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Scenarios and Options for Productivity Growth in Philippine Agriculture An Application of the AMPLE

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ABSTRACT

Sustaining and accelerating agricultural growth remains a development imperative in view of persistent rural poverty and emerging threats to food security. While growth can be achieved by expansion of agricultural area and input intensification, growth through improvement in productivity is a promising option. However, productivity growth appears to be a relatively low priority for policy. Rather, the agricultural strategy is oriented toward domestic protection to achieve self-sufficiency and to support production by generous subsidies. In contrast, an alternative strategy may be one that is competition-oriented and productivity-based, i.e., one that favors integration with the international economy through trade, as well as making domestic investments targeted at productivity growth.

Scenarios for Philippine agriculture under these policy options are evaluated using a new supply and demand model (Agricultural Multi-market Model for Policy Evaluation or AMPLE). Model simulations suggest that: rapid productivity growth, even when combined with trade liberalization, is generally favorable for farmers and consumers based on improved outlook on production, exports, and food consumption. In contrast, trade liberalization alone has a contractionary effect on agriculture; and production support is a costly instrument for promoting agricultural growth. The model experiments suggest that a back-to-basics strategy for agriculture, incorporating various productivity-based instruments such as investments in R&D, extension, rural infrastructure, protection of the resource base of agriculture, and even human capital formation and institutional reforms, are key to long-term agricultural growth.

Keywords: Productivity growth, agriculture, scenario analysis, supply and demand, technological change

Scenarios and Options for Productivity Growth in Philippine Agriculture

An Application of the Agricultural Multimarket Model for Policy Evaluation (AMPLE)

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1. INTRODUCTION

Sustaining and accelerating agricultural growth remains a development imperative. Poverty in the country is concentrated in rural areas, for which agriculture remains a major if not primary source of income. The importance of agriculture has been highlighted recently following concerns about food security after the recent round of commodity price increases in world markets.

For agricultural output to grow, the simplest approach would be to increase the flow of resources into agriculture, such as say by the expansion of farming area. Farmland however is scarce and, and many countries (including the Philippines) are already approaching their agricultural land frontier. Area expansion is therefore an unsustainable strategy for agricultural growth. Alternatively, agricultural output can grow by the addition of more inputs per unit of land, a process called *intensification.* However resource scarcity can also be a limiting factor to growth by intensification; moreover, intensification does not guarantee that farmer incomes increase (as added output revenue is accompanied by added input cost).

There is a third route, which is productivity growth. Evidence reviewed in World Bank (2008) show that, at least in Asia, productivity growth has been steady at about 1-2% per year since the 1960s. Investments in science, roads, human capital, and adoption of better policies and institutions, made these productivity gains possible. From 1980 to 2004, world agriculture has been doing well, with agricultural GDP growing faster than that of global population. Much of was driven by productivity growth; hence, for instance, the real prices of grain in world markets fell by 1.8% p.a. over the same period.

The country's agricultural development strategy does affirm the need for productivity improvement, but appears to assign it a less-than-primary status terms of its expenditure programs and market policies. The response to the rice crisis, dubbed FIELDS (Fertilizers, Irrigation, Extension, Loans, Dryers and other postharvest facilities, and Seeds), emphasizes a significant subsidy component, expanding input usage in agriculture, and thereby boosting agricultural output. Policies are explicitly inward looking: growth in output, specifically for rice, aims at achieving self-sufficiency at an early date of 2013, when domestic production would have equaled domestic demand (estimated at about 140 kg/yr per capita). Meanwhile the government continues to protect heavily the major import-competing sectors, such as rice, corn, sugar, and meat. The current policy may be characterized as biased towards input support and price intervention.

The tendency to insulate domestic agriculture from the world market is motivated by large price volatilities in the latter, combined with the perception that world markets are heavily distorted by protectionist and subsidy-oriented policies in OECD countries. Possibly, liberalization of domestic markets may follow as a *quid pro quo* for foreign market access, negotiated in trade agreements. There is however another alternative, which is more open to the price system, but strives as well to address market failures; the outcome of which is demonstrable improvement in productivity growth.

This paper provides an assessment of the future of Philippine agriculture under the current and alternative strategies for agricultural growth. Productivity growth immediately impacts supply; however economic outcomes result from the interaction of both supply and demand in agricultural markets. To incorporate these interactions into our analysis, we apply AMPLE (Agricultural Multi-market Model for Policy Evaluation), a new supply demand model of

Philippine agriculture. AMPLE draws heavily from previous modeling work on Philippine agriculture, hence we proceed first with a review of related studies (Section 2), before presenting the model in detail (Section 3). Past growth and productivity performance of Philippine agriculture is reviewed in Section 4; future scenarios are presented in Section 5. Section 6 concludes.

2. SURVEY OF AGRICULTURE- RELATED MODELS

Overview of models

We limit our review of models to those that are based on an *equilibrium* in supply and demand. Quantities of supply and demand for each given market are represented by functions of price and other variables; equilibrium is represented by the constellation of price and other endogenous variables that equalize the quantity supplied in each market. We include in this review only those models that have been specified numerically, i.e. the functions are assigned numerical parameters and baseline data, which is replicated as a baseline equilibrium.

These models are based on static equilibrium, i.e. conditions of demand and supply balance within a single time period. Dynamic equilibrium models allow supply and demand to be determined over multiple periods; applications of these in for Philippine are sparse or non-existent. Static models can be distinguished according to the scope of equilibrium being computed. General equilibrium models attempt to simulate the operations of the entire real economy, i.e. the complete set of goods and factor markets (suitably disaggregated). Partial equilibrium models attempt to simulate only a subset of the real economy (often omitting factor markets altogether). These models in turn divide into multi-market and single-market models; in the former, price variables affect supply and demand of different commodities, while for the latter, the supply and demand of a commodity is affected only by its own price. Due to the obvious limitations of the latter we omit it from the coverage of this survey.

Computable general equilibrium models

A number of computable general equilibrium (CGE) models have been constructed for the Philippines. In the following we focus only on those that have been applied to agricultural policy analysis. The following discussion draws heavily from Yap (2003) for models up to 2002. Ramon Clarete, Cielito Habito, and Romeo Bautista can be credited as the pioneers of CGE modeling for the Philippines in the 1980s (Bautista, 1988). In the 1990s the most disaggregated CGE model for the country (50 sectors) was the Agricultural Policy Experiments (APEX) model (Clarete and Warr, 1992). The APEX has 16 agricultural sectors. One important feature of the model is that a large number of elasticities for supply, demand, trade were estimated from data.

The TARFCOM model (Horridge et al 2001) has now replaced the APEX as the most disaggregated CGE model of the Philippines. Based on the ORANI-G of Australia, the model has 229 industries, 28 of which are under agriculture. Simulations run by Cabalu and Rodriguez (2007) finds that agriculture contracts under all scenarios (actual tariff reductions, target tariffs in agriculture, uniform tariffs, and removal of tariffs).

In the 1990s several environmental CGEs were developed, some of which were applied to the assessment of the impact of land degradation in agriculture. Coxhead and Jayasuriya (1994, 1995) specified three goods (manufactures, tree crop, and food) and two regions (lowland, upland). Manufactures are importable, tree crops are exportable, and food is nontradable. Food production in the uplands is erosive. Their simulations showed that trade liberalization in the form of tariff reduction for manufacturing shifts land use in the uplands to tree crop production from food crop production, thus reducing soil erosion. Subsequent studies using the APEX model led to similar results (e.g. Coxhead and Jayasuriya, 2003).

CGEs of recent vintage (2000 onwards) have focused on agricultural trade policies. One strand extends analysis of WTO-related reforms to household welfare. The envisaged Doha round, which continues the WTO program of trade liberalization in world agriculture, is evaluated in Cororaton, Cockburn, and Corong (2006). While having the expected positive effect on total household incomes, poverty rises slightly, especially among rural households. Similarly, liberalization of international trade in rice is found to increase poverty as a large subset of the poor are palay farmers (Cororaton and Cockburn, 2006).

Another strand applies updated versions of earlier CGE models for agricultural trade policy. Rodriguez and Cabanilla (2006) examine a possible US – Philippine free trade agreement (FTA) and its impact on agriculture; they find that such an agreement would benefit Philippine agriculture. A broader agreement covering Asia and the Pacific (the FTAAP) was also evaluated using the TARFCOM (Rodriguez, 2006). It finds that while an FTAAP would benefit the economy in general, it would have an adverse impact on agriculture.

The major advantage of applying a CGE is its comprehensive approach to economic modeling. However, for the limited purpose of agricultural sector analysis, this very comprehensiveness could be a drawback. A CGE modeler may have to rely on extensively on imputation of price (and even income) response to be able to cover all production sectors and factors of production, as well as macro-closure conditions such as the balance of trade. If the majority of economic activity were coursed through agriculture then accounting for these behaviors would make sense. However according to NSDB data, agriculture in 2007 accounts for only 14% of GDP and under 35% of employment. Hence one may trade off the need to make strong assumptions for reduced comprehensiveness, if agriculture-specific policies play a relatively minor role in economywide adjustment. This trade-off is implicit in adopting a multi-market partial equilibrium (as opposed to general equilibrium) approach to agriculture sector modeling, as advocated in this study.

Certain techniques popular in the CGE literature may on the other hand can be readily borrowed for partial equilibrium modeling, particularly in the area of trade. A common approach for modeling imports and exports (exemplified in say the TARFCOM) is to distinguish, respectively, domestic demand by source (foreign or local supply) as well as domestic supply by destination (foreign or local market). The substitution/transformation of demand/supply by source/destination is modeled by a constant elasticity function. For the demand side this is the constant elasticity of substitution first suggested by Armington (1969). For the supply side this is the constant elasticity of transformation (Powell and Gruen, 1967). This is more general than the the alternative of treating domestic and foreign sources/supplies as perfect substitutes, effectively confronting domestic producers and consumers with world prices subject to some constant margin attributed to trade barriers.

Partial equilibrium models

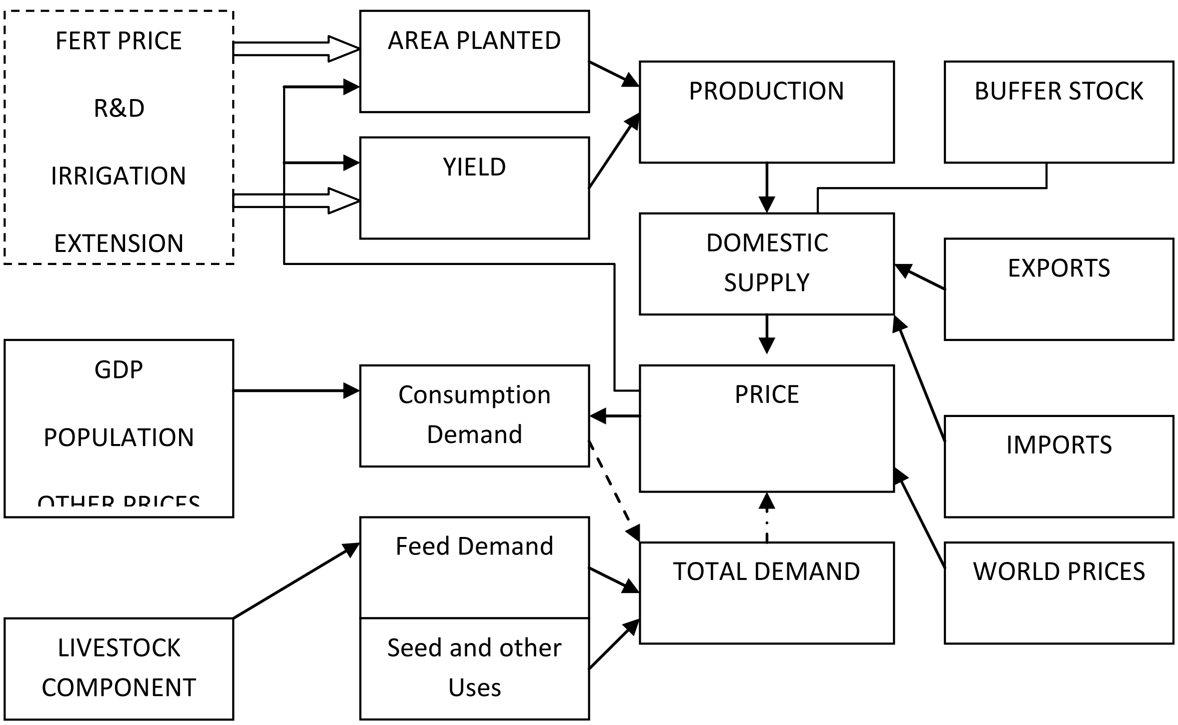
In terms of relevance to Philippine agriculture, agricultural multi-market models are either international (or even global) in scope with a country-level disaggregation explicitly incorporating the Philippines, or else have been specifically built to represent Philippine agriculture with the rest of the world as a foreign sector. Widely used for long term projections of global agriculture and food security is the IFPRI's International Model for Agricultural Commodities and Trade or IMPACT. Market equilibrium in IMPACT is at international market clearing, i.e. the sum of net trade across countries by commodity is zero; domestic producer prices equal world prices with adjustment term for marketing margin and producer subsidy equivalent

On the demand side, total demand is the sum of food, feed, and other uses. Per capita food demand is a constant elasticity function of own-price, cross-prices, income. Feed demand is a constant elasticity function of own-price, other feed prices, and quantity supplied of feed using commodity (adjusted by feed ratio). Finally, other uses is assumed to change at similar rate as rate of change of food and feed demand.

On the supply side, IMPACT adopts the widely-used area x yield formulation for modeling crop supply based on constant elasticity. The exogenous yield trend incorporates the supply shifters, primarily those relates to productivity growth, brought about by the following policy levers, among others: research; agricultural extension and farmers schooling; infrastructure; and irrigation.

The literature on multi-market modeling of Philippine agriculture is sparse. Rosegrant-Rozelle (1993), cited and applied in Balisacan and David (1995), was an earlier attempt to model Philippine agriculture. This model turns out to hae been an early version of the IMPACT model. The Philippine agricultural model that remains in active use is the Agricultural Policy Simulation Model or APSIM, which documented in APPC (2003). Figure 1 displays a schematic of APSIM.

Figure 1: Schematic of the APSIM



It has affinities with the IMPACT: consumption and production follow the constant elasticity framework, while the latter is determined by area and yield response functions. The latter are affected by "policy interventions, and other environmental variables such as input price policy, research and development [R&D] expenditures, irrigation investments, agricultural extension, and other policy variables (p. 7)."

As with IMPACT, demand components are: consumption, livestock use, and other uses (i.e. processing and seeds). Modeling of international trade allows limited pass-through from world to domestic prices via Armington coefficients; however in applied work, domestic and foreign products are perfect substitutes, hence domestic prices are equal to world prices plus tariffs (with the exception of markets with binding quantitative restrictions or for nontradable goods.) An important capability of APSIM is the calculation of income and welfare changes, comparing alternative and reference scenarios, or runs. These calculations are generated from a detailed household module, which is solved recursively from the multi-market model.

3. STRUCTURE AND SPECIFICATION OF THE AMPLE

AMPLE a multi-sector partial equilibrium model, with 18 production sectors covering crops, livestock, poultry, aquatic products. It is capable of generating projections on output, area, consumption, imports, exports, and prices. In common with other supply-demand models, AMPLE is suitable for understanding the evolution of underlying economic fundamentals, rather than in actually predicting market movements. It adopts features from APSM, and other multi-market models. Sets, variables, and equations are listed in the Annex. The model is programmed and solved with the Generalized Algebraic Modeling System (GAMS).

Supply block

The sectors in the AMMPLE should cover the major agricultural products (Table 1). We distinguish between primary and processed form of output; likewise we distinguish production systems of rice (irrigated and rainfed) as well as freshwater and marine fish (aquaculture and capture), corresponding to degree of culture intensity. The inputs are: Chemical, Fishmeal, Feed, Other intermediate inputs, labor, and other primary inputs.

For crops, we need to impose the total agricultural land area as a quasi-fixed factor, hence we model supply in terms of area allocation and yield response function (S1, S2). Both area and yield function adopts the constant elasticity form. Area shares are determined by output and input prices (S3, S4). Adding up of agricultural area shares is imposed by treating the area of Other crops as a residual (S6). Yield is determined by own-output price and input prices, but not the other output prices (S8, S9).

Table 1: Commodities of the AMMPLE

Primary form	Final form
CROPS	
Rice	Milled rice
White corn	White corn
Yellow Corn	Yellow corn
Coconut	Copra
Sugarcane	Raw sugar
Root crops	Root crops
Banana	Banana
Mango	Mango
Other fruits	Other fruits
Vegetables	Vegetables
Other crops	Other crops
LIVESTOCK	
Pigs	Pork
Poultry	Poultry meat
Other livestock and dairy	Other meat and dairy
FISH	
Marine fish	Marine fish
Seaweed	Processed seaweed
Brackishwater fish	Brackishwater fish
Freshwater fish	Freshwater fish

For non-crops, output supply is directly a function of output and input prices, in constant elasticity form (S11). That is, we dispense with the unit x unit supply formulation, as there is no straightforward counterpart of land as an industry-wide quasi-fixed factor for non-crops. Input demand is not explicitly modeled, except for feed, where spending (by livestock sub-sector) is a fixed share of livestock supply value. The various primary production supplies are summed up across categories (as applicable) in S13 to S16; they are then converted into processed form, based on fixed processing ratios (S17).

Demand block

Per capita consumption demand is based on an linear approximate AIDS share equation (D1), as suggested by Martin and Alston (1994). Total nominal food expenditure (in logs) is deflated using the stone index (D2, D3). Total nominal expenditure is based on demand under a linear expenditure system (D4). Consumption shares are converted into consumption expenditure (D5), and per capita quantities by household type, into total quantities (D6). Total demand sums up household demand with feed demand (D8, D9). The livestock sectors apportion their feed requirements to the feed-producing sectors by fixed output ratios, i.e. following a Leontieff technology (D9).

Prices, trade, and closure

The producer price, adjusted by processing, waste and by-products, as well as a marketing margin (farm to trader), becomes the supply price (T1). Likewise the world export price is converted into the domestic export price using the exchange rate (T2). Supply, valued at the supply price, must be the sum of export value and domestic production for the local market, valued at the wholesale level (T3); implicitly this defines the wholesale price. Counterpart equations for domestic import price and demand price are found in T6 and T7; for the former there is an additional adjustment in the form of tariffs or tariff equivalents (i.e. policy barriers that drive a wedge between domestic and world prices).

To model foreign trade, we propose to follow the Armington approach for the demand side, and its mirror image, the CET (constant elasticity of transformation) approach on the supply side (T4, T5, T7, T8, T9). These approaches are widely adopted in CGE models; Dey, Briones, and Ahmed (2005) is an example of its use in multi-market models.

Data and calibration

For the numerical version of AMMPLE, we need to compile a baseline data set for all of the endogenous variables, i.e. for primary production, processed (or semi-processed) output, utilization for consumption, feeds, and other uses, imports, and exports. For crops, yield and area information are also required. The data set would be a three-year spanning 2004 – 2006, centered on 2005 (as some trade data for 2007 is as yet unavailable).

Bureau of Agricultural Statistics (BAS) figures can be compiled to assemble the model data set, namely:

- Quantity and value of production;
- Crop area (i.e. area planted/harvested);
- Supply and utilization accounts;
- Quantity and value of imports and exports;
- Farmgate and retail price data.

Input data is generated under assumptions of competitive equilibrium under constant returns (i.e. total revenue equals total cost). Cost shares were obtained from the 2000 input-output table. For aquaculture systems, cost shares from Garcia et al (2009) were utilized. At the baseline, input prices are arbitrarily set at unity.

Calibration of model parameters requires a baseline data set, along with several sets of elasticities. On the supply side, output supply elasticities were derived from Dumagan and Alba (2009), with inputs from Warr (____), Edillon (___), and elasticities of the APSIM model. Note that we need only a minimal set of elasticities, as demonstrated by Alba and Briones (2009); the remaining elasticities can be recovered by applying symmetry of the substitution matrix, and zero degree homogeneity of the profit function. Supply elasticities were transformed into area and yield elasticities, consistent with a profit-maximization framework. For the aquaculture systems we based price response on Dey, Briones, and Ahmed (2005). On the demand side, for the LES we estimated the minimum food expenditure using the food subsistence threshold of the NSCB. For the food consumption elasticities we drew liberally from the APSIM. Calibration is also consistent with utility maximization in the context of an AIDS system, i.e. applying adding up, symmetry, and zero degree homogeneity.

Lastly, we need elasticities of substitution and transformation for the import and export sides of trade. Elasticities are currently set uniformly at two in absolute value, representing a greater degree of flexibility than a simple Cobb-Douglas (i.e. constant share), but much lower than perfect substitution (as in the usual open economy model).

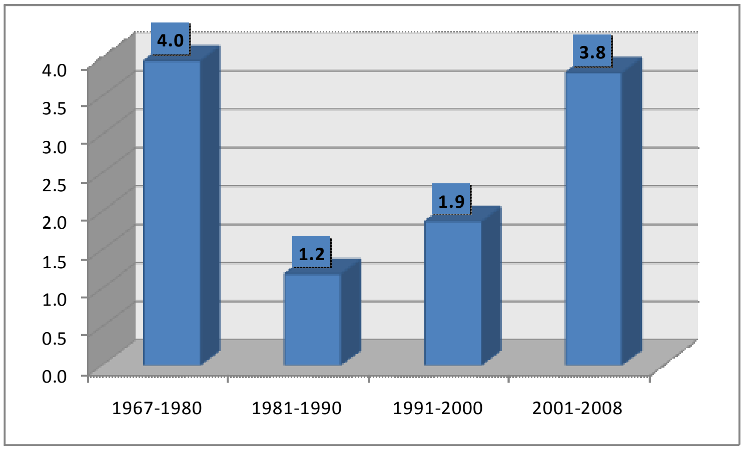
4. GROWTH PERFORMANCE OF PHILIPPINE AGRICULTURE

Trends in supply, trade, and demand

Agricultural growth in the Philippines shows a boom-bust pattern (Figure 2). Growth in the early period was respectable, comparing favorably with high-growth Asian neighbors (Balisacan, 1993). The 1980s witnessed a sharp slowdown, followed by a recovery in the 1990s, which accelerates in the 2000s. Growth in the sector tracks overall GDP growth; in the 1980s, GDP growth averaged only 1.8%, while in the 1990s and 2000s, growth climbed up to 3.1% and 4.8%, respectively. In general sector GVA grows at about 1 or so percentage points below GDP growth.

Agricultural output is produced by crops, livestock and poultry, and fisheries. Among the crops, we may highlight the ones that together account for 84% of the country's agricultural area, namely rice, corn, coconut, sugarcane, and banana (Figure 3). Nearly half of agricultural output is accounted for by non-crop commodities. Among the crops, output is highly concentrated the traditional commodities; palay alone accounts for over a third of crop value-added, matching the contribution of miscellaneous "other crops".

Figure 2: Average annual growth, in percent, of agricultural GDP (constant 1985 prices)



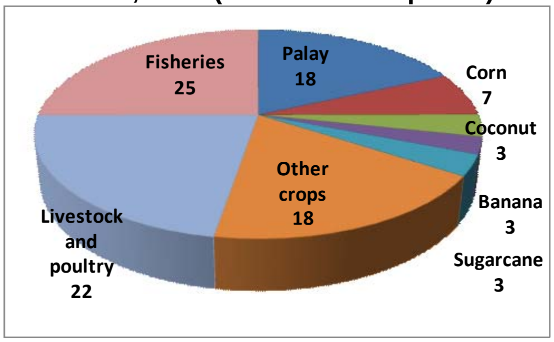
Source: BAS.

For crops and fisheries, growth has generally followed the pattern of the agriculture sector in general, namely rapid growth, then a slump, followed by recovery (Figure 5). For livestock and poultry, the slowdown occurred in the 1990s, and recovery has faltered, in contrast to the strong rebound in fisheries.

Likewise the major crops followed the boom-bust pattern (Figure 5 and 6). Palay did not escape the 1980s collapse, though the fluctuations are not that sharp: the drops have been moderated, though growth has yet to exceed 5%. Fluctuations are sharper for corn, and strikingly so for coconut, whose recovery has been fairly anemic since the 1980s. Like coconut, sugarcane's recovery from the 1980s slump has been tepid. Banana though showed spectacular growth in the early period (albeit from a small base); its recovery in recent years has been fairly robust. It is noteworthy the growth in "Other crops" have failed to recover in any significant way from its 1980s to 1990s slump, suggesting that Philippine agriculture has resisted adaptation to changing global and domestic conditions.

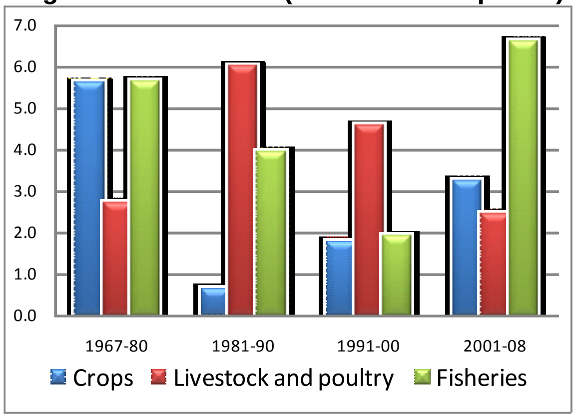
Emerging trends in global markets can be seen in world price movements (Figure 7). World prices started out at high levels in the mid-1970s owing to the commodity price boom. Over the next two decades agricultural prices rode a secular downward trend. However, since about 2000, the trend has reversed (FAO, 2004); under some plausible scenarios this appears to be a long term reversal (Von Braun et al, 2005).

Figure 3: Shares in agriculture gross value added, 2008 (constant 1985 prices)



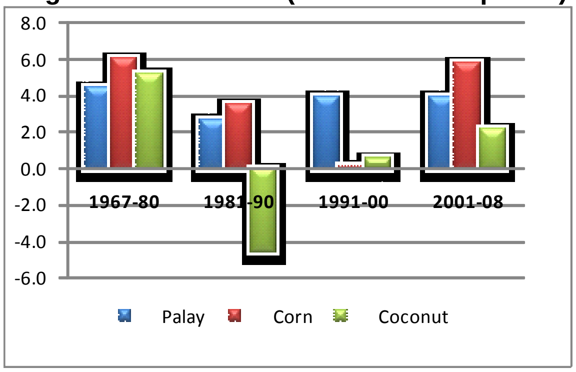
Source: BAS.

Figure 4: Average annual growth, in percent, of gross value added (constant 1985 prices)



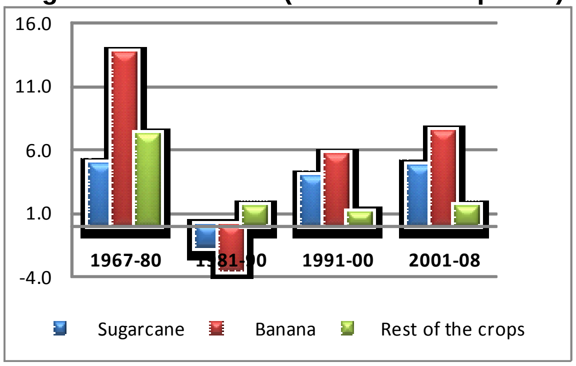
Source: BAS.

Figure 5: Average annual growth, in percent, of gross value added (constant 1985 prices)



Source: BAS.

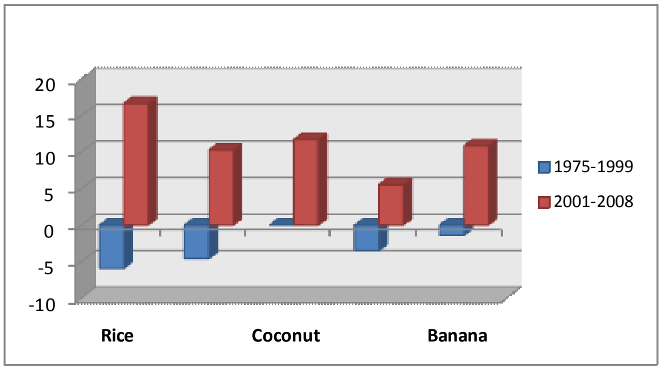
Figure 6: Average annual growth, in percent, of gross value added (constant 1985 prices)



Source: BAS.

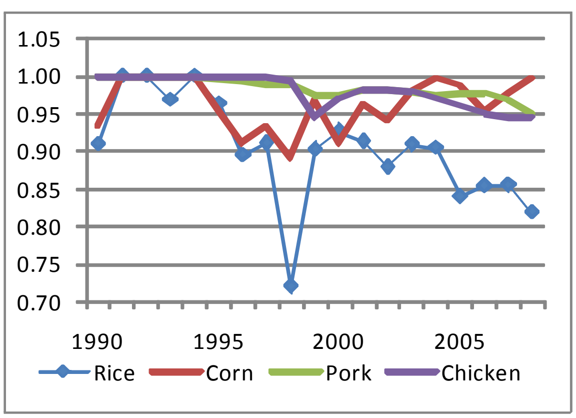
We now turn to the demand side. The foregoing world price trends are very helpful in understanding self-sufficiency ratios for major importables, namely rice, corn, and meat (Figure 8). The self-sufficiency ratio is the share of domestic production in gross supply, itself the sum of domestic production and imports, based on the supply and utilization accounts of BAS. The country is approaching self-sufficiency for pork and chicken, and in the past decade for corn. Domestic production accounts for just about 80 to 85% of gross supply of rice since 1999. Self-sufficiency even fell over the course of the food crisis, despite the sharp increases in world prices of rice, owing to policy choices made by government, in defiance of basic market forces.

Figure 7: Average annual growth, in percent, of world prices (constant 1984 $)



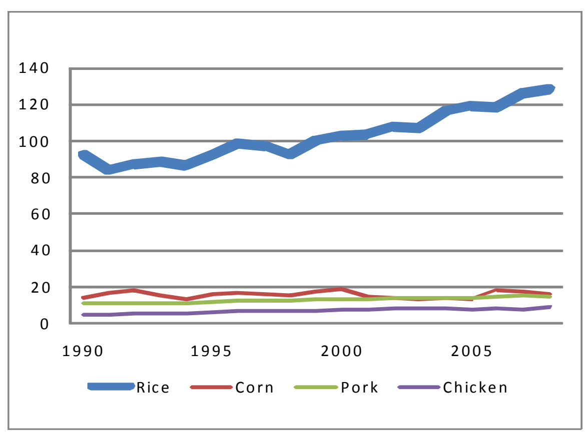
Trends in per capita consumption of rice, corn, and meat are shown in Figure 9. Each has been generally trending upward. This is most striking for rice, where per capita consumption now approaches 130 kg/yr, compared to about 100 kg/yr in 1999. Per capita consumption has grown about 3.1% per year over that period, which is remarkable as population has also been growing over 2% per year at the same time.

Figure 8: Self-sufficiency ratios for selected importable crops, 1990 – 2008



Source: BAS.

Figure 9: Per capita consumption for selected commodities, 1990 – 2008, in kg/yr



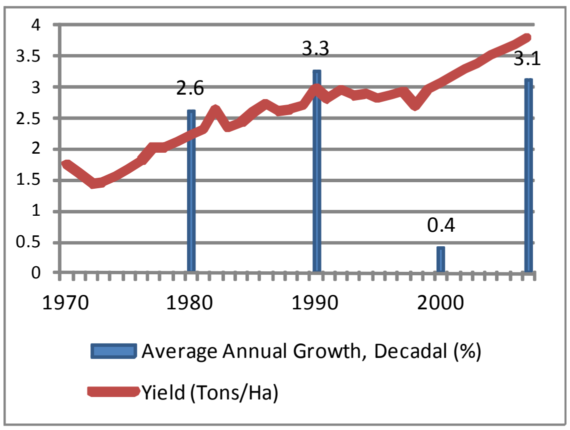
Source: BAS.

Productivity trends

One source of agricultural growth is improvements in productivity, of which a natural indicatory is yield. Yield growth trends for palay are shown in Figure 10. Productivity growth was fairly rapid in palay, during the Green Revolution period, and even during the 1980s; from 1973 to 1990 yields doubled nationwide. Yield growth however slowed down sharply in the 1990s, before resuming growth in the 2000s, with yields now approaching 4 tons/ha.

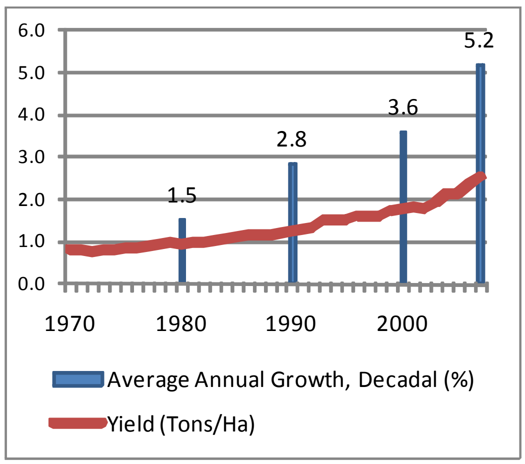
Meanwhile for corn (Figure 11), yield growth has been consistent, and in fact has accelerated over time. However this is largely due to the spread of yellow corn, a feed grain, replacing white corn, a food crop widely grown for subsistence. For coconut and sugarcane though yield trends are far more erratic (Figures 12 and 13).

Figure 10: Yield indicators for palay, 1970 - 2007



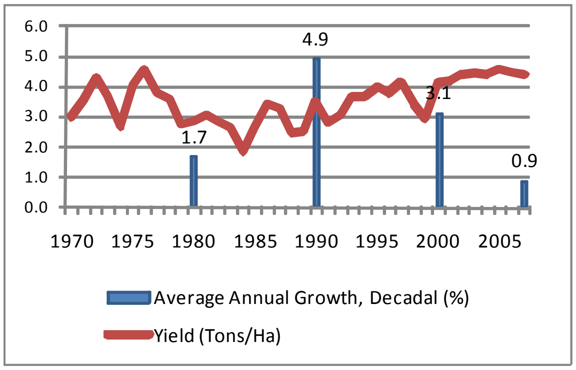
Source: FAOStat. http://faostat.fao.org, accessed December 2009

Figure 11: Yield indicators for corn, 1970 - 2007



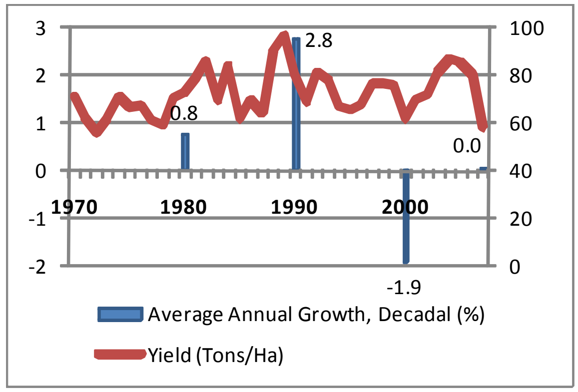
Source: FAOStat. http://faostat.fao.org, accessed December 2009.

Figure 12: Yield indicators for coconut, 1970 – 2007



Source: FAOStat. http://faostat.fao.org. Accessed December 2009.

Figure 13: Yield indicators for sugarcane, 1970 – 2007



Source: FAOStat. http://faostat.fao.org. Accessed December 2009.

Growth was rapid and increasing through the 1970s and 1980s, particularly for coconut. Note that productivity grew rapidly despite overall output contraction. Finally, yield growth slowed down and stagnated in the 2000s. In the case of sugarcane, yields even declined in the 1990s, and stabilized in the 2000s at around 60 t/ha.

Total factor productivity: trends and determinants

As mentioned earlier, TFP is more comprehensive indicator of productivity, compared to yield. Table 3 reports estimates of TFP growth for Philippine agriculture as a whole, over the span of 1970 to 2000, divided into sub-periods. The estimates may be regarded as a component of overall growth, i.e. if there is no input growth at all, then aggregate growth would be equal to TFP growth. The hypothesis that productivity may well have been a major driver of agricultural growth is broadly consistent with Table 2 estimates.

An on-going project entitled Productivity Growth in Philippine Agriculture (PGPA), has produced several estimates of productivity growth in Philippine agriculture. TFP figures from PGPA correspond to the Teruel and Dumagan estimates in Table 2, as well as the estimates in Table 2, for the agricultural sub-sectors. PGPA estimate of productivity growth in agriculture as a whole averages over 2% over the past three decades. This is a high estimate; it is quite possible that, as TFP is determined as a residual, underestimation of inputs could very well exaggerate the computed TFP. If the degree of overestimation of TFP is unsystematically related to the period, then it is the relative size of TFP growth over time that matters in the analysis. In general, the agricultural sector level estimates conform to the cyclical pattern; moreover, it confirms that recovery has continued in the 2000s. The recovery is quite strong, though falling 0.8 percentage points below the peak-growth period.

Table 2: TFP estimates for Philippine agriculture

Period	TFP growth (%)	Source
1970s	1.4 to 5.3	Evenson and Sardido
1980-1984	-0.1	
1980s	-5.4	Cororaton and Cuenca
1990s	4.2	
1960s-1970s	0.8	Mundlak, Larson, and Butzer (2004)
1980s	0.5	
1990s	0.3	
1970s	2.2	Teruel and Kuroda (2005)
1980s	-0.5	
1990s	1.4	
1975 – 1984	3.7	Teruel and Dumagan (2009)
1985 – 1994	0.5	
1995 – 2004	2.9	
1975 – 2004	2.2	

As for the commodity level TFP studies, we first note the varying scope and coverage of the estimates made. With the exception of poultry, which uses the input-output table, the commodity estimates were derived from farm-level data. For rice the sample survey is nationwide in coverage; this would therefore probably generate results of widest validity. For sugarcane, the population consists of all sugar farms in LEVIM (Luzon, Eastern Visayas, and Mindanao), i.e. excluding Negros island (which produces the bulk of sugarcane supply in the country. The aquaculture data are province-specific. Hence the results obtained also generalize, but perhaps to a lesser than that of rice. Lastly, findings for livestock, mango, banana, and coconut, were derived from site-specific case studies; hence any findings should be extrapolated with caution.

Table 3: Estimates of TFP growth in Philippine agriculture

Scope	Annualized Value	Period
Rice: farm data (nationwide)	1.6	2000 – 2004
Coconut: farm data, case study in Davao	2.3	2000 – 2003
Sugarcane: farm data (nationwide, except Negros)	3.0	2003 – 2007
Banana: farm data, case study in Mindoro	0.6	2004 – 2007
Mango: case study in Batangas	-2.1	2002 – 2008
Hogs: - case study in S. Luzon	0.6	2002 - 2008
Poultry: national, I-O table	2.5	1994 – 2000
Aquaculture: farm data (representative provinces)		
Milkfish	7.0	2001 – 2006
Tilapia	3.0	1997 – 2002
Prawn	2.0	1992 – 2003
Seaweed	3.0	1997 – 2007

Sources: PGPA Component Studies.

With that *caveat*, we note that the highest estimates are obtained for aquaculture products, which is not surprising given the fact that fisheries has shown the most rapid growth among the agricultural sub-sectors. Prawn though has continued to battle disease problems, hence it is relatively the slowest growing within aquaculture, though its TFP growth is still a respectable 2%.

At the other extreme, mango registers negative TFP growth. This seems consistent with the national data, which reveal that mango yield has been falling from 6.5 t/ha in 2003 to just 4.7 t/ha in 2008 – an average decline of 5% annually. Also showing weak, though positive, TFP growth, are banana and hogs. Weak productivity growth in banana is hard to reconcile with the yield improvements observed nationally. Note though that the case study covers only the cardaba (*saba*) variety grown by smallholders, whereas the national data incorporates the export sector (planted to Cavendish). Meanwhile, weak TFP growth for hogs is expected given weak growth performance of the livestock sector in the past decade. Chicken showed fairly rapid TFP growth, but the estimation period is limited to the 1990s, which was still a relatively high-growth period for the industry.

Evidence for statistically and quantitatively significant contribution to productivity are available from the PGPA studies with respect to the following (Tables 4 and 5):

- Protecting resource base, by dissemination of soil conservation technology
- Human capital accumulation through education investment;
- Improved connectivity, by investment in paved roads, and local accessibility of farmer to farmlot;
- R&D investment in technological change;
- Training of farmers through the extension system;
- Access to credit (though not necessarily to availment of subsidized credit);
- Farmer's endowment of social capital and possession of transferrable property rights to land. Opening up of lease rights to plantation of owners is also found to be significant in the case of sugarcane.

Table 4: Estimates of impact of productivity factors (based on cross-cutting studies)

Item	Indicator	Value	Scope and period
Past adoption of soil conservation technology	Change in yield (%)	46	Case study: corn farmers in Bukidnon (1996 – 2006)
One additional family member with high school education	Change in output per family member (%; value added)	13.2	Rice farmers in Camarines Sur
One additional family member with high school education	Change in output per family member (%; value added)	37.7	
Unit increase in paved road ratio (percentage points)	Change in real agricultural GDP per worker (pesos)	303.5	Agriculture: regional data (1990-2006)
Unit increase in domestic R&D investment indicator (%)	Cost reduction (%)	0.4	Rice: regional data (1993 – 2007)
Unit increase in domestic R&D investment indicator (%)	Cost reduction (%)	-1.0	

Sources: PGPA Component Studies

These findings substantiate the claim that a number of policy and investment levers are accelerating productivity growth in key subsectors of agriculture. These findings support the identification of scenarios for the impact assessment of current versus productivity-based strategies for agricultural growth.

Table 5: Statistically significant factors directly or indirectly affecting productivity

Commodity, indicator	Determinant	Direction of effect	Scope and period
Rice, TFP	Use of certified seed	Positive	Nationwide (2003 – 2007)
	Access to postharvest facility	Positive	
	Access to training	Positive	
	Access to credit	Positive	
	Access to marketing facility	Positive	
Corn, yield	Steep slope, with soil conservation	No statistical effect	Bukidnon (1996-2006)
	Education of farmer	Positive	
Coconut, technical efficiency	Access to training	Positive	Davao (2000 – 2003)
	Access to credit assistance	Positive	
	Education	Negative*	Davao (2000 – 2007)
Sugarcane, technical efficiency	Education	Positive	LEVIM (2003 – 2007)
	Status as lessee	Positive	
	Farmholding above 50 ha	Positive	
Mango, technical efficiency	Years of farming	Positive	Batangas (2002 – 2008)
	Status as grower-operator	Negative	
Banana, technical efficiency	Years of farming	Positive	Mindoro (2004 – 2007)
	Distance from residence to farm	Negative	
Hogs, technical efficiency	Access to credit	Positive	Batangas (2002 – 2008)
Rice, adoption of HYV	Endowment of social capital	Positive	Nationwide (1991)
	Access to formal credit	Positive	
	Access to extension service	Positive	
	Size of farm	Positive	
	Property right with freedom of use	Positive	
	Education of farmer	Positive	

Sources: PGPA Component Studies.

5. SCENARIOS FOR PHILIPPINE AGRICULTURE

Scenarios

Having examined the sources and contributors to productivity growth, in relation to policy and investment levers, we now examine the impact of these policies and investments based on alternative scenarios for productivity growth of Philippine agriculture. We define the scenarios based on the alternative development pathways or strategies confronting Philippine agriculture.

Scenarios are stated over a ten-year horizon, i.e. representing the medium- to long-term prospects of agriculture. The prominent features of the strategies relate to: a) engagement with international trade; b) expenditure programs and policies with respect to agricultural productivity. The design of the scenarios draws heavily on Paris and Antiporta (2007).

The *reference* scenario corresponds extrapolates from current and emerging trends, and corresponds to business-as-usual with respect to the policy environment. Assumptions for growth of per capita income and population are obtained from various sources (Table 6). The reference scenario also incorporates the current bias for self-sufficiency and domestic protection by maintaining high tariffs (and other import barriers) in key agricultural sub-sectors.

Productivity growth is based on modified estimates from the PGPA component studies, with some modifications. Some low estimates from case studies are elevated to correct small sample bias. Some high estimates over a limited time period are moderated to correct for adjustment to medium to long term equilibrium. We also provide for heterogeneity between domestic and export supply sub-sectors, in terms of technology and productivity growth; this distinction is relevant to the case of banana.

There are two alternative scenarios. The first of these is called *market access*, and focuses on the role of the external policy environment on Philippine agriculture. Here we suppose that trade negotiations are successful and market access is opened up to Philippine agricultural products by the drop in trade barriers worldwide, combined with the elimination of distortionary subsidies in OECD agriculture. The *quid pro quo* requires only an internal tariff reduction in the primary staple, rice, down to 10% within ten years.

The second alternative scenario, called *reform*, examines the role of the domestic environment. We adopt the same external environment as in the business-as-usual scenario, but assume that policy and governance reforms are implemented: tariffs are all reduced to a uniform rate of 10% in 10 years, while the expenditure program with accompanying institutional reforms is conducted to accelerate productivity growth. One effect of these reforms to increase the responsiveness of the domestic economy to market signals.[1]

The other is to boost the rate of productivity growth to double the rates in the reference scenario (mango productivity growth is assumed identical to that of other fruits in the reference scenario). The doubling of productivity growth is arguably a feasible scenario if the appropriate priorities are observed in the expenditure program, and institutional reforms are instituted to enhance the effectiveness of productivity investments.

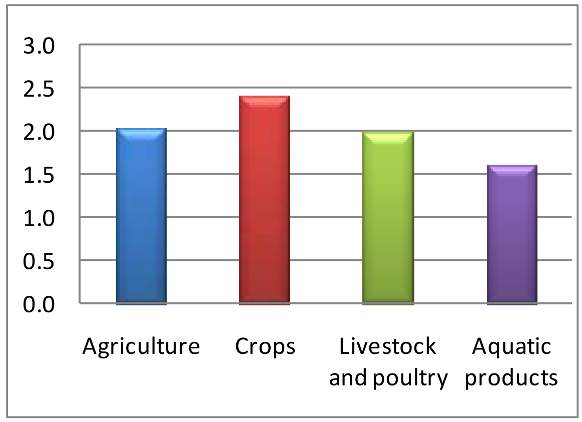
Table 6: Growth rates of exogenous variables for the reference scenario, in percent p.a.

Exogenous variable	Value (%)	Source
Per capita income	2.0	World Bank
Population growth	2.0	NSCB
Productivity growth		PGPA Component studies
Rice	1.6	
White corn	0.0	
Yellow corn	1.6	
Sugarcane	3.0	
Coconut	2.0	
Banana (domestic)	1.0	
Banana (export)	2.0	
Mango	0.0	
Other fruit	2.0	
Cassava	2.0	
Vegetables	2.0	
Other crops	2.0	
Poultry	2.0	
Swine	1.0	
Other livestock	1.0	
Freshwater fish	3.0	
Brackishwater fish	3.0	
Seaweed	3.0	
Marine fish	3.0	

Reference scenario

Under the reference scenario, growth in agricultural gross value added is projected to slow down from current rates (Figure 14). Its average growth over the projection period is two percentage points below the implicit growth of national income (around 4%). Reversing earlier trends, growth is now led by the crops sub-sector, followed by livestock and poultry, with aquatic products lagging.

Figure 14: Growth in gross value added, percent p.a., reference scenario



Among the major crops, growth is expected to be led by sugarcane, due to high rates of productivity growth (Figure 16). White corn is also resurgent, while rice and yellow corn also grow faster than the sector average. Rapid growth is observed for cassava and vegetables, though these are starting from a relatively small base (Figure 15). Unfortunately, output growth of mango and banana, the current export mainstays, are relatively stagnant, while other fruits in fact suffer an output decline.

Among the non-crops, the fastest growth is observed in seaweed and brackishwater fish; this is consistent with their relatively rapid productivity growth (4%).The other non-crop products suffer from slower growth on average, except for poultry.

Figure 15: Growth in output, percent p.a., reference scenario projections

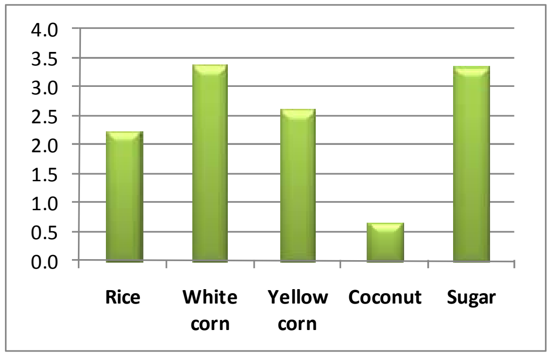


Figure 16: Growth in output, percent p.a., reference scenario projections

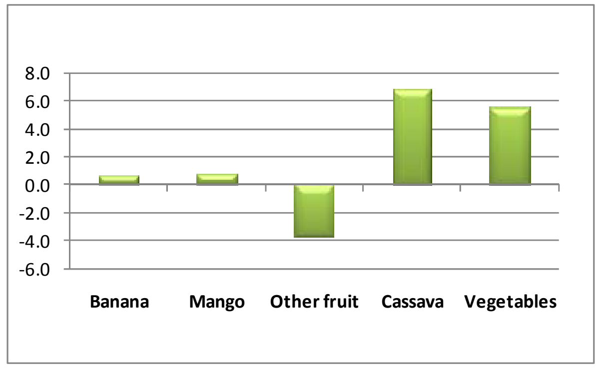
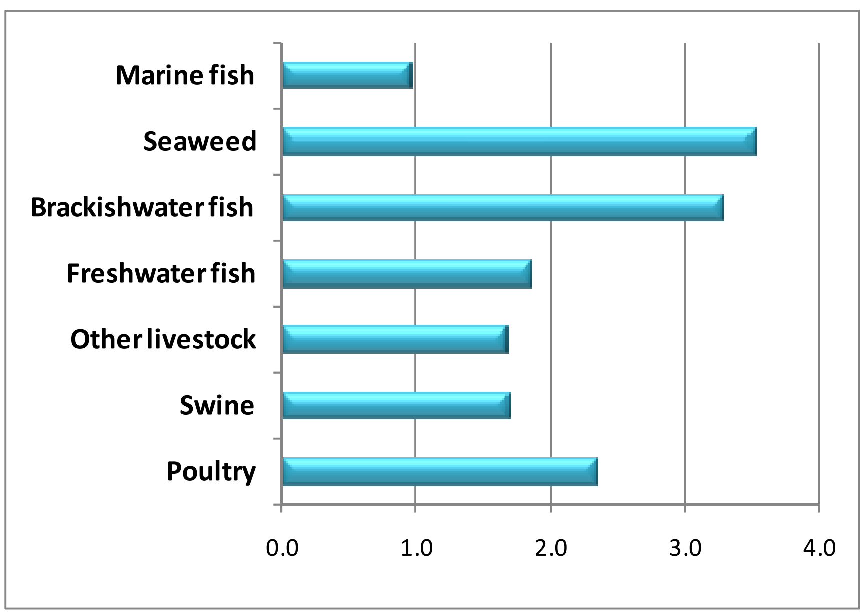


Figure 17: Growth in output, percent p.a., reference scenario projections



Trade and projected world prices are major drivers behind some of these trends. Among the major crop exports, coconut and banana continue to grow, in line with positive productivity growth and relatively better world market prospects (Figure 19). However mango, facing weak productivity prospects, suffers an export contraction; the export decline is more severe for other fruits. On the other hand, vegetables and other crops are projected to post strong export performances, despite stagnant world prices. The other side of trade is imports (Figure 20): for most commodities imports are projected to increase, despite mostly world prices, with the the exception of rice, cassava, and sugar.

Figure 18: Growth indicators for exports, in percent p.a., reference scenario

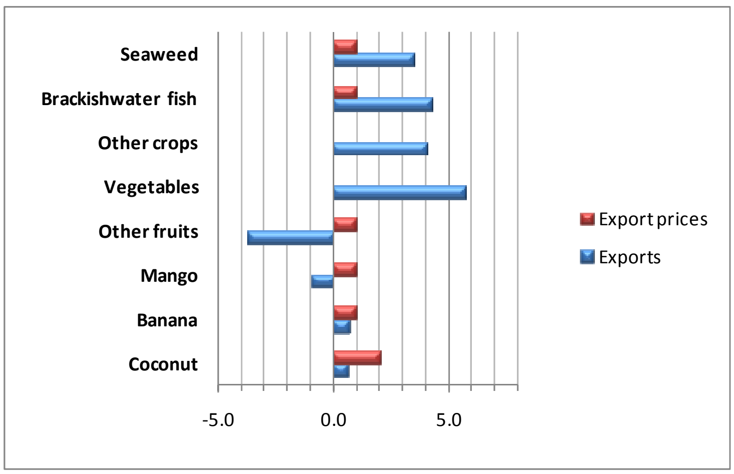
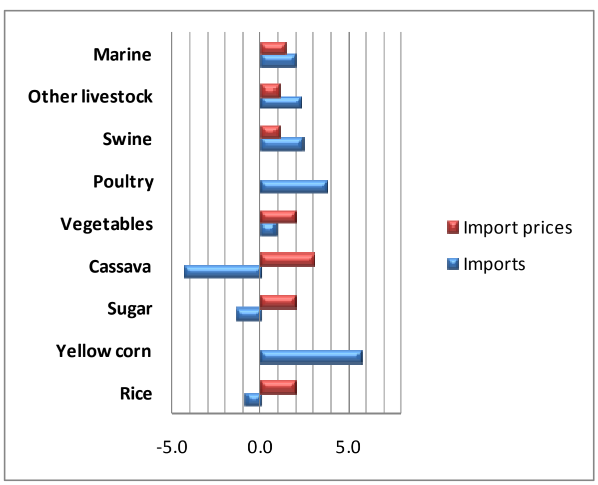
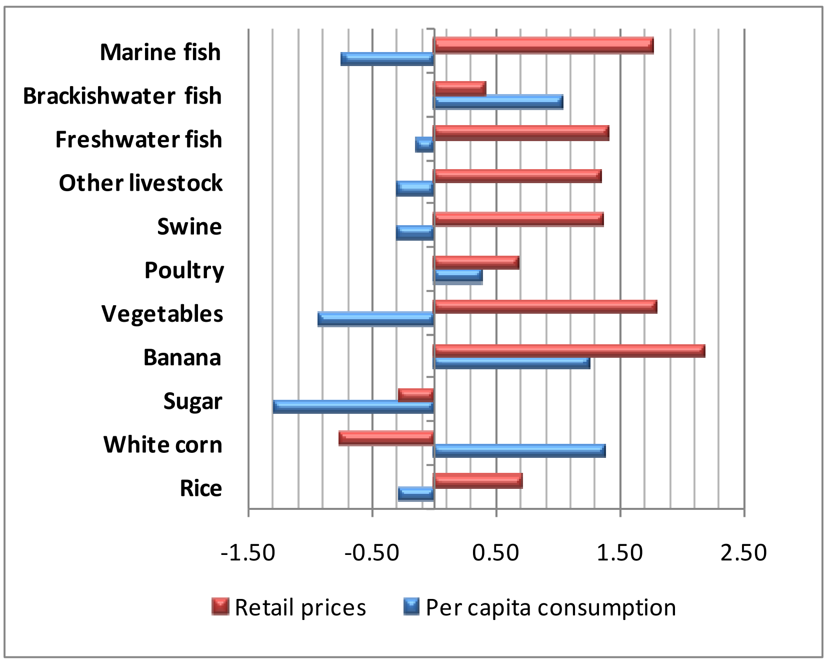


Figure 19: Growth indicators for imports, in percent p.a., reference scenario



Lastly we look at per capita consumption trends (Figure 21). The trend of rising per capita consumption for rice is expected to halt and mildly reverse, as retail prices increase (in response to rising world prices and domestic demand). Per capita intake of meat and fish (except brackishwater fish), sugar, vegetables, are all projected to diminish. Retail prices generally increase, except for sugar and white corn; increasing consumption of the latter may be related to the rising cost of rice.

Figure 20: Growth indicators for consumption, in percent p.a., reference scenario



<u>Alternative scenarios</u>. In the following we report results of alternative scenarios in terms of differences from the reference case. First we consider aggregate growth: The market access scenario suppresses growth of the agricultural sector, particularly in aquatic products, though it slightly accelerates growth in crops and meat (Figure 22). Meanwhile under the reform scenario, growth is accelerated overall, as well as in the aggregated sub-sectors, particularly for meat. Among the crops, market access more often than not leads to a decline in output (Figure 23). However, output increases are

projected for mango, banana, and coconut, as major export crops benefit from market access.

Figure 21: Annual growth of agricultural value added, alternative scenarios (percentage point difference from reference case)

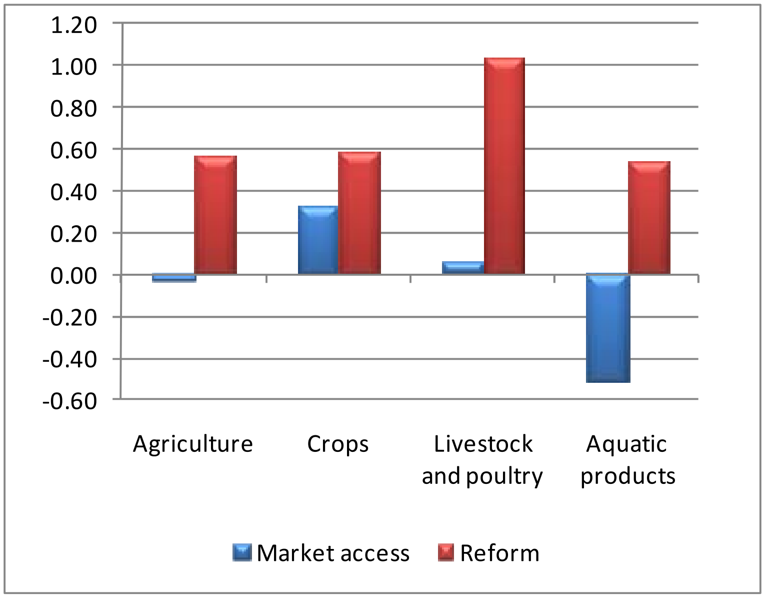
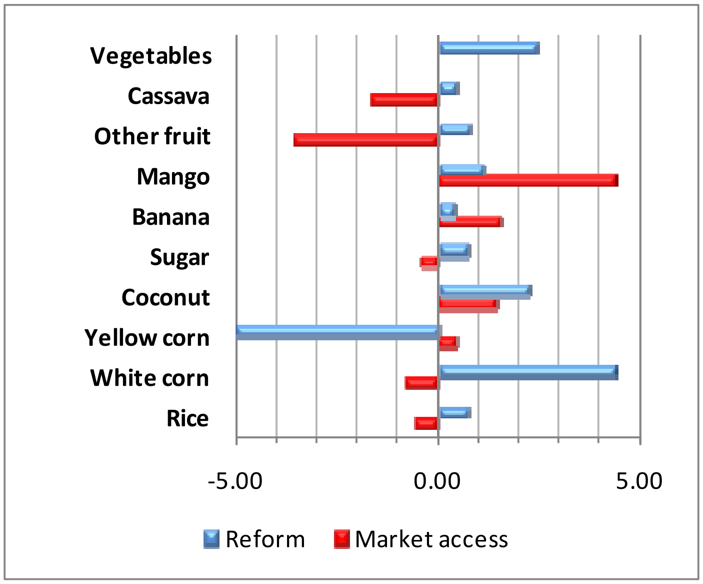


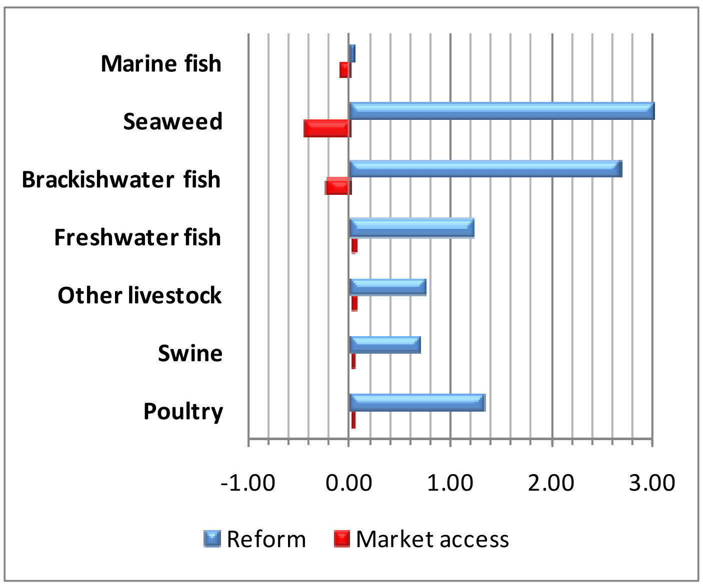
Figure 22: Annual growth in output, alternative scenarios (percentage point difference from reference case)



On the other hand, output of the crops generally increases under the reform scenario, save for yellow corn, which is strongly affected by the decline in import tariff. With the notable exception of banana and mango, growth under reform exceeds that under market access.

Among the non-crops, the effect of market access on output growth is positive but imperceptible, and in some instances even negative, as in seaweed and brackishwater fish (Figure 24). The reform scenario however leads to expansion in output across the board; the differences over the reference are quite sharp in the case of seaweed and brackishwater fish, in keeping with the large productivity growth in these commodities.

Figure 23: Annual growth in output, alternative scenarios (percentage point difference from reference case)



Market access accelerates export growth relative to the reference case, except for vegetables and aquatic products (Figure 25). Exports grow faster under the reform scenario; in the case of aquatic products the improved is quite pronounced. However, export growth under reform is not necessarily faster than under market access, as can be seen in the case of fruit products, except for mango. Growth in imports under market access is likewise stronger than in the reference case, except for corn and other crops (Figure 26). Rice in particular experiences a comparatively rapid surge in imports, accounting in part for its output growth slowdown. The reform scenario meanwhile accelerates import growth, most sharply for yellow corn, followed by swine and poultry. On the other hand, due to faster productivity growth, reform slows down import growth relative to market access for rice, and even relative to the reference case for cassava and other crops.

Figure 24: Annual growth in exports, alternative scenarios (percentage point difference from reference case)

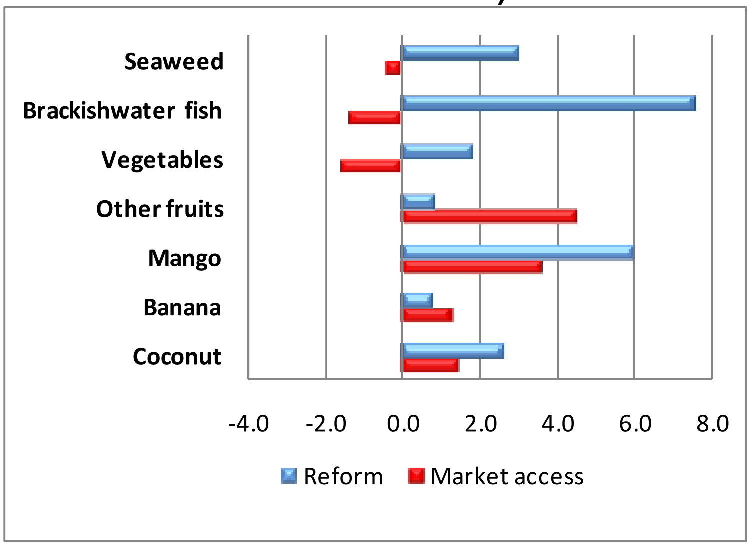
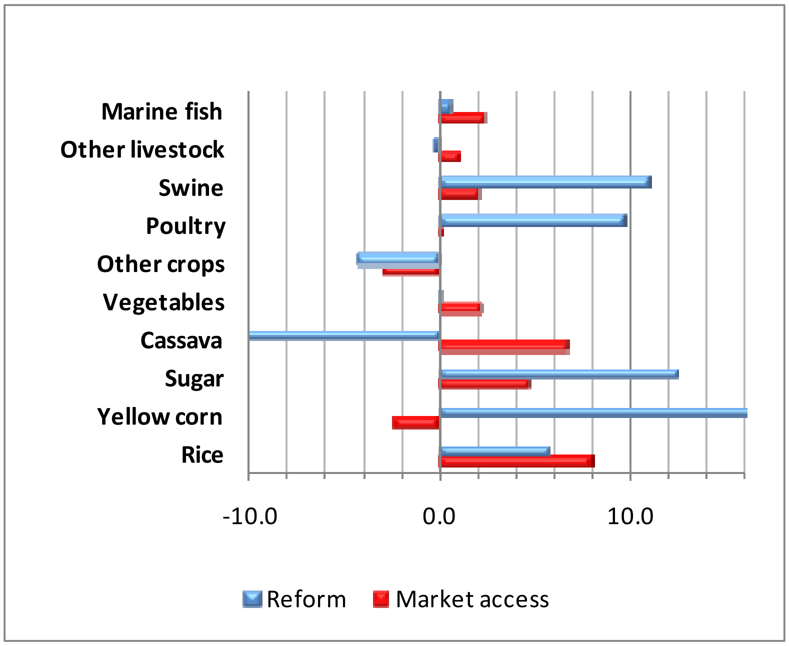
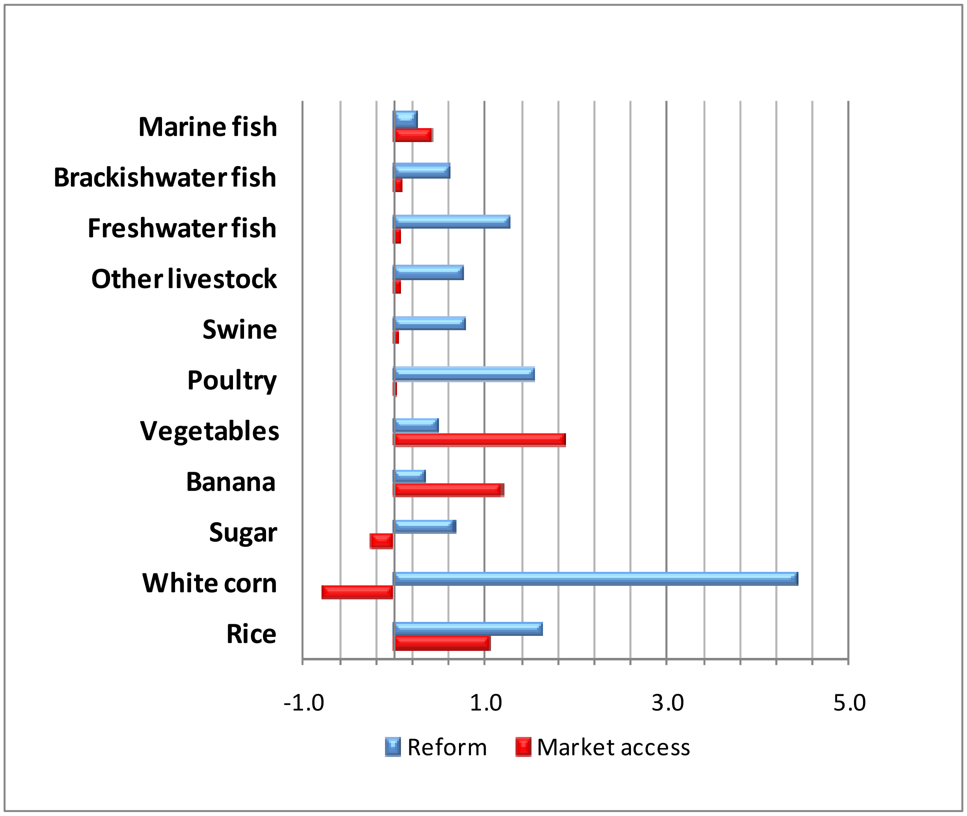


Figure 25: Annual growth in imports, alternative scenarios (percentage point difference from reference case)



Lastly we look at demand in terms of per capita consumption (Figure 27). Market access does increase growth in per capita consumption for most products, except for white corn and sugar; for most however the increase is minimal. For all products, per capita consumption growth rises under reform, relative to either the reference case or market access; the difference is most conspicuous for the staples, followed by poultry and freshwater fish.

Figure 26: Annual growth in per capita consumption, alternative scenarios (percentage point difference from reference case)



To summarize: the scenario analysis suggests that under business-as-usual, agricultural growth is headed for a slowdown in the medium term. Demand growth continues, and is met by both higher domestic production and imports. Rising foreign demand (implicit in rising world prices) would also be met by export growth in the case of aquatic products and some of the crops, but the fruit exports, may even suffer export contraction, if it is true that their world market prospects are weakest. Expanded market access is generally not favorably domestic producers, and only mildly favorable to consumers. However rapid productivity growth under an aggressive reform scenario, even when combined with trade liberalization, is generally favorable for farmers and consumers, based on improved outlook on production, exports, and food consumption.

6. POLICY IMPLICATIONS

In recent years, the national development strategy has correctly renewed its focus on accelerating agricultural growth. However this shift has been weighed down by the baggage of traditional thinking related to food self-sufficiency, protection of domestic markets, and support to farmers and consumers through input and output subsidy.

Rather, the highest priority should be accorded to *growth via improvements in agricultural productivity*. The PGPA studies have demonstrated that productivity growth has contributed greatly to the agricultural sector recovery in recent years. The role of productivity growth can be further widened if the requisite reforms are in place for a faster and more sustained growth of agriculture. A more detailed discussion of these reforms is available in the PGPA component studies; in general however their recommendations are a reiteration of the call to return to the fundamentals of efficiency, innovation, and modernization in agriculture.

Changes in technology and farm efficiency

First is in the area of technological change. The basis of agricultural innovation is R&D, where public resources remain seriously underinvested. However in addition to increasing R&D investment, reforms are also required in terms of R&D governance, and investment allocation. Drawing on Gapasin (2006), Francisco and Bordey (2009) note that “the present R&D system is constrained by large number of public R&D institutions with overlapping functions and roles, many duplicating R&D networks, weak linkages to farmers and fishers, the LGU extension units, and the private sector, and serious under-funding of R&D programs and projects due to drastic reduction of government budgets.” This should be remedied by a comprehensive rationalization program, combined with a re-orientation of the bureaucracy towards client- and performance-based planning, monitoring, and evaluation. Expenditure composition should also be refocused by an objective priority setting exercise, even if this entails a more neutral treatment towards heavily favored crops, such as rice (World Bank, 2007).

Technological change on the ground would also need to be supported by a strong producer services system. Among these services, *extension* would need to remain heavily supported by government, particularly for smallholder agriculture. Levels of public support for extension are generally adequate, but remain misallocated. At the local level, funds are normally taken up by personnel compensation, with no leeway for operations or capital outlay; these are still provided by national government in the context of commodity and other programs, therefore perpetuating the cycle of centralized, top-down service delivery. Indicated reforms are therefore to institute a more authentic decentralization, with central government function oriented towards building up organizational capacities of LGUs. Even more basic than extension is the human capital of farmers and farm household members, which is largely (but not solely) accumulated by investment in education. This underscores the need for a convergence strategy for Philippine agriculture (i.e. agricultural development is by no means the function of DA or even agriculture-related agencies alone!)

As for the other producer services such as financing, marketing, and provision of seed, planting material, and other inputs, public policy should refocus on creating a favorable climate for private sector investment in these functions. Subsidies to government entities, parastatals, or a few large suppliers should be phased out. Public policy should adopt a more neutral stance, relying rather on facilitation and easing of regulations, though maintaining a strong emphasis on technical standards and promotion of new technologies.

As shown by Edillon (2009), farmer-level incentives also matter greatly for technology adoption. Reform of the land reform program should be implemented swiftly to avoid the erosion of property rights of farmers, by enforcing individual ownership, security of tenure, and allowing property transfer. Furthermore, public policy should now begin to recognize the role of informal rural organizations and networks, as *social capital* has been found to play a key role in technology diffusion.

Infrastructure

The PGPA studies confirms the importance of connectivity and reduction of internal transaction costs; a major policy and investment lever in this regard is investment in paved roads. However, investments can deliver productivity benefits only if creates the right assets, in the right locations, and of suitable quality. The key is again rational planning and decentralized decision-making – particularly with respect to infrastructure finance.

Another important infrastructure concern is irrigation. The PGPA studies – including the commodity study on rice – have failed to detect a statistically significant effect running from irrigation (or irrigation investment) on productivity.2 It is possible that irrigation investments have had muted effect on productivity in more recent years, owing to the following: i) investments are monopolized by rice, whose share in agricultural GVA has been falling; ii) LGUs, which now have jurisdiction over communal systems, lack funding for expanding irrigation facilities, even for small-scale systems (Llanto, 2009); iii) in recent years, national investments have largely been devoted to rehabilitating existing areas rather than expanding service areas; iv) iv) irrigation is now expanding through private or individual systems rather than through public systems (Barker and Innocencio, 2007). The priority action for irrigation is not expanding investments (at least in the short-term), but in proper use of current investments, towards: small-scale systems, design improvements via decentralized and client-based planning, institutional reforms towards cost-recovery and participatory maintenance, as well as rationalization of the NIA.

The resource base

While we have touched upon the sustainability of growth, in a fiscal sense, the environmental sustainability of agricultural growth is equally important. Agricultural intensification on the same areas, combined with expansion of intensive farming into frontier areas, is gradually eroding the resource base of the sector. Compounding these is global climate change, which bodes further ill for future agricultural growth. Investments that anticipate and prevent resource degradation, such as soil conservation technology for upland agriculture, are vital to sustainability in the face of these threats.

Concluding Remarks

Pardey and Beintema (2002) have aptly referred to agricultural innovation, backstopped by R&D investment, as “slow magic”. The same term can be applied to productivity growth in general. As its effects are slow, it is easily overlooked, particularly when the policy environment welcomes quick fixes and tangible results, which subsidy-based policies can readily deliver. This study adds to the distinguished body of work calling for a back-to-basics agricultural strategy towards long-term growth based on productivity improvement.

The potential of productivity growth is most impressive: it has repeatedly pushed back the specter of hunger and population collapse, and delivered large swathes of humanity in the developed countries from the Malthusian trap. The magic of productivity growth has also enabled the farmer in these countries to escape a life of subsistence and poverty, to a prosperous life secured by farms that are capable of feeding the planet. Productivity growth offers the same promise to Filipino farmers and consumers, if only the right policies and institutions are in place to unleash it.

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ANNEX

SETS

Label	Definition	Relationship
S	Systems	
GIn	Goods and inputs	
G	Goods	$G \subset GIn$
Cr	Crops	$Cr \subset G$
$CrMult$	Mult-system crops	$CrMult \subset Cr$
$CrUni$	Uni-system crops	$CrUni \subset Cr$
$CrResid$	Crop grown in residual area	$CrResid \subset CrUni$
$CrResidN$	Uni-system crop not grown in residual area	$CrResidN \subset CrUni$
CrN	Non-crop agricultural sectors	$CrN \subset G$
$CrNMult$	Multi-system non-crop sectors	$CrNMult \subset CrN$
$CrNUni$	Uni-system non-crop sectors	$CrNUni \subset CrN$
Lv	Livestock products	$Lv \subset CrNUni$
In	Inputs {Feed, Fishmeal, Chemical, OthInt, Labor, OthPrim}	$In \subset GIn$
$InCr$	Crop inputs	$InCr \subset In$
H	Household types	
GC	Goods consumed as food	$GC \subset G$
GCN	Goods not consumed as food	$GCN \subset G$

SUPPLY BLOCK

Variables

Label	Definition	Relationship
$QPCrU_i$	Primary production of crops from uni-system	$i \in CrUni$
$AshU_i$	Area share of crop in uni-system	$i \in CrUni$
AU_i	Area of crop in uni-system	$i \in CrUni$
YU_i	Yield of crop in uni-system	$i \in CrUni$
$QPCrM_{ij}$	Primary production of crops from multi-system	$i \in CrMult$ $j \in S$
$AshM_{ij}$	Area share of crop in multi-system	$i \in CrMult$ $j \in S$
AM_{ij}	Area of crop in multi-system	$i \in CrMult$ $j \in S$
YM_{ij}	Yield of crop in multi-system	$i \in CrMult$ $j \in S$

$QPCrNU_i$	Primary production of non-crops from uni-system	$i \in CrNUni$
QFd_i	Feed demand from livestock products	$i \in Lv$
$QPCrNM_{ij}$	Primary production of non-crops from multi-system	$i \in CrNMult$ $j \in S$
PP_i	Output price received by farmer	$i \in G$
QSS_i	Supply quantity per good	$i \in G$
QS_i	Supply quantity after conversion, by-product, and waste	$i \in G$

Parameters

Label	Definition	Relationship
w_i	Primary production of crops from uni-system	$i \in In$
atot	Total crop area	
$\alpha A0U_i$	Constant term in area share function	$i \in CrResidN$
$\alpha A0M_{ij}$	Constant term in area share function of crops	$i \in CrMult$ $j \in S$
$\alpha A1U_{ij}$	Output price elasticities of area share for uni-system	$i \in CrResidN$ $j \in Cr$
$\alpha A1M_{ijk}$	Output price elasticities of area share for multi-system	$i \in CrMult$ $j \in Cr; k \in S$
$\alpha A2U_{ij}$	Input price elasticities of area share function of crops in uni-system	$i \in CrResidN$ $j \in InCr$
$\alpha A2M_{ijk}$	Input price elasticities of area share function of crops in multi-system	$i \in CrMult$ $j \in InCr; k \in S$
$\alpha Y0U_i$	Constant term in yield function for uni-system	$i \in CrUni$
$\alpha Y0M_{ij}$	Constant term in yield function for multi-system	$i \in CrMult; j \in S$
$\alpha Y1U_i$	Own-price elasticity term in yield function for uni-system crop	$i \in CrUni$
$\alpha Y1M_{ij}$	Own-price elasticity term in yield function for multi-system crop	$i \in CrMult; j \in S$
$\alpha Y2U_{ij}$	Input elasticity term in yield function for uni-system crops	$i \in CrUni; j \in InCr$
$\alpha Y2M_{ijk}$	Input elasticity term in yield function for multi-system crops	$i \in CrMult$ $j \in InCr; k \in S$
$\alpha 0CrNU_i$	Constant term in supply function for uni-system non-crop	$i \in CrNUni$
$\alpha 0CrNM_{ij}$	Constant term in supply function for multi-system non-crop	$i \in CrNMult$ $j \in S$
$\alpha 1CrNU_{ij}$	Output price elasticity in supply function for uni-system non-crop	$i \in CrNMult$ $j \in S$

Label	Definition	Relationship
$\alpha 1CrNM_{ijk}$	Output price elasticity for multi-system non-crop	$i \in CrNMult$ $j \in CrN; k \in S$
$\alpha 2CrNU_{ij}$	Input price elasticity term in supply function for uni-system for non-crop	$i \in CrNUni$ $j \in In$
$\alpha 2CrNM_{ijk}$	Input elasticity term in supply function for multi-system non-crop	$i \in CrNMult$ $j \in In; k \in S$
$shfeed_i$	Share of feed cost in value of livestock output	$i \in Lv$
gratot	Growth in crop area	
$grAU_i$	Growth in area of non-residual crop	$i \in CrResidN$
$grAM_{ij}$	Growth in area of multi-system crops	$i \in CrMult; j \in S$
$grYU_i$	Yield growth for uni-system crops	$i \in CrUni$
$grYM_{ij}$	Yield growth for multi-system crops	$i \in CrMult; j \in S$
$grCrNU_i$	Supply growth for non-crop in uni-system	$i \in CrNUni$
$grCrNM_{ij}$	Supply grown for non-crop in multi-system	$i \in CrNMult; j \in S$
grw_i	Growth in input prices	$i \in In$
$grtar_i$	Growth in tariff rate	$i \in G$
$conv_i$	Conversion ratio from primary to processed	$i \in G$
$byprodw_i$	Ratio of byproducts and waste	$i \in G$
λ_i	Productivity parameter for export side	$i \in G$

Equations

Label	Statement	Relationship
S1	$QPCrU_i = AU_i \cdot YU_i$	$i \in CrUni$
S2	$QPCrM_{ij} = AM_{ij} \cdot YM_{ij}$	$i \in CrMult;\ j \in S$
S3	$\log AshU_i = \log \alpha A0U_i + \sum_j \alpha A1M_{ij} \cdot \log PP_j - \sum_k alfA2U_{ik} \cdot \log$	$i \in CrResidN$ $j \in Cr; k \in InCr$
S4	$\log AshM_{ij} = \log \alpha A0M_{ij} + \sum_k \alpha A1M_{ijk} \cdot \log PP_k$ $- \sum_l \alpha A2M_{ijl} \cdot \log w_l$	$i \in CrMult$ $j \in S;\ k \in Cr$ $l \in InCr$
S5	$AM_{ij} = AshM_{ij} \cdot atot$	$i \in CrMult;\ j \in S$

S6	$AshU_i = 1 - \sum_j AshU_j - \sum_{kl} AshM_{kl}$	$i \in CrResid$ $j \in CrResidN$ $k \in CrMult; l \in S$
S7	$AU_j = AshU_j \cdot atot$	$i \in CrUni$
S8	$\log YU_i = \log \alpha Y0U_i + \alpha Y1U_i \cdot \log PP_i + \sum_j \alpha Y2U_{ij} \cdot \log w_j$	$i \in CrUni; j \in InCr$
S9	$\log YM_{ij} = \log \alpha Y0M_{ij} + \alpha Y1M_{ij} \cdot \log PP_i - \sum_k \alpha Y2M_{ijk} \cdot \log w_k$	$i \in CrMult$ $j \in S;\ k \in InCr$
S10	$\log QPCrNU_i = \log \alpha 0CrNU + \sum_j \alpha 1CrNU_{ij} \cdot \log PP_j$ $- \sum_k \alpha 2CrNU_{ik} \cdot \log w_k$	$i \in CrNUni$ $j \in CrN$ $k \in In$
S11	$QPCrNM_{ij} = \log \alpha 0CrNM_{ij} + \sum_k \alpha 1CrNM_{ijk} \cdot \log PP_k$ $- \sum_l \alpha 2CrNM_{ijl} \cdot \log w_l$	$i \in CrNMult$ $j \in S; k \in CrN$ $l \in In$
S12	$w_i \cdot QFd_j = shfeed_j \cdot PP_j \cdot QPCrNU_j$	$i =$ feed $j \in Lv$
S13	$QSS_i = QPCrU_i$	$i \in CrUni$
S14	$QSS_i = \sum_j QPCrNM_{ij}$	$i \in CrMult$ $j \in S$
S15	$QSS_i = QPCrNU_i$	$i \in CrNUni$
S16	$QSS_i = \sum_j QPCrNMult_{ij}$	$i \in CrNMult$ $j \in S$
S17	$Qs_i = conv_i \cdot QSS_i \cdot (1 - byprodw_i)$	$i \in G$

CONSUMER CORE

Variables

Label	Definition	Relationship
PC_i	Retail price	$i \in GC$
SH_{ij}	Share of food item in food expenditure	$i \in GC;\ j \in H$
$STONE_i$	Stone price index	$i \in H$
$RFEX_i$	Real food expenditure	$i \in H$
FEX_i	Food expenditure	$i \in H$
QC_{ij}	Quantity demanded- consumption by household type	$i \in GC; j \in H$

Label	Definition	Relationship
QDC_i	Quantity demanded- all consumption	$i \in GC$
QD_i	Quantity demanded- market	$i \in G$
$QDLv_i$	Demand by poultry and livestock sector	$i \in G$

Parameters

Label	Definition	Relationship
$\gamma 0_{ij}$	Intercept term in AIDS	$i \in GC;\ j \in H$
γ_{ij}	Coefficient of log price in AIDS	$i \in GC;\ j \in H$
β_{ij}	Coefficient of expenditure term in AIDS	$i \in GC;\ j \in H$
$feedsh_i$	Share of sector in feed demand of poultry and livestock	$i \in G$
y_i	Household income	$i \in H$
θ_i	Share of food expenditure in household income	$i \in H$
sub_i	Floor expenditure	$i \in H$
$subf_i$	Subsistence expenditure	$i \in H$
pop_i	Population	$i \in H$
$grpop_i$	Population growth	$i \in H$
gry_i	growth of fish expenditure	$i \in H$

Equations

Label	Statement	Relationship
D1	$SH_{ij} = \gamma 0_{ij} + \sum_j \gamma_{ij} \cdot \log PC_i + \beta_{ij} \cdot RFEX_j$	$i \in GC; j \in H$
D2	$RFEX_i = \log FEX_i - STONE_i$	$i \in H$
D3	$STONE_i = \sum_j SH_{ij} \cdot \log PC_j$	$i \in H; j \in GC$
D4	$FEX_i = subf_i + \theta_h \cdot \left(y_i - sub_i \right)$	$i \in H$
D5	$PC_i \cdot QC_{ij} = SH_{ij} \cdot FEX_j$	$i \in GC; j \in H$
D6	$QDC_i = \sum_j QC_{ij} \cdot pop_j$	$i \in GC;\ j \in H$
D7	$QD_i = QDC_{GC} + QDLv_i$	$i \in GC$
D8	$QD_i = QDLv_i$	$i \in GCN$

D9	$QDLv_i = feedsh_i \cdot \sum_j QFd_j$	$i \in G$ $j \in Lv$

TRADE, PRICES AND CLOSURE

Variables

Label	Definition	Relationship
PS_i	Producer price after conversion to processed form	$i \in G$
PX_i	Export price	$i \in G$
PWH_i	Wholesale price	$i \in G$
QSF_i	Export component of CET composite	$i \in G$
QSL_i	Domestic component of CET composite	$i \in G$
PD_i	Commodity price on demand side	$i \in G$
PM_i	Import price	$i \in G$
QDF_i	Import component of Armington composite	$i \in G$
PDL_i	Domestic component of Armington composite	$i \in G$

Parameters

Label	Definition	Relationship
exr	Exchange rate in PhP per dollar	
pwx_i	World price of exported good in dollars	$i \in G$
pwm_i	World price of imported good in dollars	$i \in G$
tar_i	Tariff rate in percent of world price	$i \in G$
$marh_i$	Marketing margin of trader from farm to wholesale	$i \in G$
$marr_i$	Marketing margin from wholesale to consumer	$i \in G$
σD_i	Elasticity term in Armington composite	$i \in G$
δDF_i	Coefficient of foreign component in Armington composite	$i \in G$
δDF_i	Coefficient of domestic component, Armington composite	$i \in G$
σS_i	Elasticity term in CET composite	$i \in G$
δSF_i	Coefficient of foreign component, CET composite	$i \in G$
δSL_i	Coefficient of domestic component, CET composite	$i \in G$
$grpwx_i$	Growth rate of world price of exported good	$i \in G$
$grpwm_i$	Growth rate of world price of imported good	$i \in G$

Equations

Label	Statement	Relationship
T1	$PS_i = \left(\frac{PP_i}{conv_i}\right) \cdot (1 - byprodw_i) \cdot (1 + marh_i)$	$i \in G$
T2	$PX_i = pwx_i \cdot exr$	$i \in G$
T3	$PS_i \cdot QS_i = PX_i \cdot QSF_i + PWH_i \cdot QSL_i$	$i \in G$
T4	$QSF_i = QS_i \left(\frac{\delta SF_i \cdot PS_i}{PX_i}\right)^{\sigma S_i}$	$i \in G$
T5	$QSL_i = QS_i \cdot \left(\frac{\delta SL_i \cdot PS_i}{PWH_i}\right)^{\sigma S_i}$	$i \in G$
T6	$PM = pwm_i \cdot exr \cdot (1 + tar_i)$	$i \in G$
T7	$PD_i \cdot QD_i = PM_i QDF_i + PWH_i \cdot QDL_i$	$i \in G$
T8	$QDF_i = QD_i \cdot \left(\frac{\delta DF_i \cdot PD_i}{PM_i}\right)^{\sigma S_i}$	$i \in G$
T9	$QDL_i = QD_i \cdot \left(\frac{\delta DL_i \cdot PD_i}{PWH_i}\right)^{\sigma S_i}$	$i \in G$
T10	$PC_i = PD_i \cdot (1 + marr_i)$	$i \in GC$
T11	$QSL_i = QDL_i$	$i \in G$

[1] Technically, we increase the absolute values of the elasticities of substitution and transformation.

[2] Mangabat et al (2009) showsthat irrigation shifts the farm-specific production frontier upward. However it has a negative effect on efficiency: *ceteris paribus*, farmers with irrigated parcels tend to be lower relative to the production frontier, than a similar farmer without irrigated parcels. The effects cancel out with respect to total factor productivity.