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Case-Studies on the measurement of productivity and efficiency in agriculture

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Case-Studies on the measurement of productivity and efficiency in agriculture

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Acronyms and Abbreviations

AAFC	Agriculture and Agri-Food Canada
CFS	The Crop Forecasting Survey
CSO	Central Statistical Office of Zambia
Global Strategy	Global Strategy to improve Agricultural and Rural Statistics
LFS	Labour Force Survey
MFP	Multifactor productivity
PIM	Perpetual inventory method
PHS	Post-Harvest and Livestock Survey
SEPH	Survey of Employment Payrolls and Hours
SUTs	Supply and use tables
USDA	United States' Department of Agriculture

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1

Introduction and presentation

Guidelines on the measurement of productivity and efficiency in agriculture have been published in 2018 as part of the research activities of the Global Strategy (Global Strategy, 2018). These Guidelines present the conceptual framework for the measurement of agricultural productivity, the different productivity indicators as well as the associated data collection requirements.[1]

The present document presents two case-studies, to illustrate the process of compilation of productivity indicators: i) the calculation of labour productivity based on data collected at farm-level, and ii) the construction of aggregate and country-level information on agricultural productivity from aggregate time-series.

The illustration or case-study on the calculation of labour productivity is based on a pilot survey in Zambia that aimed at testing an approach to collect data on agricultural costs of production. This pilot-survey was conducted in the last quarter of 2016 by the country's Central Statistical Office (CSO), with the financial and technical support of the Global Office of the Global Strategy. The case-study on the construction of agricultural TFP from aggregate data sources is based on the experience of Canada, a country with a long-standing experience in the compilation and dissemination of productivity statistics. A similar case-study was prepared in the Literature Review on Agricultural Productivity and Efficiency Measurement (Global Strategy, 2017), but to describe the prevailing statistical process in the United States' Department of Agriculture (USDA).

These two case-studies have been chosen to illustrate to different dimensions of productivity measurement (partial or single-factor productivity vs. total or multifactor productivity) and two different calculation approaches (from farm-level information vs. aggregated time-series). These two case-studies have also been chosen for their relevance for national statistics, labour productivity as well

[1] The reader is advised, prior to reading this document, to refer to the Guidelines for precise definitions of these concepts, which will not be repeated here.

as total factor productivity being two important metrics for policy and economic analysis.

The results presented here, especially for the case of Zambia, are intended for illustration and pedagogical purposes only, and should not be in any way interpreted as representative of the country's agricultural sector and practices.

2

Case-study 1: Measuring labor productivity using farm-level data in Zambia

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2.1. Introduction

The objective of this case-study is to illustrate the construction of a labour productivity indicator directly from farm-level information on output and expenses. This approach differs from the one presented in Case-study 2 (cf. Chapter 3), which presents methods typically used in statistical organizations based on aggregate time-series and data sets. Although the direct approach presented in this case-study is more adapted to individual research pieces than to the construction of country-level statistics, it provides an easier way to decompose the different steps of productivity measurement: identification of basic data, preliminary data manipulation and estimations, compilation of the indicator and dissemination. It is a useful pedagogic exercise in which the reader is taken step-by-step through the different phases of the calculation.

Labour productivity is a partial productivity indicator, and as such suffers from the limitations attached to these type of metrics: for example, labor productivity can increase because capital or other inputs are used more intensely or efficiently but not because the workforce is being intrinsically more productive, as a result of improved skills or experience for example (see Global Strategy, 2018, for a more detailed description of these limitations). Labour productivity is nevertheless a key indicator of the performance of farming and is closely linked to the generation of income, especially in developing countries where the share of labour in total farm expenses is high, often above 50%. This is one of the reasons why the compilation of this indicator is generally amongst the priorities of national productivity measurement programs, as in the case of Statistics Canada (Chapter 3).

The case-study presented here is based on farm-level data collected in the context of a pilot survey conducted in 2016-2017 in Zambia. The illustration covers the whole data cycle, from the data collection to the compilation of the final indicator, including the preliminary calculations, estimations and assumptions that were made

2.1.1. The survey: objectives, design and main data items

Objective of the pilot survey

A pilot-survey was designed and conducted in Zambia, between October 2016 and February 2017, to test an approach to collect data on farm returns and costs in this country. This exercise was one of the technical assistance activities in Africa of the Global Strategy to improve agricultural and rural statistics, and was led by the Central Statistics Office (CSO), Zambia's official statistical organization.

Survey questionnaire and main data items

The questionnaire used for the pilot-survey was constructed from the two existing annual surveys: The Crop Forecasting Survey (CFS) and the Post-Harvest and Livestock Survey (PHS). These questionnaires were first assessed to identify gaps in terms of coverage of important output and expense items. The different questions were also analysed as to their relevance to collect quality information to measure the profitability of farming activities. Questions and sections from the CFS and PHS were combined, reformulated and restructured to form the final questionnaire to be used in the pilot-survey.

The questionnaire of the pilot-survey contains all the necessary information to compile profitability metrics at commodity and farm-level: major data items are output quantities for all the crops and livestock products produced by the farm and their respective unit selling prices. The farm expenses are also covered comprehensively: expenses in inputs, such as agrochemicals for crops or feed costs for livestock, information on labour costs (time spent, for family work) and on capital stock (characterization and market value). For each item, when feasible, information was asked on the quantities purchased as well as on the unit prices, so as to construct accurate cost estimates.

This information constitutes the basic data for the measurement of farm profitability and productivity presented in this case-study. The data was collected for a single agricultural season only, which means that the indicators only refer to a single period and, hence, can only be presented in levels.

Sampling design, coverage and field activities

The survey was conducted in November 2016 immediately after the training of the field teams, on a randomly selected sample of 320 small and medium-scale farmers located in the Southern and Eastern Province of Zambia. The survey covered both crops and livestock but given time constraints only indicators for crops were compiled. There was no *a priori* restriction in the coverage crops, as the field enumerators asked the farmers information regarding all the crops that planted. However, given the crop mix in the provinces chosen for the pilot survey and the small size of the sample (320 farmers) meaningful results are available only for maize, groundnuts and soybeans.

The interviews, made with tablets, were completed in roughly 2 weeks during November 2016. The data was then processed and cleaned by officers from the CSO, and the final datasets prepared early 2017.

Prior to the analysis of the survey results and the compilation of productivity indicators, a certain number of preliminary calculations and estimations were necessary to conform the data with the requirements of productivity measurement by commodity. These data processing operations are described in the following section.

2.1.2. Preliminary calculations, estimations and assumptions

Estimation of missing prices and expenses

Certain inputs may not be purchased by farmers but rather produced and used by the farm itself. Examples include the production of organic fertilizer from manure or organic matter generated and used by the farm, the cultivation of forage crops destined to feed the farm's animals or the provision of unpaid labour, often by household members. The latter case will be addressed in greater details later in this chapter. As these inputs are self-supplied and not purchased, there are no prices attached to them. To measure profitability and productivity, the compilation of costs in monetary terms is necessary. Prices for these inputs therefore need to be estimated.

The estimation method that was used here relies on the opportunity cost principle: instead of consuming its self-produced inputs, the farm could sell them on the market and receive an income from it. Market prices, when available, can therefore be used to impute a price for self-supplied inputs or simply as an estimation method when the information on prices is missing. Indeed, market prices are a good reflection of the opportunity cost of producing its own inputs vs. purchasing them or selling them on the market.

The imputation method used here estimates missing prices of a given input by the median unit price of the district.[2] More details on this approach in the case of the imputation of unpaid labor is provided in Section 0.

[2] Two districts were covered in this pilot-survey, each with 160 farmers selected

Allocating common costs to individual commodities

Some cost items can be directly attributable to a single commodity, while other expenses may be shared across different activities of the farm. Seeds, fertilizers, pesticides or feed for instance, can generally be reported by the farmer by commodity (e.g. seed expenses for maize, for wheat). On the contrary, expenses in labour, capital or overheads (electricity, fuel, water, etc.), are often reported as a total for all the activities of the farm (common costs).

As one of the objectives of this pilot-survey is to measure profitability and productivity by commodity, it is necessary to devise an appropriate methodology to allocate common costs to the individual commodities. The choice was to use a simple rule based on planted area to allocate common costs, such as labour (paid and unpaid) or depreciation, to the different crops. More sophisticated model-based or multiple-allocator rules can be used but are more adapted to academic research than to routine statistical work.

Estimation of the output value

To measure productivity, the total output of the farm needs to be accounted for, not only the share that is sold on the market. In the productivity measurement framework, the total output needs to be valued: the value of the unsold share of the output needs to be estimated.

The method used here to value the unsold output by farm and commodity is based on: i) the average unit price (or the reported unit price) for the sold output, for a given farm and crop, or ; ii) if the output is fully consumed/used by the farm, or if the amount sold is negligible, the median district crop price is used for the estimation. Market prices, as discussed above, constitute a good approximation of opportunity costs. For a farm/household consuming part or all its output, the opportunity costs is indeed given by the amount that the farm would receive if instead it had sold this output on the market.

2.1.3. Labour costs: data collection and estimations

Data collection and compilation

The information on labour is collected for the agricultural holding and not for each of the commodities it produces. For ease of reporting, the data on expenses and time spent is asked by task or activity, both for paid and unpaid labour. Putting aside these commonalities, the information on labour expenses is collected in different ways for paid and unpaid labour (mainly from family or household members), using a different set of questions.

For paid labour, the farmer is asked, for each task (planting, weeding, etc.), how many persons have been hired to complete the task and how much time each of them spent for this activity (average number of days per person and number of hours per person and per day). With this data, the quantity of (paid) labour put into cultivation, or the labour input, is measured. The farmer is then asked the total expense related to the hiring of workers to complete the task (total cost by task), both the cash cost and the cash equivalent of any in-kind payment. With this information, average daily or hourly wage by task (and cultivation activities as a whole) can be measured. These unit wages are used to impute wages for unpaid labor, as explained further below. The total expenses for each farm are calculated by summing up the expenses calculated for the different tasks.

The procedure is slightly different for unpaid labor (family or household labor): as there is no cash cost associated to family labour, the questions only focus on the number of persons involved in each task and on the time spent, on average, by each of them to complete the activity (average number of days spent by person and task and average number of hours spent in a day). The total labour input for family work can then be calculated in terms of hours spent by multiplying the number of persons by the number of hours and summing across all tasks. An extract of the section on labor expenses in the survey questionnaire is provided in Figure 1.

Figure 1. Survey section on labour expenses and input (extract, source: 2016-2017 pilot-survey on agricultural cost of production. Zambia).

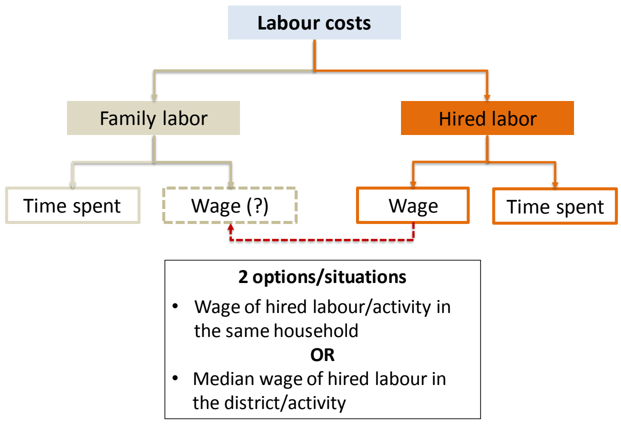
Activity		**Family Labour**					**Hired Labour**					
		Did the household use unpaid family labour to do ______? ***1=Yes*** ***2=No→ skip to PHL6*** ***3=Did not do this activity→ skip to next activity***	How many male/female adult members were involved in______? [Age 12 and over] *(Enter 0 if none)*		On average how many days did each house hold member work on___?	On average how many hours did each household member work per day on ___?	Did the household use hired labour to do ______? ***1=Yes*** ***2=No→ skip to next activity***	How many people did the household hire to do ____? ***Enter number of people*** *Enter 0 if none and skip to **next activity***	On average how many days did each worker spend on____?	On average, how many hours did each worker spend each day on__-?	What was the total price paid by the household to hire labour to complete___? *Enum: If the payment was in-kind (party or entirely) ask respondent to estimate the cash-equivalent of this in-kind payment* *(in Zambian Kwacha)*	
			Adults									
			Male	**Female**	Days	Hours per day			Days	Hours per day	Cash	In-Kind
PHL00		**PHL1**	**PHL2**	**PHL3**	**PHL4**	**PH5**	**PHL10**	**PHL11**	**PHL12**	**PHL13**	**PHL14**	**PHL15**
Land Prep	1											
Planting	2											
Basal Fert. Application	3											
Top Fert. Application	4											

Estimation of the cost of unpaid labour

A wage and expense must be imputed to unpaid labour to account for the opportunity cost of unpaid family or household labour. This is one of the most challenging aspect related to the valuation of labour input. The options range from the most sophisticated, using hedonic regressions that attribute fictive wages to unpaid workers by estimating the contribution of individual (such as sex or education) and global factors (for example, region), to the simplest approach, based on average or median agricultural wages. From the perspective of national statistics and developing countries, the recommended approach is the simpler "average/median wage" method, where wages for unpaid workers are imputed using average or median wages for a given category of workers and farms.

The method adopted in this case-study uses wages paid by the farm, when they are available, to impute the wages of unpaid workers from the same farm (by task). When the farm does not employ any paid worker (or when the information on wages, for one reason or another, cannot be used), median wages per district and per task (planting, harvesting, etc.) are used for the imputation (Figure 2).

Figure 2. Estimation procedure for costs of family labour.



Source: Pilot survey on agricultural cost of production (Zambia, 2016–2017)

Attribution of labour costs to specific commodities

Information regarding labour input is reported as a total for all the cropping activities. To construct commodity-specific labour productivity indicators, these expenses have to be distributed to each crop using an adapted allocation procedure. For consistency purposes, the same approach than for the other cost items is used: planted area for each crops is used as the allocation key. While this method may be questionable for items such as overhead costs or certain fixed assets (buildings, for example), it is likely to yield satisfactory results for labour given the direct proportionality of the labour input with the cultivated area for the different crops. The time spent by workers, and the related expenses, on tasks such as planting, weeding or harvesting for instance are directly proportional to the cultivated area.

By using simple proportionality relationships, however, we make the implicit assumption that the input intensities (for crops, quantities of inputs used per area unit) are the same across all crops, which may in certain cases constitute a strong assumption. For example, it is known that the cultivation of soya in southern Africa is much more labor intensive than, say, maize. Using a proportional allocation therefore leads to understate differences in productivity between crops.

2.2. Labour productivity indicators

2.2.1. Labour productivity – gross output

This indicator is defined as the output value per unit of labour input, expressed in time spent. As this is a partial productivity indicator that is expressed only in levels, physical (here, time) units can be used instead of monetary units for the input. This indicator measures how much monetary output one unit of labour (e.g. one day) can generate.

This indicator is produced for total labour, paid and unpaid, and separately for each of these categories.

Measurement of gross output

Gross output is the value of the output produced by the farms of the sample (noted O): the sum of the sold output and unsold output valued at market prices. In this exercise, only the crop output is considered, even though the farm may also generate income from livestock activities.

Measurement of labour input

Labour input is measured in number of hours, the lowest ad most accurate reporting unit used in the questionnaire. For the purposes of measuring productivity in the farming sector, expressing the indicator per hour worked is less meaningful than, say, converting the hours worked in full-time day or year-equivalents which can be more easily related the activities of the farm. This is the approach adopted for this exercise.

The calculation process of labour input for each farm of the sample is as follows:

- Calculate, for each task, the total number of hours worked, using the following formula: $H_{task} = pr.d.h$, where pr is the number of persons involved in the task, d is the average number of days spent per worker and per task and h is the average number of hours spent in a day per person and per task
- Aggregate the total number of hours across all tasks performed on the farm: $H = \sum_{task} H_{task}$
- Finally, convert the total number of hours in full-time day-equivalents, assuming a typical working day of 8 hours: $L = {}^{H}/_{8}$ (for full time-year equivalents, 8 can be replaced by the typical number of working days per year)

The calculated labour productivity indicator is: $l_O = {}^{O}/_{L}$

2.2.2. Labour productivity – value-added

This indicator is defined as the value-added per unit of labour input, expressed in time spent. This indicator measures how much net income one unit of labour (e.g. one day or one year) can generate. This indicator can also be produced for total labour, paid and unpaid, and separately for each of these categories.

Measurement of value-added

We adopt the gross value-added measure, defined as the output value net of the costs of intermediate inputs: $V = O - IC$, where IC represents the expenses in intermediate (or variable) inputs such as seeds, fertilizers or agrochemicals.

Measurement of labour input.

The same measure than for the gross output-based indicator is used.

The calculated labour productivity indicator is: $l_V = {}^{V}/_{L}$. This indicator measures more precisely the specific impact of labour on farm productivity and profitability as it accounts for the intensity of the link between labour and other inputs in the determination of productivity. Indeed, this indicator is equal to the gross output-based productivity metric corrected by a term which is proportional to the ratio of the quantities of intermediate inputs (ic_j) to labour.:

$$l_V = {}^{O}/_{L} - {}^{IC}/_{L} = {}^{O}/_{L} - {}^{\sum_j p_j \, . ic_j}/_{L}$$

To better understand this corrective effect on productivity, we can go one step further and specify the demand functions for each intermediate input. We can assume, to simplify, that the demand for each intermediate input depends on the area cultivated, on the demand of the other inputs, including labour, as well as on an exogenous factor measuring the quality or the effectiveness of the inputs (e.g. technological change): $ic_j = f\left(a, ha, ic_{j' \neq j}, L\right)$, where a is the technological change component and ha the number of cultivated hectares

The change in the level of labour productivity is therefore equal to:

$$\partial l_V = \frac{\partial O}{\partial L}\frac{\partial L}{L} - \sum_j p_j \cdot \frac{\partial ic_j}{\partial L}\frac{\partial L}{L}$$

If the demand for intermediate inputs and labour are positively related ($\frac{\partial ic_j}{\partial L}$ is positive), a correction is made to the labour productivity measure to deduct the increase in output that should be in fact attributable to the use of an additional amount of inputs other than labour. Conversely, if the relationship is negative ($\frac{\partial ic_j}{\partial L}$ is negative), the indicators is corrected upwards to account for the reduction in output due to a lower use in intermediate inputs. For example, everything else held equal, using more labour reduces the availability of resources to spend on items such as fertilizer, which are positively linked to output. The measure the efficiency of labour only (e.g. in terms of quantities harvested per day worked, for example), the reduction in the overall output due to a lower use of fertilizers is deducted from the labour productivity indicator. In other words, the fact that the overall "cake" (e.g. potential quantities to be harvested) is lower does not mean that the workers are less efficient, but simply that the shift in the input mix has negatively affected the output. The net effect depends on the relative elasticities of the output to the different inputs used by the farm. Here we reach the limitations of partial indicators which, by focusing on one input only, tend to miss the global picture in terms of farm productivity.

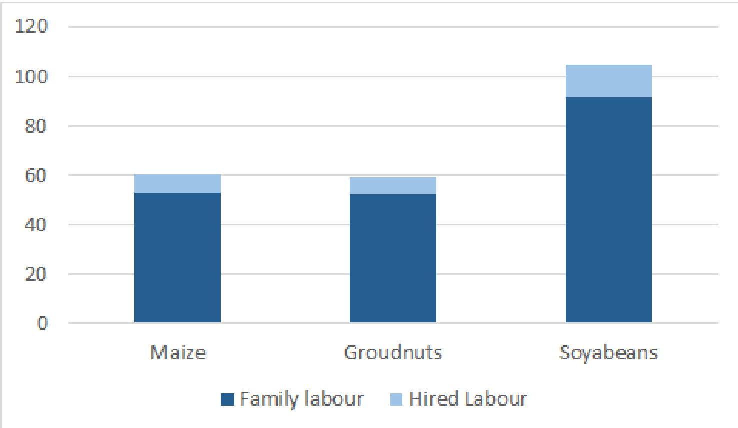
2.2.3. Results and discussion

The methodology and approach described above is illustrated with the data collected during the pilot survey conducted in 2016-2017 in Zambia. The calculation process followed all the steps described above but we only provide and discuss in this section the final results.

The first indicator, prior to calculating labour productivity, is labour intensity. It is calculated here as the number of days per hectare and year required for the major crops identified for the pilot-survey: maize, groundnuts and soyabeans. The results (Figure 3) indicate similar labour intensities for maize and groundnuts (approximately 60 days per hectare and per year), much less than soyabeans (approximately 100 days per hectare and per year). According to this measure, the cultivation of soyabeans, a major cash crop in Zambia, requires significantly more labour than the cultivation of maize or groundnuts. The estimate of labour requirements for soyabeans is in line with the results provided in other studies. For example, Nieuwenhuis and Nieuwelink (2010) estimate a total of 724 hours per hectare for soya (for traditional/manual practices, also the case of the farmers interviewed in the Zambian pilot-survey), which is equivalent to roughly 90 days per hectare. The results presented in Figure 3 also highlight the large share of family labour in total labour (between 85% and 90%), across the three crops. While this certainly confirms a known feature of the Zambian farming sector (and of other Sub-Saharan countries), the importance of the difference indicates a possible overestimation of family labour, a bias also widely encountered in farm surveys.

While labour intensities are necessarily connected to productivity through their effect on costs of production (higher labour intensities leading to higher labour costs, and reciprocally), the labour productivity results clearly show that other factors are at play.

Figure 3. Labour intensity by crop (in working days per hectare per year).

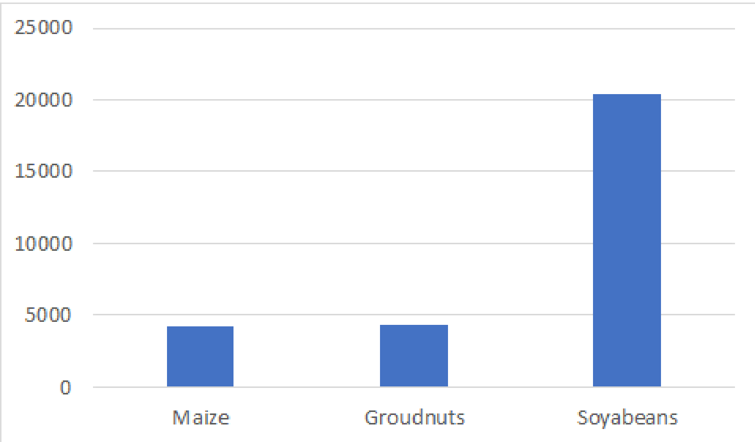


Source: Pilot survey on agricultural cost of production (Zambia, 2016–2017)

Indeed, labour productivity, measured using the l_V metric, (i.e. based on the value-added concept) is significantly higher for soya compared to the other two crops. Labour productivity for soya is measured at around ZMK 20,000 per worker per year (approx. USD 1,600), compared to ZMK 4,000 to 4,500 for maize and groundnuts (roughly between USD 320 and 370). This result reflects differences in value of production, given that soya is typically grown for selling purposes and that the prices obtained by farmers for this crop are generally significantly higher than for groundnuts and maize.

The labour productivity indicator used in this illustration refers to the value-added generated by a person working full-time during a year. It can therefore be compared to the average yearly wages received in other industries to see if labour is more or less productive in agriculture (here, for maize, groundnuts and soya) than in other sectors of the economy. For example, according to the Zambia Development Agency, the average wage of an unskilled operator in Zambia currently ranges between ZMK 18,000 and 24,000. While this figure is much higher than the labour productivity results for maize and groundnuts, it is similar to the productivity of a worker cultivating soya. Analyses of this kind contribute to build the evidence base for important policy decisions, such as the creation of incentives to foster highly profitable sub-sectors and to accelerate the transition of the workforce from low-yielding activities to more profitable ones.

Figure 4. Labour productivity by crop (Zambian kwacha of value-added generated by one person working full-time during one year).



Source: Pilot survey on agricultural cost of production (Zambia, 2016–2017)

2.3. Conclusion

This case-study has described the process of construction of a labour productivity indicator, from the initial data collection phase to the calculation of the indicator and the dissemination and interpretation of the results. It has also described the implications on the final results of the choices regarding the data collection procedures as well as of the different methodological decisions regarding the definition and calculation of the indicator.

The different steps of the process of construction of labour productivity statistics have been illustrated with concrete examples, taken from a pilot-survey carried out in 2016-2017 by the Zambian statistical office (CSO), with the technical and financial support of the Global Strategy. While this case-study only addresses a specific component of productivity measurement (it only covers labour and does not discuss issues related with the construction of Total Factor Productivity indicators, for example), we believe that it can provide useful and directly applicable guidance to statisticians and analysts in developing countries and elsewhere to engage in the process if compiling relevant and coherent statistics on labour productivity.

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3

Case-study 2: Agriculture multifactor productivity (MFP) measurement at Statistics Canada

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3.1. Objective

The objective of this case-study is to provide a concrete example of the process of compilation of TFP for agriculture from aggregated data sources by a national statistical organization. This illustration takes the reader through the different steps of the process, from the identification of the data sources (many of them from national accounts), the construction of the output and input measures, the determination of the weights, to the computation and dissemination of the TFP. This illustration also presents how labour productivity, the other indicator produced by Statistics Canada's productivity program, is defined, constructed and disseminated.

3.2. Introduction and background

3.2.1. Introduction

In Canada, official measures of productivity for agriculture are produced by Statistics Canada, the public organization in charge of compiling national statistics. Agricultural productivity indicators compiled by Statistics Canada include multifactor productivity (MFP, annual)[3] and labour productivity (annual and quarterly). The measures are published at both national and sub-national (provincial) levels.

The productivity measures for agriculture are part of Statistics Canada's productivity accounts where estimates of labour productivity, multifactor

[3] In this document, we use multifactor productivity (MFP) and total factor productivity (TFP) as synonyms

productivity and related variables for all industries that make up the business sector are produced and published.

This note describes the basic concepts, methods and data sources used by Statistics Canada to produce productivity measures for Canadian industries with emphasis on the productivity measures for agriculture. For a more comprehensive description of Statistics Canada's productivity measures, see Baldwin, Gu and Yan (2007) and Baldwin et al. (2014a, 2014b).

Independent of Statistics Canada, agriculture productivity measures are also produced by Agriculture and Agri-Food Canada (AAFC) and by researchers on an ad hoc basis. These measures provide important feedback on the productivity measures produced by Statistics Canada.

3.2.2. Background on productivity measurement at Statistics Canada

Statistics Canada began producing productivity measures in the late 1940's in response to government officials' interest in better understanding the Canadian economy and tracking its progress. At the time, the measures were limited to estimates of labour productivity even though it was widely accepted that there were significant limitations of a single factor productivity measure. The main limitation for single input productivity measures is that measured productivity can increase due to an increased use of other inputs. For example, measured labour productivity can increase just by increasing the amount or the intensity of capital or intermediate inputs used in the production process, leading to a misrepresentation of the underlying productivity of the workforce, which depends on factors such as its education, experience and level of skill.

Beginning 1987, Statistics Canada formalized a "Productivity Program" which had the mandate to produce the productivity accounts for Canada, comprising multifactor productivity, labour productivity and related variables. These measures are now produced and available by industry, including agriculture (crop and animal production) at the national and provincial levels and have been refined as data sources have improved and methodologies have evolved.

The quarterly labour productivity measures were added in the early 2000's in response to user demand of more granular and frequent information related to the labour market.

Statistics Canada's productivity program publishes the growth rates of productivity. It has also experimented with estimating productivity levels and comparing the productivity of Canadian firms with those of the United States. These estimates are considered less robust than the growth rates because of the difficulty in comparing the relative price levels between the two countries as data are often incomplete, not collected on a regular basis and not always adhering to the same accounting principles.

3.3. Methodology

3.3.1. Overview

Measurement principles

At Statistics Canada, productivity measurement follows the growth accounting framework, developed and successively refined by Jorgenson (1966), Jorgenson, Gollop and Fraumeni (1987) Diewert (1987), and OECD (2001).

Accordingly, multifactor productivity growth is defined as output growth that is not accounted for by the growth of inputs, that include capital, labour and intermediate inputs. It measures the overall efficiency with which the inputs are used in production. Productivity growth is often associated with technological change, technical efficiency, organizational change, economies of scale.

Statistics Canada measures the contribution to labour productivity of gains in labour input intensity (for example, number of labour units per hectare of cultivated land) and changes in the structure of the workforce in relation to skills[4] (from lower skilled towards higher skilled workers). The residual is defined as the growth in multifactor productivity (MFP).

Statistics Canada's productivity measures are derived using the "growth accounting" model where productivity growth is measured as the difference between output and input growth. In other words, the growth in outputs in an industry is attributed first to the volume, quality and intensity of factor inputs (capital and labour), while any unexplained or residual growth is attributed to technological progress. This approach requires a full accounting and estimation of outputs and inputs, both in value and volume terms, and is therefore often regarded as data intensive.

[4] Skills can be measured through education level or age (as a proxy of experience), for example.

Based on the economic and index number theory along with some restrictive assumptions concerning the underlying form of the actual production function, total factor productivity can be defined as the ratio of the measure of aggregate volume of outputs to the measure of aggregate volume of inputs used in the production process. In keeping with the theory, superlative index numbers, such as the Fisher index, are used to deflate inputs and outputs.

In terms of sectoral coverage, MFP measures are available for crop and animal production combined, while labour productivity measures are available for crop production and animal production separately.

Business sector output for productivity measurement is of value added measured at basic prices. At the industry level (agriculture, manufacturing and services), the output measure can be either gross output at basic prices or value added at basic prices. When gross output is chosen for productivity measures, the corresponding inputs include capital, labour and intermediate inputs. MFP growth is defined in this case as the difference between growth in gross output and growth in the total of all inputs (capital, labour and intermediate inputs). When value added is used for productivity measures, the inputs only include capital and labour, as the intermediate inputs have already been deducted from gross output to construct value-added. In this case, MFP growth is defined as the difference between growth in value added and growth in combined capital and labour inputs.

Integration with the System of National Accounts (SNA)

The productivity measures of Statistics Canada are fully integrated with the Canadian System of National Accounts (SNA) which enhances the value of the measures, allowing productivity to be compared across industries using consistent measurement methods. Gross output, value-added and intermediate inputs are derived from the annual supply and use tables (SUTs), formerly called Input-Output tables in the SNA framework. Capital inputs are estimated from data on investment and capital by industry from the capital account and the "Use" tables for final consumption from the SUTs. The compensation of employees and mixed income are obtained from the Income Accounts of the SNA.

The rest of this note presents concepts, methods and data sources used to estimate output, intermediate inputs, labour and capital, necessary for the compilation of multifactor productivity for the agriculture sector at Statistics Canada.

3.3.2. The numerator: gross output and value-added

Statistics Canada publishes labour productivity and MFP for agriculture using both the value-added and the gross output concepts. When value added is used, labour productivity is defined as the ratio of value-added to hours worked while MFP is the ratio of value added to the total of capital and labour input. When gross output is used, labour productivity is defined as the ratio of gross output to hours worked and MFP is the ratio of gross output to combined capital, labour and intermediate inputs.

Gross output is valued at basic prices, that excludes taxes and subsidies on products while intermediate inputs are valued at purchaser price, that includes tax and subsidies on products, transport and trade margins. Value added is calculated at basic prices, as the difference between gross output at basic price and intermediate inputs at purchaser prices.

Gross output for the agriculture industry is derived from the Statistics Canada's supply tables of the SUTs. These are available in nominal (current dollars) and constant dollars and are part of the Canadian SNA. The supply tables are in turn derived from estimates from Statistics Canada's Agriculture Division and are based on a combination of annual and sub-annual commodity surveys, administrative data sources and the quinquennial Census of Agriculture. The commodities that are estimated as part of the agriculture productivity measures are:

- Canola (including rapeseed)
- Oilseeds (except canola)
- Wheat
- Grains (except wheat)
- Fresh potatoes
- Fresh fruits and nuts
- Other miscellaneous crop products
- Fresh vegetables (except potatoes)
- Imputed feed (animal feed produced for own consumption)
- Nursery and floriculture products
- Cattle and calves
- Unprocessed fluid milk
- Hogs
- Eggs in shell
- Poultry
- Other live animals
- Raw furs and skins, and animal products n.e.c.

3.3.3. Intermediate inputs

Intermediate inputs used to produce agriculture outputs are valued at purchaser prices and are derived from estimates produced by the Agriculture Division of Statistics Canada. These estimates, collected in value-terms, are deflated using prices coming from a variety of sources including import prices, the farm input price index and the farm product price index. Estimated inputs included in agriculture productivity measurement include:

- Property taxes
- Electricity
- Heating fuel
- Machinery fuel
- Fertilizer and lime
- Pesticides
- Commercial seed and feed
- Artificial insemination and veterinary fees
- Repairs to buildings and fences
- Telephone
- Machinery repairs and other expenses
- Irrigation
- Twine, wire and containers
- Crop and hail insurance
- Business insurance
- Custom work
- Stabilization premiums
- Other operating expenses
- Legal and accounting fees

3.3.4. Labour input

The estimates of hours worked used to produce Canadian productivity measures are mainly derived from the two principal surveys conducted by the agency, the Labour Force Survey (LFS) and the Survey of Employment Payrolls and Hours (SEPH).

The LFS is a household survey that collects data on persons, hours worked, and earnings. Every five years, the estimates are benchmarked to the Census of Population. SEPH is an industry (establishment) survey of businesses that collects data on firm employment, paid hours and payrolls.

Given its approach and survey frame, the LFS is considered the more comprehensive of the two labour surveys and used to provide an estimate of hours worked for the aggregate business sector. However, the distribution of employment by industry obtained from SEPH is considered to be superior to that of the LFS because of a larger sample size and the mechanics of industrial coding. The estimates of labour compositional changes are derived from the LFS and Census of Population. The Census is used to derive the benchmark tables of hours worked and labour compensation cross-classified by gender, age, education and employment class (employee, self-employed or unpaid family labour). The LFS is used to estimate the tables of hours worked and compensation between Census years.

The labour input estimates used in the MFP measures for agriculture also reflect the composition of the agriculture workplace by adjusting for worker characteristics, such as education, experience and class of workers (paid versus self-employed). The growth of labour input is an aggregate of the growth of hours worked by different types of workers, with weights based on the hourly wages of each type[5]. In other words, the change in labour input is the sum of the change in hours worked and the change in labour composition between different types of workers.

The labour composition measure in the MFP calculation framework excludes gender groups in the calculation. Essentially, it is assumed that the earning differences between male workers and female workers—after controlling for the differences in age, education and two employment categories—is not a result of productivity differences between male and female workers. Rather, it is a result of other factors, such as workplace discrimination.

The share of mixed income of self-employed workers going to labour is estimated by assuming that the hourly earnings for self-employed workers is proportional to that of paid workers with the same level of education and experience. The "scaling" factor for each level of education and experience is based on the relative hourly earnings of paid versus self-employed workers derived from the Census of Population.

[5] A higher wage is indicative of a higher-skilled worker, with potentially higher productivity

3.3.5. Capital input

Capital stock and services

Capital input is measured as the services that flow from the stock of capital used in the industry. This differs from the stock of capital sometimes used in productivity measurement because not all forms of capital provide services at the same rate, just as not all hours worked provide labour services at the same rate. Short-lived assets, such as a car or computer, must provide all of their services in just the few years before they completely depreciate. Buildings typically provide their services over decades. Therefore, in any single year, a dollar's worth of capital service from a car provides relatively more capital services than a dollar's worth of service from a building. Because of differences in capital service rates between assets, capital input can increase not only because investment increases the total of the capital stock, but also if investment shifts towards assets that provide relatively more service per dollar of capital stock.

The capital service flows for agriculture are derived from an aggregation of detailed types of fixed assets plus land and farm commodity inventories, using weights based on their user cost of capital. This is analogous to labour where different types of labour are aggregated using weights based on their hourly compensation.

The value of investment for fixed assets are derived from estimates of capital expenditures conducted by Statistics Canada and adjusted to be consistent with the concepts used by the Canadian SNA. The value of the capital stock is derived by accumulating current and previous years investments using the perpetual inventory method (PIM) and a geometric depreciation pattern. The depreciation rates are taken from Baldwin, Liu and Tanguay (2015) who estimated depreciation rates using a combination of ex-ante and ex-post deprecation estimates.

The value and area of land used in agriculture is estimated from the Census of Agriculture every five years. Administrative data sources are used to estimate land value between census years.

User costs and aggregation of capital services

The estimation of capital services includes the estimation of capital stock at the asset level and the aggregation of these capital assets using weights based on the user cost of capital. The user cost of capital is defined as the sum of the rate of return on capital, depreciation and capital gains adjusted for the effects of tax treatments. The rate of return can be either set to the endogenous rate of return or exogenous rate of return. In the past the endogenous (or internal) rate of return method was used in Canada, where the rate of return is estimated from the identity that the user cost of capital across assets is equal to capital income. Using this approach, the sum of input costs exhausts the value of output. The approach assumes perfect competition and constant return to scale production.

Internal rates of return for agriculture and several other sectors were found to be volatile. Therefore, the average rates of return for the business sector are now used to estimate the user cost of capital for agriculture. This approach for estimating capital input provides an estimation of a surplus which is the difference between capital income and capital cost. This difference could be the result of imperfect competition. It could also arise because the list of inputs included in the MFP estimates is incomplete (for example, many intangibles are excluded). Or it could arise because of economies of scale, so that paying inputs their marginal revenue product does not completely exhaust the value of output.

3.4. Agricultural productivity statistics at Statistics Canada

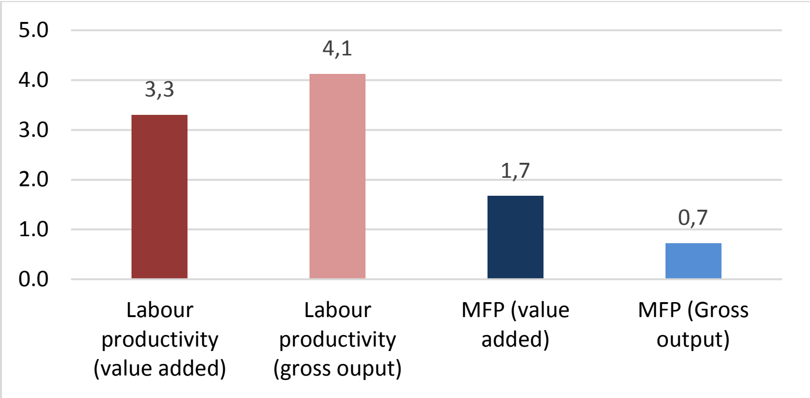
3.4.1. Dissemination

Statistics Canada makes its data available through the Statistics Canada Daily (the official data release vehicle) as well as on the electronic dissemination data base (CANSIM). The research and analysis are available from the Canadian Productivity Review and the Analytical Studies Branch Research Paper series.

MFP and labour productivity growth and levels

Figure 5 shows four measures of productivity for crop and animal production: labour productivity and MFP based on gross output, and labour productivity and MFP based on value added. The discussion below will focus on the two productivity measures based on gross output.

Figure 5. Productivity growth in crop and animal production (%), annual average, 1961-2014.



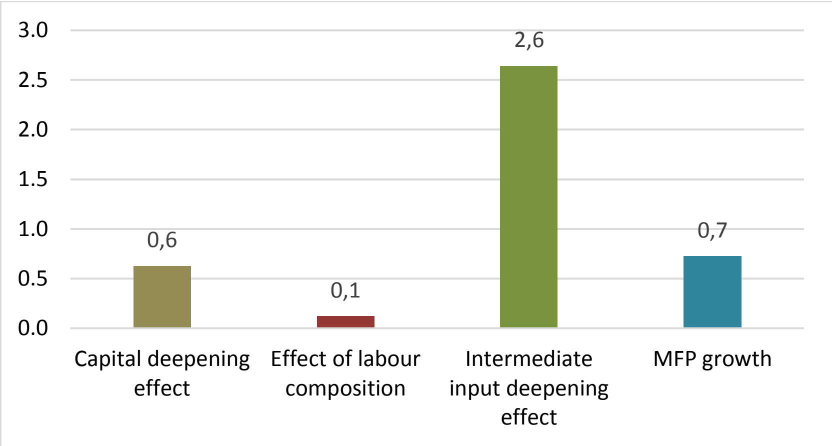
Source: Statistics Canada

MFP based on gross output increased 0.73% per year in Canadian crop and animal production for the period from 1961 to 2014: the level of MFP in crop and animal production in 2014 is 50% higher than what it was in 1961. Labour productivity as defined as gross output per hours worked rose 4.12 % per year in Canadian crop and animal production for the period 1961 to 2014: the level of labour productivity in the crop and animal production sector in 2014 is 9.6 times the level in 1961.

Quantification of the sources of labour productivity growth

Figure 6 presents a decomposition of labour productivity growth based on gross output in crop and animal production into its four main components: capital deepening effect, intermediate input deepening effect, labour composition changes and MFP growth (improvements in technology). For the period 1961 to 2014, the most important contributor to growth in labour productivity in crop and animal production is the increase in intermediate input intensity (use of seeds, feeds, etc.), which accounted for 2.64 percentage points or 64 % of the 4.12% per year growth in labour productivity for that period. MFP growth is the second most important contributor to labour productivity growth, accounting for 0.63 percentage points or 18 % of the growth in labour productivity. Capital deepening effect accounted for 0.63 percentage points or 15 percent of the growth in labour productivity. The changes in the composition of agricultural towards the use of more skilled workers made a positive but small contribution to the growth in labour productivity.

Figure 6. Sources of labour productivity growth in crop and animal production (%), annual average, 1961-2014.



Source: Statistics Canada

3.4.2. Quality assessments and improvements to the productivity program

Statistics Canada has implemented a formal quality assurance framework with the aim of constantly improving its outputs including analytical products. The agency has worked with other national statistical organizations, international statistical bodies (such as the United Nations' Statistics Division and the OECD), academics and researchers to develop methods and refine estimation processes. When a revision is made, user notes document the reasons for the change.

Like most statistical programs that produce indicators that are derivations from multiple sources rather than obtained directly from survey estimates, quality assurance for the most part takes the form of data confrontation. In the case of the productivity measurement program, all data sources are examined to determine if data breaks exist, to confirm that they make sense in terms of level and trend and that they are congruent with similar or related series. In addition, there are some more rigorous techniques used to determine if any statistical outliers exist within the data sources. Recognized as a best practice, the program publishes quality and fitness for use guides of its outputs for users.

Statistics Canada also benefits from being a central and integrated national statistical organization and having the productivity research group as part of Statistics Canada's core mandate offers several advantages for productivity measurement. The proximity of the analysts and researchers that compile the productivity measures to the statisticians that produce and gather the primary data improves both data sets, resulting from the synergy and continuous feedback that this proximity brings.

3.5. Conclusion and perspectives

Statistics Canada's productivity program is one of the few long-standing and established statistical programs on productivity measurement that includes agriculture. It has many of the features that are recommended as first best methods to productivity measurement: it uses the growth accounting to measure MFP, has a comprehensive coverage of both outputs and inputs, compiles indicators using the complementary gross output and value-added approaches, has an aggregation method, based on superlative index numbers such as the Fisher index, consistent with theory and, finally goes beyond the measurement itself to quantify the sources of productivity growth. The program focuses on the compilation of MFP on the one hand and labour productivity on the other hand, which is also a recommendation made in Global Strategy (2018).

Statistics Canada's productivity program has evolved to reflect developments in the economic literature and to meet the needs of data users. The changes increased understanding of the process of economic growth in Canada and the country's productivity performance compared with its major trading partner, the United States. The future developments of the program include the planned development of an MFP measure of agriculture that accounts for the effect of agriculture on environment using a recent methodology from Gu and Willox (2018) who have developed such measure for the manufacturing sector. The work is also planned to improve land estimation designed to take into account the effect of land quality on crop production.

While it is not the intention of the authors of the present report to recommend developing countries to adopt all the features of Statistics Canada's productivity program, many of which require an advanced statistical data collection system covering agriculture and the rest of the economy, which many countries are lacking, it can serve as a useful point of reference for statistical organizations wishing to develop productivity statistics or upgrade their existing system.

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