis, $H_o : u_i = 0$, is accepted, then this means that there are no significant observed and unobserved fixed group effects or that they are equal across all farms. In this case, Pooled OLS Model is appropriate model to use. The second step is to use the Breusch-Pagan Lagrange Multiplier (LM) test to examine if there exists any random effect, or if individual (or time) specific variance components are zero, i.e., $H_{o:}$ Var $(u_i) = 0$. This test helps to decide between the Random Effects Model and the Pooled OLS Model. If the null hypothesis is accepted, then this means that there are no significant differences across farms or there is no panel effect and the Pooled OLS model is appropriate to use. The third step is to use the Hausman test if the null hypotheses of the F-test and the Breusch-Pagan LM test are rejected. The Hausman test helps to decide between the Fixed Effects Model and the Random Effects Model. The null hypothesis of the Hausman test is that there is no correlation between the error term and the independent variables in the panel data model, i.e., H_o : Cov $(\alpha_{i}, x_{it}) = 0$. If the null hypothesis of the Hausman test is accepted, then the Random Effects Model is appropriate to use. Table 5.3 shows the summary of results of the selection process on which specific form of panel data model to estimate based on the F-test, Breusch- Pagan LM test, and Hausman test.

Table 5.3 Results of process for choosing specific form of panel data model, 247 samples

Test Performed	Test Statistic	*p* value	Decision
For *ln N* regression			
F-test effect (all u_i =0), F (1,238)	1.06	0.305	Accept H_o, use OLS
Breusch-Pagan LM	35.83*	0.000	Reject H_o, use REM
Hausman	3.93	0.788	**Accept H_o, use REM**
For *ln P* regression			
F-test effect (all u_i =0), F (1, 238)	30.95*	0.000	Reject H_o, use FEM
Breusch-Pagan LM	12.04*	0.002	Reject H_o, use FEM
Hausman	8.51	0.289	**Accept H_o, use REM**
For *ln BOD* regression			
F-test effect (all u_i =0), F (1, 238)	0.02	0.901	Accept H_o, use OLS
Breusch-Pagan LM	8.02*	0.018	Reject H_o, use REM
Hausman	0.02	0.990	**Accept H_o, use REM**

Source: Author's estimations (2019)

Note: Sample size used is unbalanced panel data: 207 samples for year 2002 and 40 samples for year 2015

For *ln N* and *ln BOD* egressions, the F-test results were 1.06 and 0.02, respectively, both of which were not significant. This implies that Pooled OLS Model is more appropriate to use than FEM. For *ln P*, the result of the F-test was 30.95 which was significant and, therefore, FEM is the more appropriate to use than Pooled OLS. Results of the Breusch-Pagan LM tests for all 3 regressions were significant which means REM is more appropriate to use than Pooled OLS Model. Lastly, results of Hausman tests for *ln N*, *ln P*, and *ln BOD* regressions were 3.93, 8.51, and 0.025, respectively, and all were not significant which means REM is more appropriate to use than FEM. Results of the selection process confirm the use of Random Effects Model as more appropriate. Moreover, when t is small, FEM is not appropriate to use because the coefficients are not reliable and may be potentially biased due to possible low degree of variation in the variables (Nickell, 1981 as cited by Hill, et al., 2019). Sample size may likewise be reduced under FEM because of the number of dropped cases and this can lead to low statistical power and consequent loss of degrees of freedom (Gujarati, 2004).

For this dissertation, t is small, with only 2 reference years, $t = 1$ (2002) and $t = 2$ (2015) because there are no available longitudinal farm-level data for swine production inputs and outputs. Two cases of panel data samples for estimation using REM were tried:

Case 1: 207 swine farms (2002) + 40 swine farms (2015), N = 247

Case 2: 40 swine farms (2002) + 40 swine farms (2015), N=80

REM regressions were estimated using Case 1 in order to determine whether better results can be attained with greater number of samples and higher degrees of freedom (DF)[35]. Using Generalized Least Squares (GLS), results of REM regressions for Case 1 were not as good as those using Case 2. Autocorrelation within panels and cross-sectional correlation and heteroskedasticity across panels are likely. Thus, to fit a model with autocorrelated errors, data have to be equally spaced in time and to fit a model with cross-sectional correlation, panels have to be balanced or must have the same number of observations (Wooldridge, 2012; Cameron & Trivedi 2010). Therefore, for the analysis of factors affecting green growth indicators, this dissertation used Case 2 which consists of balanced panel data set of 40 sample swine farms surveyed in 2002 and the same 40 sample swine farms surveyed in 2015. Appendix D shows results of estimation using REM on Case 1 with 247 samples.

[35] DF was calculated as follows: DF = $nT - (n - 1) - k - 1$ where n is the number of samples, T is the number of time period, and k is the number of independent variables including constant.

The final form of estimation models using REM on Case 2 are as follows:

$$ln\, N_{it} = \beta_0 + \beta_1 SIZE_{it} + \beta_2 PA_{it} + \beta_3 TE_{it} + \beta_4 WTF_{it} + \beta_5 SIZE_{it} * WTF_{it} + \beta_6 PA_{it} * WTF_{it} + \beta_7 TE_{it} * WTF_{it} + v_{it} \quad \text{(Equation 5.17)}$$

$$ln\, P_{it} = \beta_0 + \beta_1 SIZE_{it} + \beta_2 PA_{it} + \beta_3 TE_{it} + \beta_4 WTF_{it} + \beta_5 SIZE_{it} * WTF_{it} + \beta_6 PA_{it} * WTF_{it} + \beta_7 TE_{it} * WTF_{it} + v_{it} \quad \text{(Equation 5.18)}$$

$$ln\, BOD_{it} = \beta_0 + \beta_1 SIZE_{it} + \beta_2 PA_{it} + \beta_3 TE_{it} + \beta_4 WTF_{it} + \beta_5 SIZE_{it} * WTF_{it} + \beta_6 PA_{it} * WTF_{it} + \beta_7 TE_{it} * WTF_{it} + v_{it} \quad \text{(Equation 5.19)}$$

The Generalized Least Squares (GLS) method was used to estimate the 3 REM regressions with the following specifications : 1) a heteroskedastic but uncorrelated error structure; 2) within panels, there is autocorrelation and the coefficient of the autocorrelation process is common to all panels so that the autocorrelation parameter is the same for all groups.

5.3 Results and Discussion

5.3.1 Descriptive Statistics

In 2002, 62 percent of the 40 sample swine farms were smallholder in size but in 2015, 52 percent of the 40 sample swine farms were commercial size. There was a prevalence of independent swine farms (70 percent) over contract swine farms in 2002, a value which increased (85 percent) in 2015 (Table 5.4). Only half of the 40 sample swine farms had installed waste treatment facilities in 2002 and this proportion slightly increased to 60 percent after 13 years because of investment costs. Biogas digesters and lagoons are the more commonly used waste treatment facilities. Although biogas digesters typically reduce 80-90 percent of N and P in manure liquids compared to only 25-30 percent of N and 35-50 percent of P reduction by lagoons, there were fewer sample swine farms that installed them.

Table 5.4 Descriptive statistics of variables on changing structure of swine production and green technology, 2002 and 2015

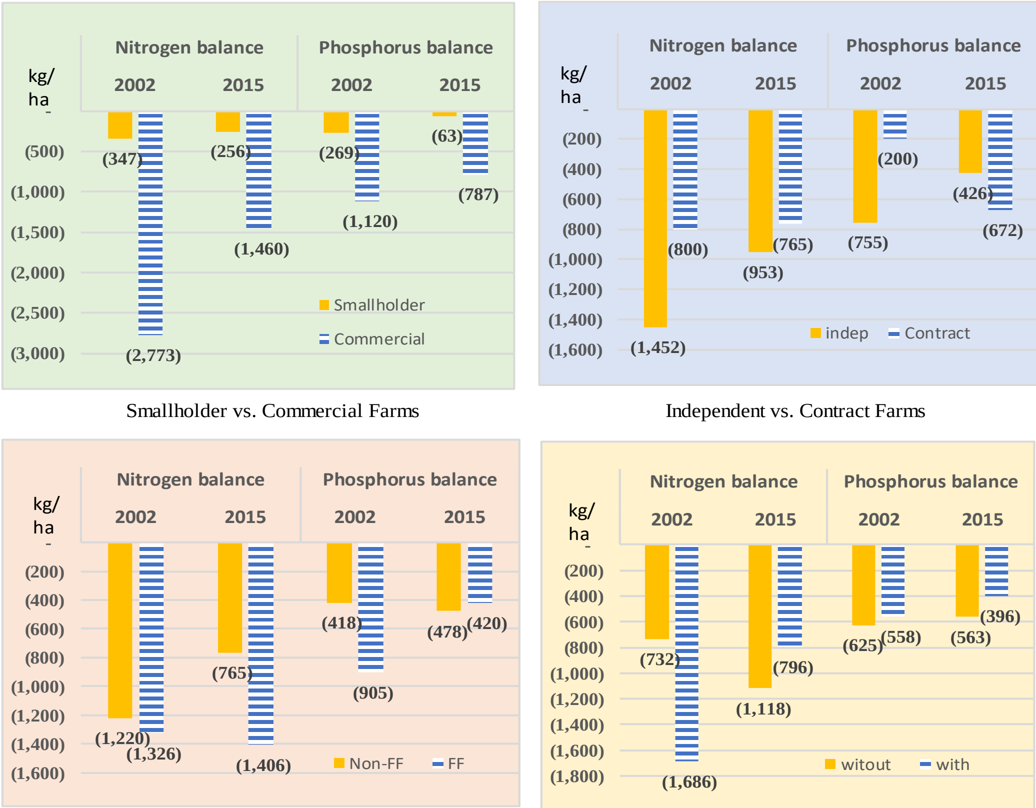
Variable	2002 % (*n*= 40)	2015 % (*n*=40)
Size of Production		
Smallholder	62	48
Commercial	38	52
Production Arrangement		
Independent	70	85
Contract	30	15
Waste Treatment Facility		
Without	45	40
With	55	60

Source: Costales, et al. (2003); survey by Author (2015)

5.3.2 Results of Mass Balance Calculation

Figure 5.1 shows that although there were marked improvements in the period of 2002 to 2015, average N and P nutrient balances of 40 sample swine farms were negative. For instance, negative mass balance of -347 kg for N in 2002 means that, on average, swine farms are loading N at the net rate of 347 kg/ha and this will cause problematic surpluses. Smallholder swine farms had significantly lower negative N in 2002 and 2015 and P nutrient balances in 2015 (*p* value =.016 for N in 2002, *p* value = .004 for N in 2015; *p* value = .228 for P in 2002, *p* value = .002 for P in 2015)[36] which imply that they have higher potential to assimilate the excess nutrients from manure than do commercial swine farms. This may be because of the relatively limited cropland on which commercial swine farms have to spread the manure. Moreover, contract swine farms had generally higher potential to absorb excess N and P nutrients than do independent swine farms (*p* value =.028 for P in 2002). Farrow-to-finishing wine farms had lesser potential to assimilate N and P nutrients vis-à-vis non farrow-to-finishing swine farms, but difference in N and P nutrient balances were not significant. This is true for

[36] *p* value means probability value of results of t-test of means.



Smallholder vs. Commercial Farms

Independent vs. Contract Farms

Farrow-to-Finishing vs. Non-Farrow-to-Finishing

With and Without Waste Tretament Facility

Figure 5.1 Average N and P nutrient balances of 40 sample swine farms, 2002 and 2015

Source: Author's estimates (2019)

swine farms with and without waste treatment facilities. Negative nutrient balances underscore importance of cropland availability for nutrient absorption or any other simple and cheap technology or approach that can make use of excess nutrients in a sustainable manner, particularly by smallholder swine farmers. Off-farm uses such as selling manure or having the technology to convert manure into products with added value can also be solution but the practicality and affordability may not be realistic in the short term without the necessary support services.

5.3.3 Natural Asset Base Indicators

Table 5.5 shows average values of BOD loading (kg), BOD loading/kg of swine output, and BOD concentration (mg/li) in the period of 2002 to 2015. The good news is a generally decreasing trend in these indicators across size of production.

Table 5.5 Average values of BOD loading of 40 sample swine farms, 2002 and 2015

Variable	BOD Loading (kg)		BOD Loading (kg/output)		BOD Concentration (mg/li)	
	2002	2015	2002	2015	2002	2015
Size						
Smallholder	1,961	696	1.06	1.32	214	635
Commercial	9,647	5,143	0.55	1.57	205	341
Difference	-7,685	-4,448*	0.51	-0.25	9	294
p value	0.119	0.001	0.107	0.632	0.112	0.230
Production arrangement						
Independent	5,475	3,074	1.19	1.61	500	545
Contract	1,897	3,632	0.12	0.82	37	172
Difference	3,578	-558	1.07*	0.79	463*	373*
p value	0.107	0.733	0.000	0.232	0.000	0.028
Waste treatment facility						
Without	1,976	2,731	1.4	2.37	597	804
With	6,386	3,443	0.44	0.9	168	279
Difference	-4,410	712	0.97*	1.47*	429*	524
p value	0.064	0.629	0.007	0.022	0.020	0.068

Source: Author's estimates (2019)

Notes: * denotes significance of t-test at p value ≤.05

BOD loading was significantly higher for commercial swine farms (*p* value = .001) than smallholder swine farms in 2015 and understandably so due to their bigger herd size that generated larger volumes of manure and wastewater. Contract swine farms and those with waste treatment facilities had significantly lower levels of BOD loading/kg of swine output and BOD concentration vs. independent swine farms and those without waste treatment facilities. In fact, these swine farms had the lowest BOD concentration and BOD loading/kg output.

Overall, in 2015, only 5 percent of the 40 sample swine farms had BOD concentration that achieved the EU standard of 25 mg/li and the 50 mg/li standard set by the DENR. With the new DENR standard of 100 mg/li, 15 percent of the 40 sample swine farms achieved this. A very important implication of these findings is that swine farms need technological assistance and innovation to improve wastewater treatment that meets effluent (BOD) standards so as not to create more damage to the natural asset base.

5.3.4 Factors Affecting N, P, and BOD loading: Results of the Random Effects Model Regressions

Table 5.6 shows summary of results from the 3 Random Effects Model regressions that were estimated using Case 2 with 80 samples (40 samples in 2002 and 40 samples in 2015) in order to determine factors affecting green growth indicators: *ln N*, *ln P*, and *ln BOD*. Appendix E presents the Stata 11 regression outputs. All 3 REM regressions fitted the data well as indicated by Wald chi^2 test values, all of which were highly significant with p values $\leq .05$. Numerals in parentheses are standard errors (S.E.).

5.3.4.1 Effects of Size of Production and Production Arrangement on N, P, and BOD Loading

The coefficients of the dummy variable for size of production for *ln N, ln P* and *ln BOD* were positive (2.690, 2.574, and 1.980, respectively) and highly significant (p value = 0.000). Positive coefficient means that relative to smallholder swine farms, commercial swine farms are associated with higher levels of total nitrogen and phosphorus, and total BOD loading, and, therefore, higher levels of environmental pollution. This finding is not new since commercial swine farms have bigger herd size and will consequently generate larger volumes of wastewater and animal manure.

Table 5.6 Results of regressions on factors affecting green growth indicators in swine production, 2002 and 2015

Variable	*ln N* (total kg)	*ln P* (total kg)	*ln BOD* (total kg)
Size of production [SIZE]	2.690*	2.574*	1.980*
(smallholder: 0; commercial: 1)	(.418)	(.518)	(.414)
Production arrangement [PA]	.697	.572	-1.430*
(independent: 0; contract: 1)	(.452)	(.603)	(.471)
Waste treatment facility [WTF]	-.715*	-3.030*	-1.230*
(without: 0; with: 1)	(.328)	(.428)	(.334)
Livestock training attended in last 2 years	.025	.025	.017
and visit by extension workers [TE]	(.018)	(.025)	(.019)
Size of production x Waste treatment	-.938*	-.724	.331
Facility [SIZE*WTF]	(.470)	(.613)	(.479)
Production arrangement x Waste	-.601	-.698	1.171*
treatment facility [PA*WTF]	(.490)	(.681)	(.520)
Livestock training and visit x Waste	-.013	-.009	.050
treatment facility [TE*WTF]	(.042)	(.060)	(.046)
Constant	5.300*	4.670*	6.602*
	(.257)	(.307)	(.251)
Wald chi^2	71.71*	157.69*	74.01*
Breusch-Pagan LM Test (Prob>chi^2)	5.55*	.020	0.13
	(.054)	(.990)	(.937)
Hausman Test (Prob>chi^2)	9.87	16.70*	.960
	(.196)	(.019)	(.995)
Effect test (F-test)	4.52*	3.17	5.19*
Number of observations, *N*	80	80	80
Number of groups	2	2	2
Degree of Freedom (DF)	71	71	71
Specific model used	REM	REM	REM

Source: Author's estimates (2019)

Notes: Standard errors in parenthesis; * denotes statistical significance (p value $\leq$.05)

The effect of production arrangement on green growth indicators was mixed. Coefficients of the dummy variable for production arrangement for *ln N and ln P* were positive although they were not significant. For *ln BOD,* the coefficient was -1.430 (p value = 0.000). This means that contract swine farms generated lower level of BOD loading than did independent swine farms. This is because environmental mitigation by contract swine farms is typically stipulated in the terms of agreement with their integrators.

5.3.4.2 Effects of Green Technology in Swine Production on N, P, and BOD Loading

Biogas digesters and lagoons are a form of green technology because they are facilities that treat the wastewater that comes out from swine farms before it drains into water courses. These waste treatment facilities were installed by half of the 40 sample swine farms in 2002 and this proportion very slightly increased in 2015. The coefficients of the dummy variable for waste treatment facility (WTF) for *ln N*, *ln P* and *ln BOD* were negative and highly significant at -.715 (*p* value = 0.029), -3.03 (*p* value = 0.000), and -1.230 (*p* value = 0.000), respectively. An important implication of this finding is that for half of the swine farms that had installed waste treatment facility, in 2002 and 2015, their pollution abatement technology had significant influence on the level of the 3 green growth indicators. This means that, taken individually, the effect of the WTF variable significantly matters in reducing environmental pollution.

5.3.4.3 Effect of Trainings Attended and Visits by Extension Workers on N, P, and BOD Loading

The number of livestock related trainings (TE) participated in by the swine farmer or farm manager in the last two years prior to the 2002 and 2015 surveys and the number of visits to the farm by agricultural extension workers in the past 3 months prior to the 2 surveys serve as proxies for experience and acquired knowledge in feeding and manure management which could contribute to lowering N, P, and BOD loading. The coefficients of this variable (TE) for the 3 green growth indicators were positive but not significant. An insight to this finding is that access of swine farms to such trainings and information related to swine waste disposal practices, feeding, and manure management may not have been easy for some of them in 2002 and did not become any easier in 2015. It can also be that swine farms who were able to have access to such trainings and information were unable to effectively apply the knowledge acquired from the trainings in order to reduce their environmental pollution. Related to this training and information access issue could be the irregularity or lack of visits by agricultural extension workers (whether private or government provided) who could have bridged the information gap related to decreasing the levels of N, P, and BOD loading.

5.3.4.4 Effect of Interaction Terms on N, P, and BOD Loading

As intimated earlier in Section 5.2.4 of this Chapter, interaction terms were included as explanatory variables in order to test conditional hypotheses or context conditionality and at the same time, reduce the risk of omitting variables in the model. A conditional hypothesis is one in which “a relationship between two or more variables depends on the value of one or more other variables” (Brambor , et al., 2006).

The variable WTF or waste treatment facility was interacted with size of production (SIZE*WTF). The REM regression results in Table 5.6 convey that WTF is somewhat of a modifying variable for certain outcomes. The outcomes of the interaction of WTF variable with SIZE particularly in the *ln N* and *ln P* REM regression models are -.938 and -.704, respectively, although only the coefficient of the interaction term for *ln N* regression turned out to be significant (p value = 0.046). These results imply that commercial swine farms are associated with an increase in *N* and *P* when WTF is absent or not installed in commercial swine farms. However, and more importantly, commercial swine farms are associated with a decrease in *N* when WTF is present or is installed in these commercial swine farms. Thus, even if the individual effect of SIZE on *ln N* and *ln P* seem to put commercial swine farms in a bad light, a different story can occur when SIZE is interacted with WTF.

WTF was interacted with production arrangement (PA). The coefficients of PA*WTF in the *ln N* and *ln P* REM regressions were -.601 and -.698, respectively. However, although the signs of these interaction term coefficients were reversed relative to when their effects were taken individually, they were not significant for both *ln N* and *ln P* regressions . Therefore, it cannot be said with confidence that contract swine farms are associated with lower *N* and lower *P* when WTF is installed in these farms.

Lastly, WTF was interacted with TE and the results were also inconclusive since the coefficients of the interaction terms were not significant although their signs were reversed particularly for *ln N* and *ln P* regressions. This could imply that swine farms whose managers/decision makers were able to participate in livestock related trainings and whose farms were frequently visited by extension workers were not necessarily associated with lower *N and P* when WTF is present. Theoretically, there should be complementarity between green technology and technical knowledge that is provided by trainings with the assistance of agricultural extension workers in reducing the levels of green growth indicators. The empirical evidence of this study, however, could not confirm this association. It could be surmised that some swine farmers may have WTF but may not have sufficient technical know-how to use it correctly and effectively. Another insight is that the proportion of swine farms that had installed WTF may not be sufficient enough to affect the levels of N, P, and BOD loading. The bottom line is that these conjectures need further empirical investigation.

5.3.5 Environmental Dimension of the Quality of Life

Catelo, et al. (2003) provided estimates on recurring annual health costs incurred by households of swine farms and those that lived near swine farms for various air-borne and water-borne related diseases that were caused by constant exposure to foul odors, flies, and untreated swine waste in the Philippines. These health costs (at 2001 prices) ranged from USD 50 for simple cases of diarrhea and skin allergies to USD 8,000 for treating serious illness as pneumonia. Swine farm households also spent for additional sources of cleaner air and disease-prevention measures.

Other impacts of untreated swine waste were decline in quality of water bodies that were previously used for washing and laundry and even for fishing, decades before swine farms were established. A decline in property and tourism values was likewise experienced by affected communities (Catelo, et al., 2003).

These aforementioned health and community impacts may still be experienced at present given that only half of 40 sample swine farms in the top two swine-producing regions had waste treatment facilities in the period of 2002 to 2015.These facilities were apparently not effective to generate wastewater that meet even local effluent standards and yet these swine farms were allowed to continue to operate.

5.3.6 Economic Opportunities and Policy Responses

Environmental Management Bureau (EMB) of the Philippines came up with new water quality guidelines (WQG) and general effluent standards (GES) in May 2016. This was in view of adhering to the basic policy of the Clean Water Act of protecting all forms and classes of water bodies while pursuing economic growth. It was also an offshoot of their monitoring activities in the period of 2011-2015 which revealed that 29 percent of effluent load from municipal water was accounted for by agriculture and livestock. Moreover, not even half of 8,700 monitored establishments within the Manila Bay region complied with BOD effluent standards. Thus, on top of existing environmental regulations, DENR is leading a multi-agency coordination program consisting of public and private institutions with ADB and the WB in order to develop wastewater treatment systems in 17 major cities.

To curb the environmental and public health consequences of untreated and ill-disposed swine waste, the Laguna Lake Development Authority implemented the Environmental User

Fee System (EUFS) in 1997. The EUFS is a market-based instrument[37] that covers firms that discharge wastewater into the Laguna Lake region. A separate regulation for smallholder swine farms had been also enacted in 2001 but unfortunately, problems with enforcement and compliance still abound. Catelo, et al. (2007) revealed that in the period of 1997-2004, the EUFS had generally incentivized more than half of the regulated industrial and commercial firms to comply with BOD standards over time. But majority of the 40 sample swine farms were not able to meet the 50 mg/li BOD standard due to the organic nature of swine production. There is no recent data on the impact of the EUFS on compliance of swine farms.

Implication of the above findings is that a more effective and coordinated enforcement of environmental laws and compliance monitoring is imperative. Technical and financial incentives for investing in waste treatment facilities are likewise needed as recommended likewise by Gonzales & Cleofas (2016) and Catelo, et al. (2007). Economic opportunities of providing green goods and technology such as biogas digesters are available in the market. Online trainings in biogas digester construction are also provided (Baron, n.d.). It seems to be just a matter of swine farms having access to this kind of information as well as having access to the financial facility that can support the acquisition of such waste treatment facilities.

5.4 Conclusion

This study found that the 40 sample swine farms incurred negative N and P nutrient balances implying that there is still environmental pollution that is caused by swine farms particularly because cropland to assimilate nutrients was insufficient. Absence or lack of technology and markets transforming swine manure into useful by-products that lower nutrient

[37] Market-based instruments (MBIs) refer to economic incentive instruments to protect and manage the environment. Examples of MBIs include corrective taxes; pollution charges; deposit-refund systems; tradable permits; market barrier reductions; and government subsidy reductions (Stavins, 1998).

balances of swine farms is vital implication of this finding. But to be more pragmatic about this issue, there should be simpler approaches for smallholder swine farms to be able to assimilate the excess N and P nutrients in a more sustainable manner because the market and technology for transforming swine manure into useful by-products may not yet be developed or could be beyond the reach of smallholder swine farms.

Results of REM model regressions on factors affecting green indicators – N, P, and BOD loading – confirm the natural and expected outcome that commercial swine farms contributed to higher levels of pollution due to the larger volume of waste generated by bigger herd size. In the presence of waste treatment facilities, commercial swine farms are actually associated with lower level of N. An insight drawn from this finding is the unobserved characteristic of commercial swine farms' ability and capability to access and install green technology in order to lower or mitigate green growth indicators.

Contract swine farms, relative to independent swine farms, generated significantly lower levels of BOD loading. Thus, production arrangement has some influence on the level of this green growth indicator. What is it about contract swine farms that enable them to access and adopt green technology? It could be the nature of their contracts that serve as incentive for them to adopt green technology in swine production. It can also be the technical know-how in feeding and manure management that is passed on to them from constant information exchange with their integrators and from trainings.

Results of the interaction terms in the REM model regressions did not produce the expected outcome of WTF as a modifying variable except when it is interacted with SIZE in the *ln N* regression. Nevertheless, some insights can be derived from the findings and an important one is that, WTF, taken individually, has significant effects in reducing the levels of N, P and BOD loading. While this seems a natural outcome, it emphasizes all the more the role of access to green technology in dealing with environmental pollution and in increasing the environmental productivity of swine farms. On the other hand, the crucial interplay of access to information, green technology, and assistance of extension workers by swine farmers in reducing the levels of green growth indicators warrants more empirical investigation.

With respect to two other green growth indicators of environmental dimension of the quality of life and the economic opportunities and policy response, the insights that can be drawn from the qualitative discussions are that market-based instruments, technical and financial incentives for investment in farm-level innovation, and waste treatment facilities systems on top of a stricter and coordinated enforcement of environmental regulations will help swine farms in achieving increased environmental productivity and in developing towards green growth.

Underlying the above-mentioned conclusions and insights is that there could be factors that constrain swine farmers from being able to access green technology, technical know-how, and support of agricultural extension workers, among other things, in order to increase their environmental productivity. The presence of these constraints imply that green growth is not yet mainstreamed in swine production. The identification of and potential solutions to these constraints is imperative. Corollary to this is the crucial role played by institutions and institutional change to ease up these constraints and facilitate the ability of swine farmers to increase their environmental productivity and enable them to achieve green growth.

Chapter 6

Mainstreaming Green Growth in Smallholder Swine Production: Constraints and Potential Solutions

6.1 Introduction

Chapters 3, 4, and 5 have shown that just like many emerging economies in Southeast Asia (e.g., Thailand, Myanmar, Viet Nam, Cambodia, Lao PDR), swine production is a vital economic activity that is still dominated by smallholder swine farms in the Philippines. Swine production is beset with resource inefficiencies and its development is not sustainable due to many undesirable environmental externalities that occur due to expanding production (Gerber, et al,. 2012). Therefore, it behooves the Philippines and these countries to pursue and mainstream green growth. Though the Philippines has a comprehensive set of environmental regulatory policies at the national level, only 1/3 of the sample swine farms have achieved an increase in environmental productivity. This finding demonstrates two things. The first is that for the larger 2/3 of the sample swine farms who were unable to achieve an increase in environmental productivity, the constraints that prevented them from doing so remained binding and they cannot catch up with green growth unless there are enabling factors[38] that will assist them in hurdling the constraints. The second is that, for the 1/3 of the sample swine farms who were able to achieve an increase in environmental productivity, they have the capability to catch up with green growth because they were able to overcome constraints by having access

[38] Enabling factors are defined as "factors that make it possible (or easier) for individuals or populations to change their behavior or their environment. Enabling factors include resources, conditions of living, societal supports, and skills that facilitate a behavior's occurrence" (https://www.encyclopedia.com/ education/encyclopedias-almanacs-transcripts-and-maps/enabling-factors)

to information on swine waste management and access to financial resources to invest in green technology such as waste treatment facilities. From Chapter 4 of this dissertation, it can be recalled that the group of small independent swine farms who did not achieve an increase in environmental productivity had low mean Environment Technical Change (ETC) of 0.798, and only very few of them had installed waste treatment facilities. On the other hand, contract swine farms regardless of size, who achieved an increase in environmental productivity, had significantly higher mean Environment Technical Change (ETC) of 1.119, and majority of them were able to install waste treatment facilities.

The findings from Chapter 5 confirms the importance of access by swine farmers to green technology such as waste treatment facilities. Moreover, the role of institutions that will provide swine farmers with information and trainings with the support of agricultural extension workers was highlighted as an area for more empirical investigation.

The low turnout of smallholder swine farms that achieved an increase in environmental productivity in Chapter 4 and the incapacity of most swine farms to assimilate excess nutrients of N, P, and BOD loading in Chapter 5 can be due to various constraints in the implementation of environmental regulatory policies that affect the significant improvements in environmental quality of the natural asset base and environmental productivity of swine farms. Following the Framework in Chapter 1 of this dissertation, the gap in the implementation of environmental regulatory policies can be narrowed by examining, in an integrated manner, a spectrum of constraints to mainstreaming green growth in smallholder swine production in the Philippines. A part of this spectrum of constraints may lie along the transmission mechanism or may exist even before activities start at, and through the transmission mechanism. Moreover, even as the transmission mechanism process reaches smallholder swine farms, there could still be constraints that already pre-exist. Identifying the potential solutions to overcome these constraints will help smallholder swine farms to achieve an increase in their environmental productivity and enable them to catch up with green growth.

The objectives of Chapter 6 are two-fold:

1. To examine a spectrum of constraints to the implementation of environmental regulatory policies that increase the environmental productivity of smallholder swine farms.
2. To recommend potential solutions to overcome this spectrum of constraints.

6.2 Methodology

The process of mainstreaming green growth in smallholder swine production involves many dimensions. This study focuses on the constraints to the implementation of environmental regulatory policies that increase the environmental productivity of smallholder swine farms. In Chapter 2 of this dissertation, a spectrum of constraints to mainstreaming green growth in smallholder swine production was identified as economic and financial constraints, market constraint, regulatory and institutional constraints, technical and infrastructural constraints, and information constraints. This dissertation makes use of this spectrum of constraints but adds three more constraints: the intermediate catalyst constraint, the shared long-term vision constraint, and the systematic feedback constraint. The intermediate catalyst constraint refers to the absence of an agent, organization, institution, or outcome of a program or policy that can trigger a radical change, for example, in behavior, perceptions, and decisions for cooperation which could, in turn, activate or hasten the impacts of environmental regulatory policies to mainstream green growth. The shared long-term vision constraint refers to the lack of harmonized view among and across the hierarchy of environmental regulatory policies implementers of the long-term benefits of mainstreaming green growth. It is crucial for them to have the incentive to strictly and fully implement the policy in order to make a valuable contribution to safeguard the environment and at the same time increase the environmental productivity of smallholder swine farms. The systematic feedback constraint refers to the absence or lack of regular and organized mechanism, by which the process of mainstreaming green growth is monitored and assessed at each stage and the output of each monitoring and assessment is routed back as inputs that would become part of a feedback loop. These three additional constraints are identified to be constraints to achieving particular objectives when smooth implementation does not come about. On the other hand, these three additional constraints can be identified to be enablers when they function to assist in achieving the identified objectives. The addressing of the first set of identified constraints does not take place in a vacuum but in individual and social interactions. Therefore, these three additional constraints have to do with institutions and the manner in which institutional change takes place.

For a more focused investigation and analysis of the constraints, this dissertation compresses the categorization of the 8 constraints into only 2: 1) institutional and social constraints and 2) technical constraints. Institutional and social constraints shall cover regulatory, shared long term vision, systematic feedback, and intermediate catalyst. On the other hand, technical constraints shall include information, economic and financial, and market constraints.

In order to contribute to a deeper understanding of these constraints and why environmental regulatory policies are oftentimes ineffective, this study uses an impact pathway approach that is built on blended theories of institutional change and transaction cost as proposed by North (1990) and Williamson (2000) but with some modifications derived from the viewpoints of Chang (2007).

There are three aspects of these blended theories of institutional change and transaction cost that are useful for the objectives of this study: 1) definitions and functions of institutions;

2) bounded rationality, opportunism, and transaction costs; and 3) institutional inertia and institutional path dependence. The definitions of institutions remain to be a subject of debate since many authors use different definitions. North (1990) defines institutions as the "rules of the game", both formal and informal, that impose constraints on the behavior of individuals and influence their interactions. Institutions are distinguished from organizations which North (1990) considers as players. Individuals, as part of organizations, are actors who make choices and decisions. In the process of endless interactions, North (1990) proposes that individuals' decisions will change the rules of the game or there will gradually evolve new informal rules. On the other hand, Chang (2007) believes that there are no generally accepted definitions of institutions which make it problematic to come up with a consensus on the relationship between institutions, and, say, economic development. Nevertheless, Chang (2007, p.18) provides crucial functions of institutions in order to promote economic development but this study's analysis shall be limited to the following functions: "1) coordination and administration; 2) learning and innovation; 3) development of human capabilities (as borrowed from Amartya Sen 1989)" with the addition of 4) enforcement of rules and arrangements (North 1990). In this study, institutions would refer to both formal rules such as written laws and regulations and informal rules such as social norms, habits, and conventions of organizations or society.

Institutions can either facilitate or constrain the enabling environment and internal capabilities for the process of mainstreaming green growth. Transaction cost[39] can arise and constrain the functions of institutions, and, therefore, can constrain mainstreaming of green growth because of bounded rationality and opportunism of transacting parties (Williamson 2000). Bounded rationality is the assumption that one's knowledge about a transaction or

[39]Transaction cost refers to other cost when purchasing goods and services such as search cost, information cost, bargaining cost, decision cost, policing cost, and enforcement cost (Williamson, 2000).

transacting parties is limited and, hence, can lead to sub-optimal decisions and unintended outcomes. Bounded rationality is caused by incomplete information and mental constructs of individuals in organizations. Choices and decisions that individuals make are largely based on their perceptions and ideologies, which, in turn, are influenced by which the information is interpreted as it is received. These mental constructs are partly a result of the cultural heritage of individuals, their daily local problems, and non-local learning (North, 1990). Thus, individuals with different background may interpret the same thing differently and may, consequently, make different choices. Opportunism occurs when there is a possibility that a transacting party may seek self-interest and may take advantage of the other parties that are making the transaction. Opportunism can likewise constrain the mainstreaming of green growth.

Institutional inertia is referred by North (1990 p.89) as a situation when institutional change does not occur, or occurs very slowly, or is stalled despite changes in exogenous and endogenous parameters. Changes in relative prices, technology, or preferences are examples of exogenous parameters while enforcement (Kingston & Miguez, 2007) of rules, contracts, regulations, and policies is an example of endogenous parameter. There are many causes of institutional inertia such as bounded rationality, risk aversion, and “free-rider problems that impede collective action to change formal rules” (Kingston & Miguez, 2007 p. 18). However, North (1990) cites informal rules, which tend to change very slowly, as the main reason for institutional inertia.

On the other hand, institutional path dependence implies that choices and decisions that are made by individuals of organizations today are greatly influenced by the choices and decisions that were made in the past (North 1990; Kingston & Minguez 2007). However, the past choices and decisions made by individuals of organizations were influenced by their perceptions that were, in turn, framed from incomplete information feedback (i.e., bounded rationality), and from the conditioning effect of culture. Thus, the past perceptions have an impact on the nature and direction of future institutional change.

The roles of various categories of actors can be envisioned as operating within an impact pathway. The Impact Pathway Approach (IPA) traces a route that environmental regulatory policies would take to reach end users, giving consideration to different stages across the pathway such as technology innovation, information dissemination, technology commercialization, and end user adoption. The IPA entails the identification of intervening entities and the assessment of why one would not expect 100 percent success rate of what should be done to achieve the final objective or desired result from the innovation or technology that is introduced.

Figure 6.1 presents a sample pathway of mainstreaming green growth in smallholder swine production through the implementation of environmental regulatory policies that aim to promote an innovation that enables the recycling and/or treatment of swine waste and wastewater from smallholder swine farms. The expected output of this innovation is a range of options from simple wastewater reduction technology to waste and wastewater treatment technologies such as the construction of biogas digesters and lagoon and the use of Deep Litter Flooring System (DLFS). When the private sector (business enterprise) is expected to supply the technology or service, it can only supply the same in view of the profit that it would obtain. This has to be considered very carefully in claims that a particular technology is already mature and ready for commercialization. The adoption pathway of intended end-users who are smallholder swine farms can be traced from a series of interlinked activities that can start from an information and education campaign (IEC) that will inform end-users about the rationale, nature, benefits and costs, and other information pertinent to using the technology. Trainings

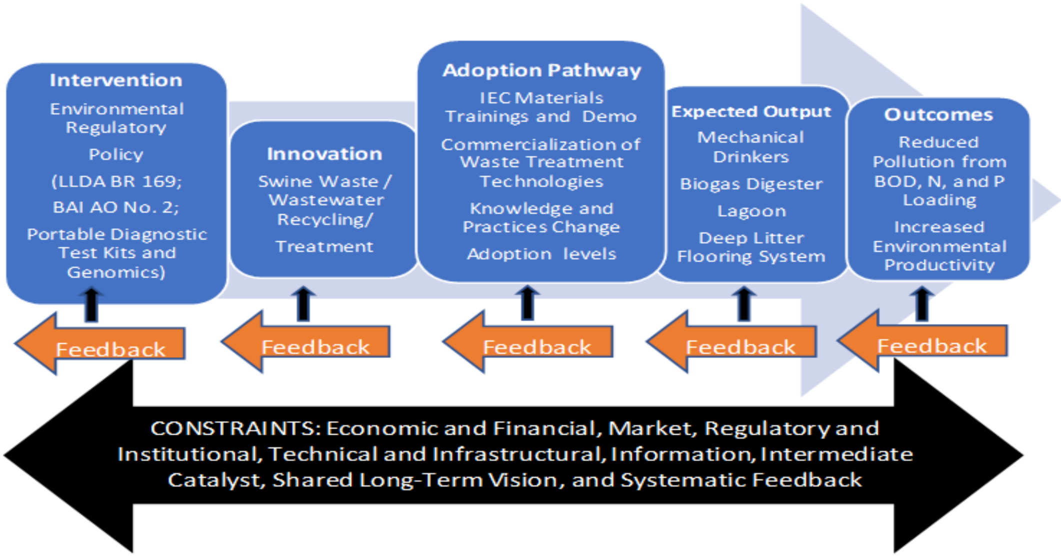


Figure 6.1 Impact pathway of environmental regulatory policies and spectrum of constraints

Source: Modified from Catelo, et al. (2015)

and field demonstrations of the technology that are being promoted may have to be conducted in order to convince end-users into adopting it. On the other hand, commercialization of the technology is also important should there be a critical mass of end-users that will choose to adopt it. The proof of the maturity and commercial viability of a technology cannot be determined by inventors of the innovation. This process has to proceed in smaller and more manageable pilot tests with smallholder swine farms in actual farm communities. This stage may still need some form of incentives and subsidy to the private enterprise taking risks in the initial application of a technology, whose widespread adoption is still uncertain. Finally, the knowledge and practices of this critical mass of technology adopters or end-users are expected to change to such extent and magnitude that will produce the outcome of reduced pollution from swine waste, thereby leading to an increase in environmental productivity of smallholder swine farms.

Each stage of the implementation of environmental regulatory policies will entail various constraints faced by agencies and organizations and smallholder swine farms -

economic and financial, market, regulatory and institutional, technical and infrastructural, information, intermediate catalyst, shared long-term vision, and systematic feedback constraints.

The impact pathway presented in Figure 6.1 is utilized as a guide in the analysis of constraints in the implementation of identified environmental regulatory policies which aim to increase the environmental productivity of smallholder swine farms.

To complement the impact pathway approach that is built on blended theories of institutional change and transaction cost, and in combination with the studies of Darwin (2005) and Lambon (2018), this study conducted key informant interviews involving a number of institutions and stakeholders in CALABARZON, a top swine producing region. Key informant interviews were conducted in order to learn more about micro-level issues that serve as constraints to mainstreaming green growth particularly in the implementation of environmental regulatory policies that increase the environmental productivity of smallholder swine farms. Aside from Tetra Tech Inc. (2010) and Trosgård (2015) who looked into the constraints to the implementation of anaerobic digestion systems (i.e., biogas digesters) in swine farms in the Philippines, there seems to be no other local study that have focused on this topic.

Key informant interviews were conducted for the period of 15 August to 20 September 2018 and April 2019 (Table 6.1). They consisted of the Office of City Veterinarian (OCV), Provincial Agriculturist Office (PAO), City Agriculturist Office (CAO), Municipal Agriculturist Office (MAO), Bureau of Animal Industry (BAI), Environmental Management Bureau-Provincial Environmental Management Unit (EMBPEMU) of the Department of Natural Resources and Environment Office (DENR), and Laguna Lake Development Authority (LLDA) to learn about constraints to information dissemination and implementation of environmental regulatory policies; the Department of Science and Technology (DOST) to learn

Table 6.1 Key informants interviewed

Key Informants	Location/Institution
City Veterinarian (OCV)	Lipa City, Batangas
Provincial Agriculturist Office (PAO)	Dept. of Agriculture, CALABARZON
City Agriculturist Office (CAO)	Lipa City, Batangas
Municipal Agriculturist Office (MAO)	Cuenca, Batangas
Municipal Agriculturist Office (MAO)	Pila, Laguna
Former Director, Bureau of Animal Industry (BAI)	National Capital Region (NCR)
Environmental Management Bureau-Provincial Environmental Management Unit (EMB-PEMU)	Dept. of Environment and Natural Resources (DENR), CALABARZON
Engineer, Environmental Regulatory Agency	Laguna Lake Development Authority (LLDA), Quezon City, Metro Manila
Senior Science Research Specialist	Environment and Biotechnology Division of the Industrial Technology Development Institute (EBD-ITDI), Dept. of Science and Technology (DOST), Bicutan, Metro Manila
Training Specialist	Agricultural Training Institute- International Training Center for Pig Husbandry (ATI-ITCPH), CALABARZON
Agriculturist	Agricultural Training Institute-National Livestock Program-International Training Center on Pig Husbandry (ITCPH) CALABARZON
Manager/Commercial Swine Farmer	Multipurpose Cooperative, Lipa City, Batangas, CALABARZON
Senior Manager	Sorosoro Ibaba Development Cooperative (SIDC), Batangas City, CALABARZON
Manager, Lending Center	Landbank of the Philippines, CALABARZON
Branch Manager	Bank of the Philippine Islands, CALABARZON
5 Smallholder Swine Farmers	Batangas and Laguna
9 Commercial Swine Farmers	Batangas and Laguna

Source: Author (2019)

about prototypes and costs of biogas digesters that are available for use by smallholder swine farmers and constraints to adoption; the Department of Agriculture-Agricultural Training Institute (DA-ATI) and the International Training Center on Pig Husbandry (DA-ITCPH) to know about trainings and extension work on how to use green technology such as biogas digesters and DLFS and constraints to their adoption; Multipurpose Cooperative and the Sorosoro Ibaba Development Cooperative (SIDC) to learn about potential solutions from the viewpoint of private sector and organization to overcome constraints to adoption of green technology; 2 commercial banks to know about credit opportunities for smallholder swine farmers and financial constraints to access these credit opportunities; and 5 smallholder swine farmers and 9 commercial swine farmers to learn about their swine waste management practices and constraints to adoption of green technology such as biogas digesters, lagoons, and Deep Litter Flooring System (DLFS)[40]; For uniformity, all names were withheld since the majority of key informants requested anonymity. Their responses to questions on constraints to mainstreaming green growth are found in Appendix G, Appendix H, and Appendix I. The Likert 4-point scale method was used for this purpose.

6.3 Results and Discussion

6.3.1 Policies to Achieve Green Growth in Swine Production

Three aspects of green growth, namely, environmental and resource productivity, pollution reduction, and social inclusion are not really new concepts in the Philippine case although these aspects are not yet mainstreamed despite decades of efforts to do so. The country is a founding member of the Global Green Growth Initiative (GGGI) through the Philippine Council for Sustainable Development (PCSD) that was established in 1992. The PCSD in consultation with various stakeholders identified two main issues which are: 1) chronic poverty and 2) the fortification of institutional framework for sustainable development (SD) from the ground up and it suggested to make SD concept more mainstream in the processes and practices in key sectors of green economy in the Philippines such as agriculture and fisheries, environment and natural resources, and waste reduction which remains to be a key challenge.

Furthermore, the medium-term Philippine Development Plan (PDP) of 2011-2016

[40] Deep litter flooring system (DLFS) is a natural swine farming method for constructing the bedding of swine housing or pens. DLFS makes use of a one meter deep bedding backfilled with layers of soil, salt, sawdust and rice hulls or coconut husk. The bedding is sprayed with a solution of beneficial microorganism that will hasten the decomposition of organic matter such as swine manure and convert it into basic minerals (Kim, n.d.)

defined inclusive growth as “rapid enough to matter, given the country’s large population, geographical differences, and social complexity; it is sustained growth that creates jobs, draws the majority into the economic and social mainstream and continuously reduces mass poverty” (PDP 2011-2016). The medium-term Philippine Development Plan (PDP) of 2017-2022 recognizes the consistent buffer role that the livestock and poultry sector had always played in the past years to help keep the agriculture, forestry, and fisheries (AFF) sector thriving. Thus, there are provisions to “revitalize and harness the growth potentials of the AFF sector to promote more inclusive growth and overcome poverty through interventions and investments that will expand existing opportunities and develop new ones” (PDP 2017-2022).

However, while it can be argued that the swine production sector may have gained from technological advances in genetics, nutrition, and animal health, the sector continues to be beset by challenges to increase production and productivity. But efforts to increase the sector’s growth would also mean a concurrent growth in the generation of wastes. Thus, there is additional challenge to recycle or reduce as much waste per unit of output as technically (and economically) proven to be feasible. However, from the discussion in Chapter 3, Section 3.5, it was confirmed that waste recycling capacities and practices are also related to size of production. This is because even the institutional innovation of vertical integration and contract farming has tended to disproportionately benefit the commercial swine farms more than they benefitted the smallholder swine farms (Catelo & Costales, 2008; Tiongco, et al., 2008; Costales & Catelo, 2010).

Mainstreaming green growth, therefore, would have to implement environmental regulatory policies that target smallholder swine farms, particularly those that are business-oriented, because they would gain from any intervention that will enhance the performance of their economic activity and allow them to expand their operation toward sustainably commercial levels. This implies that smallholder swine farms can catch up with green growth if they are assisted or if the so-called enabling factors from the government and private entities are provided.

There are other relevant policies that provide the legal and institutional framework for mainstreaming green growth in swine production. Some of these are the Climate Change Act of 2009, the Clean Water Act of 2004 and the Ecological Solid Waste Management Act of 2002. The salient provisions of these and other policies are provided in Annex F of this dissertation. This list is by no means exhaustive. For the purpose of illustrating and discussing the constraints in introducing innovations in swine production and implementing environmental regulatory policies that aim to increase the environmental productivity of smallholder swine farms, three cases are discussed:

1. The Laguna Lake Development Authority (LLDA) Board Resolution (BR) No. 169 or "Approving the Policy Guidelines Governing the Operation of Backyard/Small-Scale Hog Farms in the Laguna De Bay Region"
2. The Promotion of Biogas Digester as stipulated in the Bureau of Animal Industry (BAI) Administrative Order No. 2 or the National Animal Waste Resource Management Program (NAWRMP) of 2015
3. The Introduction of Portable Diagnostic Test Kits and Genomics or Gene Markers Innovation in Swine Production

6.3.2 Identification of the Constraints to the Implementation of Environmental Regulatory Policies

6.3.2.1 The Laguna Lake Development Authority (LLDA) Board Resolution (BR) No. 169 or "Approving the Policy Guidelines Governing the Operation of Backyard/Small-Scale Hog Farms in the Laguna De Bay Region"

The LLDA was created by the Philippine Government in 1966 by virtue of Republic Act (RA) 4850 as a quasi-government agency with regulatory and proprietary functions. This was in response to the urgent "conservation, protection, and rehabilitation of Laguna de Bay and its environment". Through Presidential Decree 813 in 1975, and Executive Order 927 in 1983, the LLDA's powers and functions were expanded and strengthened to include environmental protection and jurisdiction over the lake's basin surface water. In 1993, the administrative supervision over the LLDA was moved from the Office of the President to the Department of Environment and Natural Resources (DENR) (Darvin, 2005). In 2001, the LLDA saw the need to regulate "backyard" or smallholder swine farms because they accounted for about 70 percent of total swine population and though small in size and geographically dispersed, they were large in numbers and their collective pollution particularly in term of BOD loading would still be huge and detrimental to the environment. Thus, the LLDA enacted BR No. 169. The salient provisions of the LLDA BR No. 169 are provided in Table 6.2.

The LLDA indicated the following strategies to promote the use of waste management technologies among smallholder swine farms: 1) Intensive Education Campaign (IEC), 2) provision of technical assistance, 3) community organization, 4) involving private investors in financing costly undertakings, 5) coordination with multi-national and local companies, and 6) assistance to LGUs in drafting appropriate resolutions and ordinances. The LLDA BR No. 169

Table 6.2 Salient provisions of the LLDA BR No. 169

Salient Provisions
a. Aims to reduce/minimize the pollution load emanating from smallholder swine farms by promoting the use of waste management technologies and waste management hierarchy (WMH). The latter consists of: Waste Minimization/Reduction Waste Recycling/Reuse Waste Treatment Waste Disposal
b. Implementing Team: Community Development Division (CDD) of the LLDA LGUs River Councils/Foundations Smallholder Swine Farms/Association of Smallholder Swine Farms
c. The law applies to all smallholder swine farms that have less than 100 heads or a sow level of less than 10 heads.
d. The Waste Management Hierarchy (WMH) advocates for the adoption by smallholder swine farms of waste minimization or waste reduction technology, waste reuse, and recycling practices rather than end of the pipe waste treatment and disposal measures
e. To ensure compliance, the LLDA shall conduct water sampling and analysis every quarter.
f. Penalty for non-compliance: revocation or cancellation of sanitary and business permits.
g. Incentives for compliance: 30 percent reduction in the cost of renewing sanitary and business permits and reallocation of fines from non-complying swine farms.

Source: LLDA (2001)

was to be implemented by a multi-sectoral team headed by the Community Development Division (CDD) of LLDA.

Referring back to Figure 6.1, the constraints to the implementation of the LLDA BR No. 169 can now be traced and identified using the Impact Pathway Approach. In 2004, three years after the implementation of the LLDA BR No. 169, Darvin (2005) conducted an evaluation of its impacts on 82 smallholder swine farms in the swine-producing cities of Calamba and San Pablo and municipality of Pila in the province of Laguna in Region IV-A. These cities and municipality are within the jurisdiction of the LLDA. In 2017, Lambon (2018) conducted a similar study in the same cities and municipality as those of Darvin (2005) in order to reassess the impacts of the LLDA BR No. 169 on smallholder swine farms. In general, both studies found that there was a failure in the implementation of this environmental regulatory policy due to various constraints:

1. *Institutional and Social Constraints*

1.a Regulatory Constraint

By virtue of the Local Government Code, the Department of Agriculture devolved its extension service mandate to local government units (LGUs), particularly the Municipal Agriculturist Offices (MAOs) and City Agriculturist Offices (CAOs). Because of this transfer of responsibilities, there was a wide discrepancy in the quality and effectiveness of government extension services across the municipalities and cities. At the same time, MAOs and CAOs had limited human and financial resources to perform timely information dissemination of local ordinances and render sufficient extension services to smallholder swine farms in all barangays. A barangay is the Filipino native term for the smallest administrative division in the Philippines which is equivalent to a village, ward, or district. In 2004, the CDD-LLDA did not have enough manpower and funds to execute the LLDA BR No. 169 (Darvin, 2005). Therefore, it was not able to engage in an intensive Information Education Campaign (IEC) to the LGUs, River Councils, and smallholder swine farms. The implementation of the LLDA BR No. 169 was not smooth because the services of staff involved were discontinued due to tenure issues and replacement by subsequent administrations after the local elections. Moreover, due to bounded rationality, LGUs, MAOs, and CAOs persisted in their belief that only commercial swine farms had to be regulated and monitored because of the larger volume of swine waste that they generate relative to those of smallholder swine farms. Therefore, LGUs, MAOs, and CAOs did not have the incentive to regulate and monitor smallholder swine farms. Moreover, MAOs and CAOs did not have updated database or registry of smallholder swine farms and this contributed to the higher transaction cost of identifying, regulating, and monitoring them. In 2017, the

CDD-LLDA claimed that it no longer had financial constraint because it was able to generate positive net income for the period 2005 to 2016 (Lambon, 2018). Yet, 13 years after Darvin's (2005) study, the LLDA BR No. 169 was still not widely implemented and the CDD-LLDA reasoned that the resolution was already superseded by other LLDA environmental regulatory polices such as the Environmental User Fee System (EUFS) and the Water Quality Management Area Approach (WAQMA). However, provisions of the EUFS did not really cover smallholder swine farms (Catelo, et al., 2007). On the other hand, an important provision of the WAQMA approach is that all activities and establishments that cause pollution in the Laguna Lake are being monitored and those who will not comply shall be penalized. However, without an updated database or registry of smallholder swine farms, their lack of awareness on local ordinances and the LLDA BR No. 169 (Table 6.3), and with difference in the historical beliefs and perceptions of policy implementers, the process of institutional change, which will increase the environmental productivity of smallholder swine farms, will be slow.

Table 6.3 Status of registration of 173 sample smallholder swine farmers in Laguna and their awareness on local ordinances and the LLDA BR No. 169, 2004 and 2017

Item	Respondents (%)	
	2004 (*N*= 82)	2017 (*N*=91)
Registration		
Registered	30	10
Not Registered	70	90
Awareness on local ordinances		
Aware	8	21
Unaware	92	79
Awareness on LLDA BR No. 169		
Aware	4	2
Unaware	96	98

Sources: Darvin (2005) and Lambon (2018)

1.b Shared Long-Term Vision

If it were only widely and properly implemented, the LLDA BR No. 169 would have reduced pollution emanating from smallholder swine farms by promoting the use of waste management technologies and waste management hierarchy. However, the CDD-LLDA and LGUs, MAOs, and CAOs across the hierarchy of policy implementers and administrators did not seem to share a long-term vision of the benefits of the LLDA BR No. 169 as an environmental regulatory policy and as a means for putting public funds to good use by financing public goods such as safeguarding the environment and increasing the environmental productivity of smallholder swine farms. LGUs, MAOs, and CAOs did not have the incentive to fully implement the LLDA BR No. 169 because their priority was the regulation of solid waste disposal of households since the volume of wastes coming from individual smallholder swine farms was perceived to be not environmentally damaging.

1.c Systematic Feedback Constraint

It is a fact that LGUs across the hierarchy of policy implementers and administrators and smallholder swine farms were not fully aware of the existence of the LLDA BR No. 169 in 2004 and 2017 (Darvin 2005; Lambon 2018). It suggests that the Information and Education Campaign (IEC) of the CDD-LLDA was insufficient. It is also a manifestation of the lack of systematic coordination and feedback activities between the CDD-LLDA and LGUs. (see Appendix G).

1.d Intermediate Catalyst Constraint

The presence of institutions performing the role as catalyst in promoting cooperation among different stakeholders is important especially when commercialization and adoption of technology is concerned. Active engagement of local communities through the Association of

Smallholder Swine Farms would have served as an intermediate catalyst but the LGUs could not be relied upon to provide this service because the transaction cost of organizing many geographically dispersed and unregistered smallholder swine farms was perceived to be high.

2. Technical Constraints

Agricultural Extension Workers (AEWs), usually the Municipal Agriculturist or staff from the MAOs, are supposed to be the knowledge arm of LGUs. Unfortunately, these AEWs themselves lacked technical skills and training (Darvin 2005) to provide sufficient and updated information on agricultural technologies such as constructing lagoons or biogas digesters (See Appendix H).

2.a Market Constraint

On the other hand, LGUs and River Councils did not have extensive market knowledge and network to assist smallholder swine farms in accessing inputs and outputs markets or private institutions for waste recycling, reduction, and treatment technologies. High transaction costs were incurred in the trial-and-error search for technologies which passed the effluent[41] standards. Moreover, the biogas digester market was not yet mature and private suppliers generally did not receive incentives that could have lowered their cost of production. Thus, demand for and supply of biogas digesters were low.

6.3.2.2 The Promotion of Biogas Digester as Stipulated in the Bureau of Animal Industry (BAI) Administrative Order No. 2 or the National Animal Waste Resource Management Program (NAWRMP) of 2015

In January 30, 1930, the Bureau of Animal Industry (BAI) of the Department of Agriculture (DA) was created by virtue of RA 3639 and is mandated to oversee the development

[41] Effluent refers to liquid waste or sewage discharged into a river, sea, or any water body.

of livestock, poultry, and dairy industries. The BAI has long been aware of the pollution coming from livestock farms. It has recognized the importance of proper disposal of animal waste, especially swine waste. Thus, the BAI has been promoting the use of the biogas digester technology in the 1970s, 1980s, and 1990s, but it has not been widely adopted due to many constraints.

In 2015, the BAI established the National Animal Waste Resource Management Program (NAWRMP) in order to promote the biogas digester technology again for its "Waste-to-Energy" Project. This involved the dissemination of using the biogas digester technology through collaborative seminar-workshop, farmers' forum, and on-site demonstrated construction.

The wide or full-scale adoption of the biogas digester technology will increase the environmental productivity of smallholder swine farms and enable them to catch up with green growth if the following historical and recurring constraints in the implementation of this technology innovation were addressed:

1. Institutional and Social Constraints

1.a Regulatory Constraints

The BAI implemented a biogas project in the mid-1970s where more than 400 floating dome type digesters were installed in regions, provinces, towns, and localities (Martinez, 2017). However, monitoring the use and status of these biogas digesters seemed to have been difficult because of limited human resources and high transaction cost in locating geographically dispersed smallholder swine farms. Moreover, based on key informant interviews of commercial swine farms who had constructed such digesters.the investment and maintenance costs of the floating dome digester were large due to the concrete materials used. The life span of the floating dome digester was short and it occupied land that could not be used for any other purpose. It also required a certain level of technical knowledge to operate it which the smallholder swine farms lacked. Hence, the demand for this type of digesters by smallholder swine farms did not grow. The BAI had to search for lower cost biogas digesters that were easier to maintain and whose operational design was simple. In the 1990s, the BAI introduced the cheaper, simpler, plastic Tubular Polyethylene Digester (TPED) (Martinez, 2017). These were initially acceptable to smallholder swine farms but the adoption was also not widespread. There were cases of TPED bursting[42] because of the excess volume of swine waste that was used by smallholder swine farms who have expanded their herd. Thus, other smallholder swine farms who learned about the breakdown cases were hesitant to adopt the TPED. There were also cases of non-production of methane gas by the TPED when smallholder swine farms sold some animals. With fewer animals left, the volume of swine manure was not sufficient to generate methane gas. The supply of Agricultural Extension Workers (AEWs) who could have disseminated and reiterated the needed information about maintenance requirements and who could have regularly monitored the use of TPED was apparently inadequate. In 2013, the BAI promoted the development of High Density Polyethylene Digester (HDPED) and Scalable Polyethylene Drum Digester (SPEDD) but there is no published data yet about the adoption rate by smallholder swine farms. In a span of 4 decades, the BAI has yet to succeed in the wide promotion of the biogas digester technology. The Philippine Development Plan for 2017-2022 (PDP 2017-2022) intends to heighten the capacity of smallholder swine farms to adopt improved and innovative technology as well as strengthen the extension system for the promotion of good farming practices. The DENR aims to conduct a stricter implementation of various environmental laws and regulations[43] but more intensified information dissemination

[42] Based on key informant interviews of OCV, CAO, PENRO, and commercial and smallholder swine raisers. A similar case was documented by Catelo, et al. (2003).

[43] Based on key informant interviews of PENRO, OCV, and CAO.

of these environmental laws and regulations should systematically cascade down the hierarchy of environmental policy implementers. Thereafter, stronger and wider awareness among smallholder swine farms on the benefit of using biogas digesters and their variants must ensue.

1.b Systematic Feedback Constraint

BAI Administrative Order No. 2 or NAWRMP of 2015 came from the national government agency level and was passed on as a directive to the Regional Field Units (RFUs). RFUs are supposed to disseminate provisions of NAWRMP to provincial and municipal/city level LGUs and OCV/MAOs/CAOs and then to smallholder swine farmers. However, there does not seem to be regular and systematic coordination and feedback at each agency level particularly on the processes and constraints of cascading the information dissemination down to the level of smallholder swine farmers. Response of key informants confirm this lack of systematic feedback. Table 6.4 shows that while 66 percent of key informants agreed there is effective dissemination of environmental laws across hierarchy of policy implementers, one-third of them did not. Moreover, 75 percent of key informants did not agree that staff/agricultural extension workers give feedback to their supervisors on status of adoption of biogas digesters and other waste treatment facilities by swine farmers.

Table 6.4 Response of key informants related to systematic feedback constraint

Statement	**% Response (*n* =12)**			
	SA	**A**	**D**	**SD**
Information dissemination about swine management/environmental laws across hierarchy of policy implementers is effectively done.	8	58	33	0
Staff/AEWs always give feedback to supervisors regarding adoption of biogas digester and waste management/treatment facilities by swine farmers	0	25	67	8

Source: Author's key informant interviews (Aug-Sept 2018; April 2019)

Notes: SA – Strongly Agree A – Agree D – Disagree SD – Strongly Disagree

.c Intermediate Catalyst Constraint

Demonstration of biogas digesters that are properly functioning is the best means of promoting use and adoption of this technology among smallholder swine farms. Person-to-person assistance on technical knowledge and repair requirements of biogas digesters would have encouraged their widespread use. An AEW could serve as an intermediate catalyst if only there was one who is able to visit swine farms regularly to demonstrate how a biogas digester works. However, Table 6.5 shows that, as confirmed by 77 percent of commercial farmers and 100 percent of smallholder swine farmers who served as key informants, no AEW visited their farms in order to assist them on the use, maintenance, and repair of this waste treatment facility.

Table 6.5 Response of key informants related to intermediate catalyst constraint

Statement	**% Commercial Swine Farmers (*n* =9)**				**% Smallholder Swine Farmers (*n*=5)**			
	SA	**A**	**D**	**SD**	**SA**	**A**	**D**	**SD**
No extension worker has visited my farm to demonstrate how a biogas digester works and assist me in maintenance and repair.	44	33	11	11	60	40	0	0

Source: Author's key informant interviews (Aug-Sept 2018; April 2019)

Notes: SA – Strongly Agree A – Agree D – Disagree SD – Strongly Disagree

2. Technical Constraints

Lack of Agricultural Extension Workers (AEWs) who were knowledgeable about biogas digester technology and skilled enough in troubleshooting and repairs was another constraint for its relatively slow adoption by smallholder swine farms[44]. There were also infrastructural constraints since many smallholder swine farms did not have land and space

[44] Based on key informant interviews of Senior Science Research Specialist of DOST EBD-ITDI, Training Specialist of ATI-ITCPH, OCV, CAO, and commercial and smallholder swine farmers.

necessary for the installation of biogas digesters[45] (See Appendices G to I). Table 6.6 confirms the presence of technical constraints in implementing environmental regulatory policies or programs like the NAWRMP of 2015. This is attested to by the response of more than 80 percent of key informants (OCV/MAOs/CAOs/PAOs, Extension workers, COOP managers) who disagreed that there were enough AEWs who have very good technical knowledge on the use, operation, and repair of biogas digester. Consequently, related trainings to swine farmers on waste management/treatment technologies were not conducted on a regular basis.

Table 6.6 Response of key informants related to technical constraint

Statement	% Response (*n* =12)			
	SA	A	D	SD
There is sufficient number of staff/AEWs who conduct trainings on use of biogas digester and waste treatment facilities	0	17	67	17
Staff/AEWs have very good technical knowledge on installation, operation, and repair of biogas digester	0	17	75	8
Staff/AEWs give regular trainings to swine farmers on use of biogas digester and other waste management/ treatment technologies	0	17	75	8

Source: Author's key informant interviews (Aug-Sept 2018; April 2019)

Notes: SA – Strongly Agree A – Agree D – Disagree SD – Strongly Disagree

2.a Economic and Financial Constraint

The Department of Science and Technology Environment and Biotechnology Division of the Industrial Technology Development Institute (DOST EBD-ITDI) came up with prototypes of the Portable Biogas Digester (PBD) for the period 2008-2010[46]. However, the costs of these prototypes were Php 9,000, Php 17,000 and Php 25,000. The cost depends on whether the materials were plastic, plastic and metal, or pure metal respectively. These costs

[45] Based on key informant interviews of President of Multipurpose Cooperative and commercial swine farmers.
[46] Based on key informant interview of a Senior Science Research Specialist of DOST EBD-ITDI.

were perceived by smallholder swine farms as relatively expensive[47]. Thus, the adoption of PBD had been slow with only 20 to 30 adopters nationwide for the period 2008-2018. It can be recalled from Chapter 3 of this dissertation that less than 10 percent of the 40 sample smallholder swine farms had installed biogas digesters with costs that ranged from Php 4,000 to Php 6,000. Smallholder swine farmers did not adopt the PBD and other types of biogas digesters because of financial constraint and the difficulty to access credit from formal financial sources like banks due to non-possession of acceptable collateral for loan application such as land title and other basic requirements. For example, the majority of the sample smallholder swine farms used personal funds (Table 6.7) to finance their production operations because, in addition to the rigid and stringent bank loan requirements, they were afraid of the huge sur charges if they defaulted on their bank loans. Based on key informant interviews of commercial and smallholder swine farmers, for those who made loans for feed inputs, the distributor of feeds actually gave them a grace period of one month to four months before collecting the payment for feed inputs. On the other hand, formal financial institutions like the Landbank of the Philippines (LBP) is not structured to lend to individual smallholder swine farmers. The

Table 6.7 Sources of credit of sample smallholder swine farms

Source of Credit	**Respondents (%)**			
	2002 (*N*=40)	**2004 (*N*= 82)**	**2015 (*N*=40)**	**2017 (*N*=91)**
For Production				
Personal	88	82	78	96
Borrowed	12	18	22	4
For Feeds				
Personal	68	N/A	68	N/A
Borrowed	32	N/A	32	N/A

Sources: Costales, et al. (2003); Darvin (2005); survey by Author (2015); Lambon (2018)

Note: N/A means not applicable

[47] Smallholder swine farms engaged in grow-to-finishing production system earned average profits of about Php 20,000 per production cycle of 3 to 4 months, selling an average of 10 heads per cycle (Lambon 2018).

LBP would lend through cooperatives or farmer organizations who would serve as the major credit conduits to finance smallholder swine farmers. The LBP uses a risk-based pricing system wherein operations of the cooperatives or farmer organizations are evaluated, reviewed, and given a credit rating. If the credit rating is high, then the interest on the loan or the spread on the loan is minimal. This credit scheme reduces the LBP's credit risks and lowers its transaction costs in conducting individual credit investigation activities of potential borrowers[48]. It will be advantageous, then, for smallholder swine farms to organize themselves or become members of cooperatives and farmer organizations (See Appendix H and Appendix I).

2.b Market Constraint

More product marketing activities from local suppliers and distributors are necessary to increase the number of people who are made aware of biogas digesters, thereby increasing potential customers. Although the Bureau of Agricultural Research (BAR) assisted the BAI in providing public information of technologies that can be commercialized by potential investors or suppliers through the conduct of National Technology Forums, many smallholder swine farms apparently have not had access to this information. The majority of biogas digester suppliers cater more to the needs of commercial swine farmers.

Table 6.8 reinforces the existence of economic, financial, and market constraints in implementing environmental regulatory policies such as the NAWRMP. Among the key informants, 100 percent of the smallholder swine farmers found it difficult to purchase or construct a biogas digester because it was very expensive, they do not have sufficient financial capital, and applying for bank loans was difficult and entailed many requirements. Hence, 100 percent agreed that they should be given subsidy by government. Moreover, smallholder swine

[48] Based on key informant interview of a lending manager of Landbank of the Philippines.

farmers did not know where to purchase the biogas digester. Commercial swine farmers, on the other hand, shared the same view about the high cost of the biogas digester and difficulty in applying for bank loans. However, more than half of them had sufficient financial capital to install a biogas digester and more than two-thirds had information on where to purchase it. Eleven percent did not have difficulty applying for bank loan.

Table 6.8 Response of key informants related to economic, financial, and market constraints

Statement	% Commercial Swine Farmers (*n*=9)				% Smallholder Swine Farmers (*n*=5)			
	SA	**A**	**D**	**SD**	**SA**	**A**	**D**	**SD**
The biogas digester is very expensive to buy or construct	56	44	0	0	60	40	0	0
It is difficult to apply for a bank loan for a digester	33	56	0	11	20	80	0	0
Banks have many requirements for loan application for a digester	44	56	0	0	20	80	0	0
I have sufficient financial capital to construct a digester	0	56	33	11	0	0	100	0
Government must give us financial subsidy to buy or construct a digester	78	11	11	0	100	0	0	0
I don’t know where to buy or prefabricate a biogas digester	0	22	67	11	0	100	0	0

Source: Author’s key informant interviews (Aug-Sept 2018; April 2019)

Notes: SA – Strongly Agree A – Agree D – Disagree SD – Strongly Disagree

6.2.3.3 The Introduction of Portable Diagnostic Test Kits and Genomics or Gene Markers Innovation in Swine Production

Two examples of recent interventions and innovations to increase environmental productivity in swine production are related to reducing animal mortality and increasing animal reproduction and productivity through the use of 1) portable diagnostic test kits for early detection of key diseases in swine and 2) genomics or gene markers innovation (DOST-PCAARRD, 2016).

Portable diagnostic test kits for early detection of key diseases in swine such as gastro-intestinal and respiratory diseases promise to make quick and accurate detection so that farmers can make timely and appropriate responses. However, there are constraints in the mainstreaming pathway that may hinder the full realization of intended outcomes (Figure 6.1).

1. Institutional and Social Constraints

1.a Regulatory Constraint

Regional Field Units (RFUs), LGUs, PAOs, MAOs, and CAOs do not have sufficient manpower to regulate and monitor health status of swine farms and possible diseases that can be afflicting these farms. For both the portable diagnostic test kits and the genomics, widespread dissemination and adoption of the test kits and the improved breeds will require the establishment of a reliable database or registry of swine farmers at the LGU level as a good starting point for overcoming the series of constraints.

1.b Intermediate Catalyst Constraint

Technology demonstrations (techno-demos) are found to be effective intermediate catalyst that can encourage smallholder swine farmers to adopt a technology. However, funds for techno-demos are either very limited or not available at all. Therefore, this serves as a constraint.

Nevertheless, for portable diagnostic test kits, upon commercial production of the test kits, the mechanism for diffusing them for use by smallholder swine farms must be designed. Modes of purchase of the test kits and use by smallholder swine farms can be explored. For medium- and large-size commercial swine farms, they would likely be willing to pay for the test kits for their own use, and willing to pay for the veterinary and treatment costs that are required. But it may not be the case that smallholder swine farms would purchase the test kits themselves for their own use. Possibly, one design would be that certain professionals or para-veterinarians (intermediate catalysts) are willing to buy the test kits and then provide testing services to smallholder swine farms within their territory or area. Depending on the demand for diagnostic testing services by smallholder swine farms, some may readily be willing to pay, valuing their need for their livestock to be tested and undertake the subsequent measures. Other smallholder swine farms might not have yet the capacity to pay for the diagnostic testing services. In this case, initially, the testing fee paid to the para-veterinarians might be charged to the regular program funds of the Animal Health Unit (AHU) of the LGU. Over time, this subsidy could be phased out. Smallholder swine farms who were provided diagnostic testing services by the para-veterinarians can, in turn, serve as intermediate catalyst to other smallholder swine farms.

2. Technical Constraints

In portable diagnostic test kits, the points of intervention should be identified throughout the commercialization to the adoption chain. The commercialization stage of a seemingly 'mature' technology cannot be assured to take place by the simple demonstration of viability and profitability of the enterprise by feasibility studies. Demand for the technology at the target-beneficiaries' end (smallholder swine farms) has to be tested, and replicated over a number of target locations, as these smallholder swine farms are ultimate decision-makers in the use of the innovation. The portable diagnostic test kits should be demonstrated and tested at the smallholder swine farms' level, on a voluntary basis. Initially, the procedure should be free-of-charge at testing stage. The results are then given to these smallholder swine farms, and they are then monitored on their subsequent behavior in terms of: 1) seeking out expert veterinary or para-veterinary services, 2) seeking out the effective treatment program(s), and 3) paying for these treatment programs.

2.a Economic and Financial Constraints

For the portable diagnostic test kits, a constraint that has to be addressed is ascertaining the behavior of smallholder swine farms after the quick diagnosis is made. Will they resort to effective treatment programs, assuming these are available, or will they just remain complacent and resort to inaction because of the associated costs of the succeeding treatment after the quick diagnosis is made? Unless smallholder swine farms seek out expert veterinary services and the diagnosed disease is treated effectively, the portable diagnostic test kits will not bring out the intended outcomes of reducing mortality and increasing environmental productivity (Catelo, et al. 2015). On the other hand, if the majority of smallholder swine farms do not make the subsequent decision toward the treatment of their livestock diagnosed as needing some particular treatments, there is no sense in pushing for the commercialization of the technology. But the positive learning from this is that the determination of absence or lack of demand at smallholder swine farms' end is evidence-based.

The aim of the genomics innovation is to develop and apply microsatellite markers in selecting genes for prolificacy, disease resistance, and genetic defects which are not easily inherited. Two main groups of beneficiaries are identified: swine breeders who will make use of the genomics technology to improve and shorten their breeding selection techniques and come up with improved breeds and commercial swine farms that purchase breeding stocks from swine breeders. The intended outcome is the widespread adoption of improved breeds which will result to higher swine productivity that will increase environmental and resource productivity which is an aspect of green growth. The constraints in the mainstreaming pathway are: 1) the genomics innovation requires a long horizon for the intended outcomes of improved breeds to be realized and 2) it will likewise take time for the sector to form a critical mass of swine farms that will use the improved breeds in order to make a substantial impact.

2.b Market Constraint

For the portable diagnostic test kits, repeated tests of smallholder swine farms' behavior should reveal the extent of indirect demand for the technology in terms of their willingness to pay for subsequent treatments. If the majority of monitored smallholder swine farms do seek expert assistance and do purchase the necessary treatments, then a potential demand for the portable diagnostic test kits is revealed. In this instance, there is a strong case for the commercialization of the technology. In this case, the gaps to supplying the portable diagnostic test kits can be addressed. Initially, the entrepreneurs might need investment incentives (for example, tax and credit incentives, cost-sharing arrangements with the government) to start up the enterprise. A crucial stage in the entire pathway is the commercialization stage (Catelo, et al. 2015), during which a private company must find it profitable to produce the portable diagnostic test kits in commercial quantities. This commercialization stage, if successful, will ensure the sustained market availability of the test kits which smallholder swine farmers can access. For the innovation to be considered as mainstreamed, smallholder swine farmers are expected to make good use of the technology in order to realize the desired outcome of reducing swine mortality at the farm-level.

For the genomics, the full adoption by swine breeder farms of the gene marker technology through laboratory testing of their animals is a crucial stage. Adoption of improved breeds by all commercial swine farms is another critical stage. The access to and adoption of improved breeds by the larger group of smallholder swine farms is the most important stage (Catelo, et al. 2015). Thus, the outcome of this innovation would be long-term.

The LLDA BR No. 169 and the BAI A.O. No. 2 or NAWRMP of 2015 are public sector-led programs, in compliance with Authority and Bureau directives. In both cases, the measure of 'output' has been reckoned according to their internally defined scope of work or internally defined or perceived targets. However, in the case of LLDA, smallholder swine farms were not their concern at the outset and, therefore, the major constraint toward implementing LLDA BR No. 169 was largely and fundamentally institutional in nature because no long term vision was shared by the hierarchy of implementers of this environmental regulatory policy. Thus, the innovation was not disseminated at all, notwithstanding the lack of coordination across the hierarchy of policy implementers. In the case of the BAI A.O. No. 2 or NAWRMP of 2015, the existence of both institutional and technical constraints cannot be denied although the predominant constraint was more technical in nature. Technologies on offer were indivisible and costly and this was tantamount to excluding the smallholder swine farms which were the very target segment for innovation to achieve an increase in environmental productivity. Furthermore, AEWs with technical competence were insufficient in number, and, therefore, information on installation, operation, and maintenance of technology was not regularly and systematically disseminated particularly to smallholder swine farmers. The case of the portable diagnostic test kits and genomics or gene markers innovation is a case of potential technological intervention. The prevailing constraint is also technical in nature although this is leaning more toward the market constraint and the uncertainty of how the commercialization and adoption process of this technology will eventually play out.

Using the 3 cases cited above, Table 6.9 gives a summary of constraints that pervade in the implementation of environmental regulatory policies that are related to mainstreaming green growth in swine production.

Table 6.9 Summary of constraints that pervade in the implementation of environmental regulatory policies

Case	Constraint					
	Institutional and Social				Technical	
	Regulatory	Systematic Feedback	Intermediate Catalyst	Shared Long Term Vision	Economic and Financial	Market
LLDA	x	x	x	x	x	
BAI	x	x	x	x	x	x
Kits/Genomics	x		x		x	x

Source: Author (2020)

6.3.3 Potential Solutions to Overcome Constraints

Given the myriad of constraints to mainstreaming green growth in swine production as presented in the 3 cases above, this dissertation emphasizes the cliché that there is no 'one-size-fits-all' solution to address these constraints. However, it is important to explore potential empirical solutions that actually work and did not just spring off from textbooks.

There are 5 potential solutions that are presented in the succeeding sections and the list is by no means exhaustive. They were drawn from the author's conversations and discussions with various key informants. Each of them has the potential to address at least one predominant institutional and technical constraint in implementing environmental regulatory policies that can increase the environmental productivity of smallholder swine farms and enable them to achieve green growth even at a slow but certain pace.

As was shown in the previous section, when it comes to direct government-to-end beneficiary implementation of technical interventions, the usual constraints that were cited were the lack of extension personnel, mismatch of extensionists skills and what are required, lack of resources for training, lack of financing end-beneficiaries, and lack of incentive and systematic feedback mechanism on the part of the implementing government agency. It is just a vicious cycle unless some well-meaning private entity comes and provide the initiative for a mutually-beneficial scheme.

All 5 potential solutions demonstrate the importance of actively engaging the real and actual stakeholders in the scheme of activities through the initiative and commitment of an intermediate catalyst that can very well be any institution or agent - it can be an extension agency of the government, a private entity like a cooperative, or an individual agent that has undergone sufficient technical training . All 5 potential solutions involved institutional set ups that were successful because of incentive-compatibilities with interest groups that formed the beneficiaries 'triangle', i.e., there is something beneficial for each party, to the extent that each is willing to shoulder its part of the cost. The innovative aspects of these institutional set ups can very well be a practical solution to various constraints that befall many local and even national environmental regulatory policy implementation.

6.3.3.1 Farmer's Field School on Sustainable Pig Farming (FFS SPF)

Farmer's Field School on Sustainable Pig Framing (FFS SPF) is a collaborative project of the Department of Agriculture-Agricultural Training Institute (DA-ATI), Local Government Units (LGUs), and the Offices of the Provincial Veterinarian (OPV) of Region IV-A or CALABARZON. The FFS SPF[49] is part of the National Livestock Program that is being implemented in the 5 provinces of Region IV-A. The Agricultural Training Institute (ATI) is the extension and training arm of the Department of Agriculture (DA) and it is mandated to train Agricultural Extension Workers (AEWs) and the beneficiaries and to spearhead the delivery of e-extension services for agriculture. E-extension services mean electronic extension services. The FFS SPF in Region IV-A is an on-going program that started in 2014 and about

[49] Based from key informant interviews of the Office of the Provincial Veterinarian, Training Assistant of DA-ATI-Trece Martirez, Cavite, Region IV-A.

2,000 farmers have participated. Since the funding comes from DA-ATI through the National Livestock Program, the FFS SPF training is free of charge to smallholder swine farmers. The FFS SPF training is for 20 weeks because it involves interactive activities on the actual production of swine from the weanling stage to the finishing stage. It uses modules that promote natural swine farming in terms of feeds, pens, and bedding. The feeds contain no antibiotics, growth hormones, and animal by-products which are usually found in commercial feeds. The feeds are composed of fermented plants or plant extracts which are mixed with rice bran for easy digestion. Since the feeds are easily digested, lesser swine manure and odor are produced. The pens are made of indigenous materials such as bamboo and only a small amount of concrete is used. The bedding materials make use of the Deep Litter Flooring System (DLFS) where materials are composed of rice hull or coconut husk, soil, sand, and salt. Alternative swine waste management technologies are usually presented to the smallholder swine farmers. However, since the majority of smallholder swine farmers who participate in the FFS SPF have only a few animals in their farms, DLFS is preferred to biogas digester as a swine waste management technology. The DLFS can work even with the waste of just one or two swine animals. However, for the biogas digester, a capacity of even as small as 2 m^3 would require the waste of about 8 sows (Baron n.d.) or of 12 adult swine animals (Catelo, et al. 2001) for optimal operation.

While the FFS SPF presents an opportunity to overcome the financial, technical, institutional, and information constraints in environmental regulatory policy implementation that can increase the environmental productivity of smallholder swine farms, it should be noted that smallholder swine farmers can avail of the FFS SPF training if they are members of a swine farmer organization or a cooperative in their community. Furthermore, the LGU executive of the municipality/city, such as the mayor, needs to submit a duly signed letter of intent to the

OPV. The OPV will then undertake a pre-training evaluation of the municipality/city before it makes a recommendation to ATI to conduct the FFS SPF. There is no formal evaluation yet of the FFS SPF since it has been conducted for less than 5 years.

6.3.3.2 ITCPH-LGU-Cooperative Tri-partite Institutional Set-up [50]

It has been more than ten years now that ITCPH has been adopting communities and conducting free trainings on sustainable swine production. For ITCPH to adopt a certain community, there must be a cooperative in that community which will make the request for free training. Another requirement is that at least 50% of the members of the requesting cooperative should be swine farmers. The third requirement is that the LGU of the community where the cooperative is located must be supportive so that participants will be sent to attend the training. A Memorandum of Agreement (MOA) among ITCPH-LGU-Cooperative will then be drawn up and signed. After 5 years, ITCPH would end the training because it is assumed that human capacities of the community would have been enhanced.

Moreover, for the past two years, ITCPH has been promoting the use of a communal biogas digester in smallholder swine farms in the community that it has adopted. This is in support of the BAI Administration Order No. 2. The Cooperative provides materials of the biogas digester and these materials serve as their counterpart to the tri-partite institutional set-up. ITCPH provides technical assistance on the use of communal biogas digester and visits once a month to monitor the operation of biogas digester. LGU lends its support by providing the venue for trainings, training participants, and additional technical assistance from the MAOs/CAOs/OCVAS. The communal biogas digester is the alternative waste treatment facility for smallholder swine farmers to overcome their financial, information, technical, and

[50] Based on key informant interview of a Training Specialist at ITCPH and OPV.

infrastructural constraints. ITCPH-LGU-Cooperative tri-partite institutional set-up is successful because of the support and commitment of ITCPH, LGU, and Cooperative to provide continuous and regular extension services to smallholder swine farmers and communities. An adoption rate of about 50 percent of training participants is estimated by ITCPH.

6.3.3.3 BAI Waste-to-Energy Project

The BAI brings down the biogas digester technology at the local level, through hands-on training on biogas production and utilization using High Density Polyethylene Digester (HDPED). A training was conducted in Butuan City, Agusan del Norte in Mindanao in 2013. The participants were composed of LGU technicians and farmers. The activity aimed to increase the awareness and eventually the adoption rate of biogas digester and to enhance the knowledge of the participants regarding its production, installation, and utilization (Figure 6.2).

Figure 6.2 The 1st HDPED installed at the Biogas Training
Source: DA-RFU CARAGA

With BAI's innovative initiative to conduct hands-on-training and technology-demonstration to potential swine farmer-users, this is seen as providing a practical solution to solve the information constraint and of agricultural extension workers' unsustainable services and not having the technical capacity to train and update their clients-beneficiaries. Farmers usually have the ‘to see is to believe’ mental construct. They always want to see the outcome of an innovation or technology immediately before they can change their perceptions and be convinced to adopt the innovation and technology.

6.3.3.4 Intermediate Catalyst-Agricultural Extension Worker

This pertains to the case of an alumnus of the ITCPH in 1994 who was an AEW who applied the technical competence on sustainable swine farming that he acquired from training upon his return to his home province of Iloilo in the Office of Provincial Agriculturist (OPA). This alumnus of the ITCPH was very committed to his initial work as an AEW and he conducted seminars on swine production and extended technical assistance to smallholder swine farmers. He vigorously promoted the use of the TPED technology of the BAI when he became the project leader of the Waste Management Program in the province of Iloilo. As a result of his unceasing efforts, almost all of the municipalities in the province of Iloilo installed the TPED with 80% of the biogas digesters functioning properly. This earned an award for the province of Iloilo under the Clean and Green Program. The commitment and unceasing efforts of this alumnus of the ITCPH was an intermediate catalyst in the adoption of TPED technology by smallholder swine farmers. With the support of LGU leaders and the unwavering service of AEWs of the OPA, the LGU earned the confidence of its constituents. Alumnus of the ITCPH and his team of AEWs also rendered services to maintain and repair the biogas digesters that were adopted. Moreover, the smallholder swine farmers adopted the genetic improvement and artificial insemination (AI) technology that was promoted by the alumnus of the ITCPH and this paved the way for the establishment of 5 AI centers that were spread all over the province of Iloilo and which are being monitored by alumnus of the ITCPH.

6.3.3.5 SIDC-LGU- Farmer/Producer Tri-partite Institutional Set-up[51]

Sorosoro Ibaba Development Cooperative (SIDC) in Batangas City (CALABARZON) is a uniquely successful multi-purpose cooperative that was established back in 1960. The bulk of its activities is in feed milling but it also has a swine contract-growing operation that has earned a very good reputation for quality outputs (finishing pigs) and quality inputs (weanlings). Its membership of swine contract farms has increased tremendously because of the leadership and management style that has uplifted the livelihoods of swine farmers[52].

In recent years, the SIDC has come up with an innovative scheme in the manner of a tri-partite planning and decision-making with LGUs and corn farmers/producers. The SIDC is highly aware of the importance of corn as feed ingredient and to be able to increase swine farms' productivity, the supply of corn has to be stable and must be cheaper enough to make the price of feed affordable enough for swine farmers to earn a decent profit. To be able to do this, the SIDC goes to areas where lands are available for producing corn as feedstock. They convince the landowners, usually smallholder farmers with one or two hectares, to plant high yield corn seeds that the SIDC will provide to them on credit together with other inputs such as fertilizer. Corn farmers undergo skills and technical training with the SIDC. The scheme has practically characteristics of engaging farmers as contract growers for corn. The scheme is beneficial to both the SIDC and farmers because the SIDC is assured of a stable supply of good quality corn in feed formulation and production for animals of their swine contract farms. On the other hand, corn farmers have a steady source of income from the regular harvest and they are not cash-strapped for input payments because the SIDC offers easy credit terms of less than 12 percent per year with patronage rebates. When corn farmers realize that they have higher

[51] Based from the key informant interview of SIDC Senior Manager.
[52] For more details on SIDC operations, see Delgado, et al. (2008) and Costales, et al. (2003).

harvest of corn, the SIDC then, little by little, encourages them to become also corn contract growers. The third party in the scheme is LGU, to which the SIDC talks first to explain the scheme and seek permission in encouraging farmers to plant corn. LGU also plays an important role because it has resources to purchase the drier/sheller equipment that corn farmers will need for post-harvest operations. LGU rents out the drier/sheller equipment to the corn contract farmers and the SIDC pays LGU for the rent which just equals the recovery cost. LGU does not really earn a normal profit from investing in the drier/sheller equipment but it paves the way for its constituents (corn farmers) to be engaged in a livelihood that increases their incomes and welfare, thus fulfilling its mandate to its own constituents in the agricultural sector.

The scheme works due to effective transmission mechanism of a tri-partite planning and decision-making: the private-sector/cooperative, LGU, and the corn/swine producer. In a lot of cases, where the government/LGU does it alone in the implementation of an innovation and diffuses it down to the farmers/producers or household level, there are a lot of 'pre-requisites' that are missed, and the transmission mechanism is incomplete. This is so even in cases where it is claimed that the technology/intervention is already ripe for commercialization. The SIDC approach is a more cautious one, as it should see to it that the farmer/producer not only has primary resources, but also has capability, initiative, and willingness to take a shared risk. The SIDC knows the business, and knows what it takes to make it viable and successful. On the other hand, the farmer/producer gets on board for the longer term as soon as he/she has an evidence that the system works. The SIDC perceives LGU assistance as very valuable, especially for the resource-constrained farmer/producer. LGU assistance then becomes an intermediate catalyst in bridging some resource gaps. The SIDC functions as a stabilizing force so that these public resources will not simply go to waste, as it is also in its own interest that the whole project and system works for both farmer/producer and the SIDC as a business entity.

6.4 Conclusion

Mainstreaming green growth in smallholder swine production is beset with many interlinked constraints in the implementation of environmental regulatory policies.

In the case of the LLDA, if the implementers viewed their work as monitoring environmental compliance by industrial and commercial firms (and farms) and by waste-emitting households, and considered smallholder swine farms as insignificant contributors to lake water pollution, then smallholder swine farms are shut out of the picture. At the outset, smallholder swine farms are not their concern. In this institutional set-up, even if smallholder swine farms have the willingness to try some innovations, the organization tasked to disseminate the innovation has no incentive to do so. In this environment, the implementation of the LLDA BR No. 169 is not expected to go anywhere. The results are borne by the evidence.

In the case of the BAI NAWRMP of 2015, technologies, both the first-generation and the second-generation biogas digesters, were lifted from existing models, form, and scale. If the output of the program is the number of smallholder swine farmers who are made to attend seminars or trainings, the large number of participants would be a measure of success, as internally defined. If the technology on offer requires a minimum scale of operation, and if such a scale cannot be met by 2/3 of unsuccessful smallholders (as represented by the 40 sample swine farms), the very target segment for innovation to achieve an increase in environmental productivity becomes effectively excluded. This characteristic of technology remained to be the case, even with the modification of technology to TPED. This still remained the case with the DOST EBD-ITDI Portable Biogas Digester (PBD), where the price of prototype was beyond the reach of smallholder swine farms.

The case of the portable diagnostic test kits and genomics or gene markers innovation is a case of potential technological intervention. There remain to be many questions and uncertainties on how the impact pathway will eventually play out. There is still a lot of 'missing links', in the form of the numerous constraints, that had been identified. This is a case where the maturity and the form of commercialization of technology has still to be played out and tested.

Farmer's Field School on Sustainable Pig Farming (FFS SPF) as a collaborative project by the DA-ATI, LGU, and the OPV of CALABARZON offers a new approach which differs from that of the previous LLDA and BAI NAWRMP of 2015 approaches. This method involves close coordination across hierarchy of policy implementers who shared long term-vision of improving the environmental productivity of smallholder swine farmers and employed a feedback system. It also engaged the smallholder swine farmer at the very start, who invested his/her time (with opportunity cost) over a span of 20 weeks of training. With the smallholder swine farmer's putting his/her stake on the activity, he/she has the incentive to better make his/her involvement bear fruit. Evidently, the smallholder swine farmer will not undertake such significant investment if he/she did not see the good potential in the undertaking. FFS SPF covers a technology package that directly impacts on smallholder swine farms' environmental productivity.

The DLFS technology was compatible with smallholder swine farms with a relatively small size of production. The technology was scalable up or down, compatible with the fluctuation of size of production of smallholder swine farms over the production seasons of the year. The project presented a menu of options, and let smallholder swine farms choose in accordance with their perceptions on their own capability to bear risk.

The ITCPH-LGU-Cooperative approach also differentiates itself from the previous LLDA and BAI NAWRMP top-down approach to diffusing technology. The entry of Cooperative here comes not as a requirement for borrowing money from a formal bank, but in a manner where smallholder swine farmers who were already members of a Cooperative by choice, were presented with an opportunity to collaborate with ITCPH and LGU. In this case, various actors and the institution (agreements) that governed them were voluntary engagements, and the scope of relations was smaller and more well-defined in a smaller locational coverage. It is notable that the innovation of communal biogas digesters has taken root. Acceptability of the innovation by smallholder swine farmers is something that comes about from a communal choice. This cannot come about if there were no binding relationships among the smallholder swine farmers engaged as Cooperative stakeholders. This is a case where each party had a stake, and this gives the incentive in each party to make the agreements work.

The case of ITCPH alumnus in 1994 who returned to his home province in Iloilo in the Office of the Provincial Agriculturist reveals another insight into how technical competence and innovation of an AEW can penetrate perspectives of smallholder swine farms. This ITCPH alumnus demonstrated his commitment to make the available technology work among smallholder swine farms within his coverage. His promotion of the TPED technology resulted in a pattern of outcome that was different from that which the BAI NAWRMP promoted (same technology) in a different location to a different set of smallholder swine farms. This demonstrates that the TPED technology has a potential fit among smallholder swine farms, with the condition that this technology works properly most of the time. Smallholder swine farms are accorded a choice of using the technology, and with the demonstration that the risk of malfunction is low, smallholder swine farms voluntarily assumed the risk, being ascertained that the dedicated ITCPH alumnus and a cadre of trained AEWs will be there to supervise and support them. This case, once again, emphasizes the crucial role of collaboration of parties to the program/project, where each has a stake to nurture, and that the achievement of an increase in environmental productivity is an outcome of all parties putting their efforts to make the collaboration fruitful. The scope of this collaboration is seen to be small, in a particular location, with all actors invested in a real and dynamic relationship. Each is focused on the outcome, rather than simply in delivering his/her own inputs into the activity.

The case of SIDC-LGU-Farmer/Producer Tri-partite relationship likewise illustrates the relationship of invested partners - government-private sector-smallholder swine farmers - together trying to make their activity yield fruitful outcome that gives benefits to all parties in a form that is acceptable to all. Again, the success of the relationship is bound within an institution, where each's role is well-defined. This relationship is situated in small and well-defined location, where the relationships are self-enforcing. The element of trust is binding.

The incentives to be given to private entities like the SIDC, who can act as intermediate catalyst of development and can assume the role of government in providing merit goods such as enhancing technological and business skills in smallholder swine production as well as in swine waste management/treatment, can generate ripple effects toward increasing the environmental productivity growth of smallholder swine farms and enabling them to catch up with green growth.

Chapter 7

Conclusions, Recommendations, and Areas for Future Research

7.1 Conclusions and Recommendations

In order to assess if smallholder swine farms can catch up with green growth, this dissertation estimated an Environmentally Sensitive Malmquist Productivity Index (ESMPI) for swine production and then compared it with an estimated Conventional Malmquist Productivity Index (CMPI) so that the influence of incorporating environmental impacts on measured productivity growth in swine production could be determined. Only one-third of the 40 sample swine farms experienced environmentally sensitive productivity growth in the period of 2002 and 2015 and this was largely the result of efficiency improvements rather than technological improvements or shifts in the production frontier. Thus, environmentally sensitive productivity growth in the swine sector had declined. Those who experienced environmentally sensitive productivity growth were contract farms regardless of size and had significantly higher mean Environment Technical Change. The majority of them were able to install waste treatment facilities such as biogas digesters.

This academic finding is important because a good comprehension of the characteristics of swine farms that were able to experience environmentally sensitive productivity growth could be helpful not only in determining which of them may have potential to catch up with green growth but also in designing follow up programs that will improve capability of the other swine farms with most disadvantaged attributes such as being independent smallholder swine farms with low mean Environment Technical Change and no waste treatment facilities installed in their swine farms.

The implications of the empirical results of this dissertation are also useful in alerting policymakers that 1) given the historical trend in swine animal inventory over the years where the share of commercial swine farms is steadily increasing while that of smallholder swine farms is continuously declining, 2) with the numerous constraints that smallholder swine farms must hurdle and the various conditions that must be put in place for them to be able to adopt swine waste minimization and treatment technologies, and 3) scaling up and contract growing increase the environmental productivity of swine farms, smallholder swine farms cannot catch up with green growth.

Exacerbating this unfortunate situation is the fact that green growth is not yet mainstreamed in swine production because the core agencies that are responsible to do this task likewise have several and interlinked constraints to overcome, first and foremost of which are the institutional constraints that involve regulatory and systematic feedback constraints and the technical constraints pertaining to economic and financial hindrances.

Based on this dissertation, Environment Technical Change is crucial for smallholder swine farms to catch up with green growth. The access to waste treatment facilities such as biogas digesters are important in reducing the level of green growth indicators and enabling smallholder swine farms to increase their environmental productivity. Access of smallholder swine farms to these green technology and waste minimization practices requires access to information on technology suppliers, technological skills to operate these waste treatment facilities, and microcredit financing to facilitate access.

While certain potential solutions to constraints - both for smallholder swine farms and the hierarchy of environmental regulatory policy implementers - have been put forward and discussed in this dissertation, the aforementioned conditions for the catching up of smallholder swine farms with green growth have to realistically happen. The hierarchy of environmental regulatory policy implementers needs to get out of their institutional inertia in order to become intermediate catalysts with shared long term-vision to mainstream green growth in their respective capacities and create real process of institutional change for smallholder swine farms.

It is high time for local government units and related agencies to be made aware and to understand the reality that they lack planning, cohesiveness, unity of purpose, communication, and systematic feedback mechanism across hierarchy of their respective mandates. They ought to be made aware that there is a huge opportunity cost of going through an institutional inertia.

Overcoming all these constraints will not be feasible and could be very costly for government, considering its limited budget, inadequate number of agricultural extension workers (AEWs), and high transaction costs in searching for and reaching out to geographically dispersed smallholder swine farms, most of whom are not registered. Moreover, government cannot realistically be expected to provide solutions to these constraints in an efficient and effective manner because by its very nature, government processes are bureaucratic. In this light, there could be alternative mechanisms of provision of the similar function or service that can become more promising.

This dissertation concludes that alternative mechanisms and solutions to constraints emphasize the need to create additional incentives, increase local implementation capacities, and organize smallholder swine farms in order to trigger an institutional change that might, in the long run, increase the environmental productivity of smallholder swine farms and enable them to eventually catch up with green growth.

7.2 Areas for Future Research

This dissertation's analysis was greatly limited by the survey sample. For future research, there are a number of ways to extend this study. Panel data analysis offers rich information especially in getting a good picture of the trend in the environmental productivity growth in the swine sector which is a very important economic sector of developing countries.

Therefore, increasing the sample size and then using unbalanced panel data in lieu of the more expensive balanced panel data may be worth pursuing. This will allow for a closer investigation of productivity growth, efficiency change, and technological progress in the swine sector.

Effects of other factors that may affect environmental productivity growth of swine farms such as institutional arrangements, policy and investment instruments, public and private research and extension, transaction cost, and other economic incentives that may promote the access to and adoption of green technology innovation can be further investigated. Impact of environmental regulatory policies, compliance, and abatement costs on environmental performance of the swine sector may present opportunities in designing environmental regulatory policies toward achieving environmental productivity growth that can lead to achievement of green growth. More practical solutions to overcome constraints to environmental regulatory policies implementation is worth investigating, disseminating, and replicating. Carbon and methane footprints of swine farms under various scenarios of adoption of pollution mitigating technologies by smallholder swine farms may be interesting to estimate

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APPENDICES

Appendix A. Costs of farrow-to-wean swine production at one-sow level and one cycle, 2016

Cash Costs	**Pricing (PhP/kg)**	**Cost (PhP)**
Brood sow pellets – 180 kgs	17	2,970
Lactating pellets – 150 kgs	18	2,663
Baby pig booster crumbles – 3 kgs	68	204
Starter crumbles – 50 kgs	18	888
Subtotal: Feed Cost		6,724
Vaccines (P 150/10 dose vial)		150
Dewormers (18 tabs Latigo 50)		150
Antibiotics		150
Disinfectants (iodine/alcohol)		50
Vitamin supplement		100
Utilities		300
Service Fee		300
Boar Services		500
Sub-total: Other Cash Costs		1,700
Total Cash Costs		8,424
Non-Cash Cost		
Operation/ Labor & Mgt		2,500
Total Cash and Non-Cash Costs		10,924

Source: PB Livestock Business 2016.

Assumptions:

1. Piglets are weaned at 35-45 days old at 10 kg live weight.
2. Average litter size per farrowing is 10.
3. Prices of feeds:

   brood sow pellets (@PhP 825/50-kg bag), lactating pellets (@PhP888/50-kg bag)

   booster crumble (@PhP1,700/25-kg bag). starter crumble (@Php888/50-kg bag)
4. Ready to breed gilt was used in this production operation.
5. Labor cost was included as non-cash expense.
6. Housing is an equity of the farmer.

Appendix B. Prototypes of local biogas digesters available for swine farms

1. Scalable Polyethylene Drum Digester (SPEDD)

Photo credit: dost.gov.ph

2. High Density Polyethylene Digester (HDPED)

Photo credit: bai.gov.ph

3.Tubular Polyethylene Digester (TPED)

Photo credit: bai.gov.ph

Appendix C. Computation of variables used to estimate CMPI and ESMPI

Variable	Description/Calculation
Output ($\mathbf{y}_i$)	Total weight of swine sold and unsold (kg/cycle) = Total weight (kg) of swine animals sold in last cycle + Total weight (kg) of swine animals in inventory
Inputs ($\mathbf{x}_i$)	
Feeds	Feeds purchased (kg/cycle) = Total number of feed bags x kg/bag/cycle
Labor	Sum of hired, operator, and family labor/cycle
Water	Liter/cycle
Capital stock	
Housing	Animal housing and storage facilities (m^2) = Sum of physical dimensions of : pens (m^2) x no. of pens) + storage facilities (m^2) x no. of storage facilities +
Waste Treatment Facilities	Total dimension of biogas digesters and lagoons (m^2)
Land	Size of cropland for swine manure application (ha)
Environmental Impact ($\mathbf{z}_i$)	
BOD Loading	Biological Oxygen Demand (kg/cycle) a. Assumptions on BOD production (Hilborn and DeBruyn 2004):

No. of heads	BOD loading (kg/head/ day)	No. of days/ cycle
Sow	2.400	114
Suckling	0.032	30
Weanling	0.059	60
Grower	0.140	90
Finisher	0.180	150

BOD loading/swine farm =
Sum (No. of heads x BOD loading x No. of days/cycle)

a. Waste treatment facilities such as biogas digesters and lagoons are assumed to reduce 50% of BOD loading

Nitrogen Loading

Net nitrogen loading from swine waste (kg/ha)

a. Convert swine animals sold + swine animals in inventory into Animal Unit (AU) equivalent (Kellogg et al. 2008 cited by Delgado, et al. 2008):
   1 AU = 5 heads of swine
   For Philippine case, assume 1 head of swine = 1 slaughter hog @ 85 kg/head
   1 AU of swine generates 68 kg of nitrogen (kgN)
   1 AU of swine generates 54 kg of Phosphorus (kgP)

Appendix C. continued…

	Weight (kg/head)	Slaughter hog equivalent (85 kg ÷weight/head)
Suckling	10	8.5
Weanling	30	2.8
Grower	60	1.4
Finisher	85	1.0
Sow	150	0.6

AU of swine farm =Sum of slaughter hog equivalent ÷ 5

a. Nitrogen generated by swine farm= AU x 68 kgN

b. Total N/ha = $\frac{\text{(kgN + kg commercial N fertilizer used)}}{\text{cropland of swine farm (ha)}}$

Phosphorus Loading

a. Phosphorus generated by swine farm = AU x 54kgP

b. Total P/ha = $\frac{\text{(kgP + kg commercial P fertilizer used)}}{\text{cropland of swine farm (ha)}}$

Appendix D. Results of the REM regressions on factors affecting *ln N, ln P,* and *ln BOD*

Case 1: 207 samples (2002) + 40 samples (2015)

Dependent Variable: *ln N*

```
Coefficients:  generalized least squares
Panels:        heteroskedastic
Correlation:   common AR(1) coefficient for all panels  (0.4307)

Estimated covariances      =         2          Number of obs      =       247
Estimated autocorrelations =         1          Number of groups   =         2
Estimated coefficients     =         8          Obs per group: min =        40
                                                               avg =     123.5
                                                               max =       207
                                                Wald chi2(7)       =     24.04
                                                Prob > chi2        =    0.0011

------------------------------------------------------------------------------
        ln N |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        size |   1.199913    .432694     2.77   0.006      .351848    2.047977
          pa |  -.5915576   .5050781    -1.17   0.242    -1.581492    .3983773
         wtf |  -1.251706   .4214001    -2.97   0.003    -2.077635   -.4257767
          te |   .0141133   .0371096     0.38   0.704    -.0586201    .0868467
     sizewtf |  -.0648365    .561547    -0.12   0.908    -1.165448    1.035775
       pawtf |   .6232721   .6232764     1.00   0.317    -.5983272    1.844871
       tewtf |   .0043403   .0624619     0.07   0.945    -.1180827    .1267634
       _cons |   5.406225   .2967179    18.22   0.000     4.824669    5.987782
------------------------------------------------------------------------------
```

Dependent Variable: *ln P*

```
Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroskedastic
Correlation:   common AR(1) coefficient for all panels  (0.2387)

Estimated covariances      =         2          Number of obs      =       247
Estimated autocorrelations =         1          Number of groups   =         2
Estimated coefficients     =         8          Obs per group: min =        40
                                                               avg =     123.5
                                                               max =       207
                                                Wald chi2(7)       =    111.53
                                                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
        ln P |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        size |   .2511066   .4021003     0.62   0.532    -.5369956    1.039209
          pa |  -.5614544   .5193588    -1.08   0.280    -1.579379      .45647
         wtf |  -2.794686   .3703401    -7.55   0.000     -3.52054   -2.068833
          te |   .0149465   .0326682     0.46   0.647    -.0490819    .0789749
     sizewtf |   .8575876   .5092135     1.68   0.092    -.1404526    1.855628
       pawtf |   .0227598   .5921765     0.04   0.969    -1.137885    1.183404
       tewtf |  -.0246836   .0556137    -0.44   0.657    -.1336845    .0843172
       _cons |   5.254004   .2443135    21.51   0.000     4.775158    5.732849
------------------------------------------------------------------------------
```

Dependent Variable: *ln BOD*

```
Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroskedastic
Correlation:   common AR(1) coefficient for all panels  (0.4122)

Estimated covariances      =         2          Number of obs      =       247
Estimated autocorrelations =         1          Number of groups   =         2
Estimated coefficients     =         8          Obs per group: min =        40
                                                               avg =     123.5
                                                               max =       207
                                                Wald chi2(7)       =     38.76
                                                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
      ln BOD |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        size |   1.567857   .3189559     4.92   0.000     .9427149    2.192999
          pa |  -.9061134   .3808522    -2.38   0.017     -1.65257   -.1596569
         wtf |  -.6735051   .2912137    -2.31   0.021    -1.244273   -.1027368
          te |   .0167321   .0255839     0.65   0.513    -.0334114    .0668756
     sizewtf |  -.2499987   .3925908    -0.64   0.524    -1.019462    .5194651
       pawtf |   .3256436   .4433336     0.73   0.463    -.5432743    1.194562
       tewtf |  -.0045646   .0430817    -0.11   0.916    -.0890031    .0798739
       _cons |   6.114543   .2132235    28.68   0.000     5.696633    6.532454
------------------------------------------------------------------------------
```

Appendix E. Results of the REM regressions on factors affecting *ln N, ln P,* and *ln BOD*

Case 2: 40 samples (2002) + 40 samples (2015)

Dependent Variable: *ln N*

```
Coefficients:  generalized least squares
Panels:        heteroskedastic
Correlation:   common AR(1) coefficient for all panels  (0.3492)

Estimated covariances      =         2          Number of obs      =        80
Estimated autocorrelations =         1          Number of groups   =         2
Estimated coefficients     =         8          Wald chi2(7)       =     71.71
                                                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
        ln N |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        size |   2.690549   .4181577     6.43   0.000     1.870975    3.510123
          pa |   .6970979   .4525214     1.54   0.123    -.1898278    1.584024
         wtf |  -.7148946   .3281665    -2.18   0.029    -1.358089   -.0717001
          te |   .0251743   .0177903     1.42   0.157    -.0096941    .0600427
     sizewtf |  -.9377315   .4704784    -1.99   0.046    -1.859852   -.0156108
       pawtf |  -.6010516   .4904051    -1.23   0.220    -1.562228    .3601248
       tewtf |   .0126162   .0423444     0.30   0.766    -.0703773    .0956096
       _cons |   5.300544   .2576985    20.57   0.000     4.795464    5.805624
------------------------------------------------------------------------------
```

Dependent Variable: *ln P*

```
Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroskedastic
Correlation:   common AR(1) coefficient for all panels  (0.2329)

Estimated covariances      =         2          Number of obs      =        80
Estimated autocorrelations =         1          Number of groups   =         2
Estimated coefficients     =         8          Wald chi2(7)       =    157.69
                                                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
        ln P |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        size |   2.574517   .5177317     4.97   0.000     1.559781    3.589253
          pa |   .5725611   .6031112     0.95   0.342     -.609515    1.754637
         wtf |  -3.032943   .4289191    -7.07   0.000    -3.873609   -2.192277
          te |   .0254892   .0252449     1.01   0.313    -.0239899    .0749683
     sizewtf |  -.7244313   .6139953    -1.18   0.238     -1.92784    .4789773
       pawtf |  -.6984344   .6815905    -1.02   0.305    -2.034327    .6374583
       tewtf |  -.0088594   .0601085    -0.15   0.883    -.1266699    .1089512
       _cons |   4.669828   .3071529    15.20   0.000      4.06782    5.271837
------------------------------------------------------------------------------
```

Dependent Variable: *ln BOD*

```
Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroskedastic
Correlation:   common AR(1) coefficient for all panels  (0.2974)

Estimated covariances      =         2          Number of obs      =        80
Estimated autocorrelations =         1          Number of groups   =         2
Estimated coefficients     =         8          Wald chi2(7)       =     74.01
                                                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
      ln BOD |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        size |   1.979708   .4142472     4.78   0.000     1.167798    2.791617
          pa |  -1.429806   .4710661    -3.04   0.002    -2.353078    -.506533
         wtf |  -1.229840   .3348249    -3.67   0.000    -1.886085   -.5735956
          te |   .0165859   .0192154     0.86   0.388    -.0210756    .0542475
     sizewtf |   .3313492   .4791922     0.69   0.489    -.6078504    1.270549
       pawtf |   1.171223   .5204188     2.25   0.024     .1512206    2.191225
       tewtf |   .0499191   .0455897     1.09   0.274     -.039435    .1392733
       _cons |   6.602208   .2515812    26.24   0.000     6.109118    7.095299
------------------------------------------------------------------------------
```

Appendix F. Policies for legal and institutional framework of mainstreaming green growth

Policy	Salient Provisions
RA 9729 Climate Change Act of 2009	It is the country's roadmap in achieving a climate risk-resilient Philippines through strategies of adaptation and mitigation. Adaptation strategies are aimed to build the adaptive capacity of communities and to increase the resilience of natural ecosystems to climate change Mitigation initiatives, on the other hand, are aimed to facilitate transition of the country towards low greenhouse gas emission.
RA 9275 Clean Water Act of 2004	Aims to protect the country's water bodies from pollution from land-based sources (industries and commercial establishments, agriculture and community/household activities). It is later amended to utilize/process water for agricultural irrigation and landscaping in times of water scarcity.
RA 8749 Philippine Clean Air Act of 1999	Sets goals for the reduction of GHG emission in the country using permissible standards and control strategies.
EO 30 Philippine Energy Plan (PEP) 2017-2040	Aims on Energy Independence and focuses on attaining a sustainable 60.0 percent energy self-sufficiency beyond 2010 through alternative fuels.
RA 9003 Ecological Solid Waste Management Act of 2000	Ensures the protection of public health and environment through the adoption of a systematic, comprehensive and ecological waste management program.
RA 9513 The Renewable Energy Act of 2008	Aims to further increase renewable energy utilization in the country, including biogas. The law provides for income tax holidays, duty free importation of equipment, 0 percent VAT, among other things.
DENR AO 35 Revised Effluent Regulations of 1990, Revising and Amending the Effluent Regulations of 1982	Sets the revisions and amendments of effluent standards for various classes of water bodies.

Source: Various Republic Acts and Administrative Orders.

Note: RA – Republic Act; AO- Administrative Order; EO- Executive Order

Appendix G. Key informants' responses to questions on constraints to implementation of environmental regulatory policies

No.	Questions	% Response (n=12) Strongly Agree	Agree	Disagree	Strongly Disagree
Q1	Information dissemination about pig waste management/environmental laws across hierarchy of policy implementers is effectively done.	8	58	33	0
Q2	Staff/AEWs always give feedback to their supervisors regarding adoption of biogas digester and waste management/treatment facilities by pig farmers.	0	25	67	8
Q3	There is sufficient number of staff/Agricultural Extension Workers (AEWs) in our institution who conduct trainings on use of biogas digester ad other waste treatment facilities.	0	17	67	17
Q4	Staff/AEWs have very good technical knowledge about the installation, operation, and repair of biogas digester.	0	17	75	8
Q5	Staff/AEWs regularly give training to Coop members/backyard pig farmers on the use of biogas digester and other pig waste management/treatment facilities.	0	25	67	8
Q6	Staff/AEWs regularly give training to Coop members/ commercial pig farmers on the use of biogas digester and other pig waste management/treatment facilities.	0	8	83	8
Q7	Funding pig waste management trainings/projects/technologies is not a problem.	0	25	58	17
Q8	The cost of biogas digester is high and this constrains backyard pig farmers to adopt it.	42	50	8	0
Q9	Backyard pig farmers have difficulty accessing bank loans in order to construct or purchase biogas digester.	33	67	0	0
Q10	Commercial pig farmers have difficulty accessing bank loans in order to construct or purchase biogas digester.	8	50	42	0
Q11	Banks have many requirements for loan application.	25	75	0	0
Q12	Financial support/ subsidy to purchase biogas digesters must be given to backyard pig farmers.	42	58	0	0
Q13	DENR strictly implements environmental laws.	0	50	50	0
Q14	LLDA strictly implements environmental laws.	0	58	42	0
Q15	Our institution/COOP or Staff AEWs know who the biogas digester suppliers are and this information is relayed to pig farmers.	0	25	75	0

Source: Author's interviews (2019)

Note: Key informants here are PAO, MAO, CAO, Extension workers, DOST, COOP (See Table 6.1)

Appendix H. Key informants' responses to questions on constraints to adopting biogas digester

No.	Questions	% Responses of Commercial Swine Farmers: Strongly Agree	Agree	Disagree	Stongly Disagree
Q1.	Methane from biogas digester can be used for cooking.	44	56	0	0
Q2.	Slurry and sludge from biogas digester.	22	78	0	0
Q3.	I don't know how to use the biogas digester.	33	0	44	22
Q4.	I don't know where to buy or prefabricate a biogas digester.	0	22	67	11
Q5.	Space is not sufficient to construct a biogas digester in my farm.	0	22	44	33
Q6.	I do not have sufficient number of animals to generate waste for the biogas digester.	0	33	44	22
Q7.	No extension worker has visited my farm to demonstrate how a biogas digester works and assist me in maintenance and repair.	44	33	11	11
Q8.	The biogas digester is very expensive to buy or construct.	56	44	0	0
Q9.	It is difficut to make a bank loan for a digester.	33	56	0	11
Q10.	The bank has many requirements for loan application for a digester.	44	56	0	0
Q11.	I have sufficient financial capital to construct a biogas digester.	0	56	33	11
Q12.	DENR is strict in implementing environmental laws.	11	67	22	0
Q13.	LLDA is strict in implementing environmental laws.	0	33	11	0
Q14.	Gov't must give us financial subsidy to buy or construct a digester.	78	11	11	0
Q15.	Swine waste causes environmental pollution if left untreated or ill-dsiposed.	44	56	0	0

Source: Author's interviews (2019)

Note: Key informants were 9 commercial swine farmers.

Appendix I. Key informants' responses to questions on constraints to adopting biogas digester

No.	Questions	% Responses of Smallholder Swine Strongly Agree	Agree	Disagree	Stongly Disagree
Q1.	Methane from biogas digester can be used for cooking.	20	80	0	0
Q2.	Slurry and sludge from biogas digester.	0	100	0	0
Q3.	I don't know how to use the biogas digester.	60	20	20	0
Q4.	I don't know where to buy or prefabricate a biogas digester.	0	100	0	0
Q5.	Space is not sufficient to construct a biogas digester in my farm.	0	40	60	0
Q6.	I do not have sufficient number of animals to generate waste for the biogas digester.	0	80	20	0
Q7.	No extension worker has visited my farm to demonstrate how a biogas digester works and assist me in maintenance and repair.	60	40	0	0
Q8.	The biogas digester is very expensive to buy or construct.	60	40	0	0
Q9.	It is difficut to make a bank loan for a digester.	0	80	0	0
Q10.	The bank has many requirements for loan application for a digester.	20	80	0	0
Q11.	I have sufficient financial capital to construct a biogas digester.	0	0	100	0
Q12.	DENR is strict in implementing environmental laws.	20	20	60	0
Q13.	LLDA is strict in implementing environmental laws.[a]	0	40	0	0
Q14.	Gov't must give us financial subsidy to buy or construct a digester.	100	0	0	0
Q15.	Swine waste causes environmental pollution if left untreated or ill-dsiposed.	80	20	0	0

Source: Author's interviews (2019)
Notes: Key informants were 5 smallholder swine farmers.
[a] 3 of 5 respondents were not aware of LLDA because their farms are not covered by LLDA jurisdiction.