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Farm size and productivity

Lessons from recent literature

by
Douglas Gollin
Oxford University

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Abstract

This paper considers the relationship between farm size and productivity. It begins by discussing measurement issues and conceptual issues related to agricultural productivity, including the well-documented difficulty of measuring inputs and outputs in smallholder production systems. The paper then considers the relationship between farm size and productivity, documenting patterns both across countries and within countries. Across countries, there is a weak but positive relationship between farm size and the value of agricultural output per unit of land (i.e. yield). A much stronger positive relationship holds for agricultural output per unit of labour, which is closely correlated with farm size across countries. Within countries, the relationship between farm size and yield is often negative (the widely documented “inverse farm size-productivity relationship”). However, even within countries, there is typically a strong positive relationship between farm size and labour productivity. The paper concludes by considering the policy implications, if any, of the relationships between farm size and agricultural productivity.

1 Introduction

The spatial scale of agriculture differs enormously across countries and even across farms within countries. The world's largest farms occupy more than 1 million hectares – although these are typically commercial cattle ranches rather than crop farms. At the other extreme (and leaving aside kitchen gardens), median farm size in many parts of the developing world is less than 1 hectare. A common narrative holds that increasing farm size inevitably accompanies agricultural development and economic growth. As this paper will discuss, however, the data provide only limited support for this narrative. Small farms persist even in the richest countries, and, to some degree, the shift towards increasingly intensive modes of production has rendered less relevant the spatial footprint of farming.

This paper addresses a set of questions related to the spatial scale of agriculture, with a particular focus on the implications for agricultural development. How should we measure farm size? How does farm size typically change over the course of economic growth? What is the relationship between development and farm size? In particular, is there a direct causal relationship between farm size and the productivity level of agriculture? Should policymakers target farm size or allow market forces to determine the spatial scale of agriculture? What policies might be used to affect farm size? What do we know about the consequences of policies that distort farm size?

A large literature in development economics has focused on the so-called “inverse relationship” between farm size and land productivity (typically measured as physical output per unit of land, which is more simply termed “crop yield”). An old literature, dating back to Sen (1962), suggests that this relationship arises from imperfections in land and labour markets, such that poor households use family labour intensively on small plots, leading to high land productivity – but also associated with low labour productivity. This paper will explore new evidence on the inverse relationship. Much of the new evidence challenges the old stylized facts. More careful measurement of agricultural inputs and outputs calls into question the very existence of the inverse relationship: in many contexts, the apparent relationship appears to stem from systematic mismeasurement of land and crop output on farms of different sizes.

The existence of the inverse relationship has provided an important foundation for smallholder-targeted strategies for agricultural development. If smallholders are highly productive – indeed, more productive than larger (and richer) farmers – then there is no clear trade-off between equity and efficiency. Under the inverse relationship, programmes that promote smallholder farming systems and support smallholder livelihoods would both support the (relatively) poor and stimulate aggregate productivity. This belief has been key to agricultural development strategies over several decades and remains a central premise for a number of international organizations and aid donors.

In the last few years, however, an emerging literature has challenged the existence of the inverse relationship. Questions about the relationship between farm size and productivity have re-emerged as important for development strategy. This paper's contribution is to review issues of theory, measurement and evidence. This paper begins by reviewing the challenges of measuring farm size and agricultural productivity. These include both conceptual issues and practical challenges. Whereas much of the "inverse relationship" literature has focused on physical measures of crop yield on farms of different sizes, more critical approaches might consider a range of other measures of output: gross value of production, or perhaps value added, or even farm-household income. Different output measures are relevant for different purposes, but one clear conceptual point is that crop yield is not often a useful measure either of productivity or of welfare for rural households in developing countries. Productivity measures also require researchers to account carefully for inputs and outputs – or, at least, they require measurement error in these variables to be essentially classical. If small farms systematically over-report the amount of land that they maintain under cultivation, or if they systematically over-report their output, then the calculated crop yields will not just be inaccurate, but they will also be biased (downward, in the case of over-reporting of land area; upward, in the case of over-reporting of output). In recent years, careful measurement of farm productivity has benefited from an expansion of data collection and from the mobilization of new tools and technologies, such as the Global Positioning System (GPS)-assisted demarcation of farmland areas, or the use of mobile phone-based surveys to collect data on agricultural labour inputs. Correspondingly, a number of papers have drawn on new data sources to revisit the measurement of agricultural productivity; see, for example, Arthi et al. (2018), Carletto et al. (2015), Carletto et al. (2016), Kilic et al. (2017), Gourlay et al. (2017), Seymour et al. (2017).

After reviewing measurement issues and data quality matters, this paper looks at the relationship between farm size and productivity. Macroeconomists have tended to look at the aggregate level, noting large cross-country differences in average farm size (Adamopoulos and Restuccia, 2014, 2018). There are broad aggregate patterns that can be observed across countries, with farm size generally larger in rich and upper-middle-income countries. Moreover, the gap in farm size between rich countries and poor countries has probably been increasing over the past several decades, as farm size has been growing in rich countries and shrinking, on average, in poor countries (Lowder et al., 2016). This striking pattern in the data has led many policymakers to argue that small farms are at best an artifact of poverty – and at worst an impediment to growth (Collier and Dercon, 2014). But cross-country differences in farm size reflect many influences, and it is not completely clear that the positive relationship between farm size and income can be interpreted as causal. (Even in some rich countries, such as Japan, most farmland is operated by very small farms; across the rich countries of the Organisation for Economic Co-operation and Development, or OECD, there are substantial differences in the farm size distribution and in the share of agricultural output generated from small farms.)

An alternative to looking at cross-country differences in farm size is to look within countries, where land quality and farming systems may vary less than they do across countries. Comparisons of productivity measures across farms of different sizes can be based on standardized definitions and methods. One challenge here is that within countries, there may be too little variation in farm size to say very much that is useful about the relationship

between farm size and productivity. Nevertheless, a number of recent papers have examined carefully the ways in which different measures of productivity vary across farms of different sizes. A key contribution to this literature has been the emergence of rich datasets with highly comparable measures of productivity, across large and representative samples, such as the World Bank's Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA). These highly detailed data sources have made for careful measurement of productivity and have also encouraged a number of studies that have looked closely at the inverse relationship between farm size and productivity; examples from this literature include Bevis and Barrett (2016), Gourlay et al. (2017), Gollin and Udry (2017), and Desiere and Jolliffe (2018), among others.

With new data and estimates of farm-level productivity, policy discussions have also focused on farm size. Donors and development agencies have repeatedly sought to clarify the logic and justifications for targeting small farms for investments. Is there a productivity bonus from investing in smallholder agriculture? Or is a smallholder strategy simply reinforcing a poverty trap, holding people back from beneficial transitions into non-agriculture work and migration out of marginal areas? What are the contexts in which continued agricultural development should be expected to lead to consolidation of landholdings, and how significant are policies and other distortions that prevent the emergence of large farms? The final section of this paper reviews a growing literature on policies related to farm size. An emerging literature in macroeconomics has asked whether land market failures (and a variety of other policy-related distortions) may be limiting productivity growth in agriculture, for example, Adamopoulos et al. (2017), Restuccia and Santaaulàlia-Llopis (2017), and Adamopoulos and Restuccia (2015). This paper compares this emerging macro literature with a more sympathetic micro literature that envisions a continuing role for small farms, for example, Hazell et al. (2010), Wiggins et al. (2010), and Diao et al. (2010). An overall conclusion is that where land markets work well, there is no particular reason for policy to try to drive changes in farm size. In contexts where land markets are poorly developed, however, the paper argues that there may be reasons to try to reduce frictions in land markets and to facilitate land transactions. However, the potential productivity benefits must be weighed against the distributional impacts, the political realities and other factors.

2 Measuring farm size and agricultural productivity: conceptual and practical challenges

To understand the relationship between farm size and productivity, it is necessary to develop useful measures of both variables. Perhaps surprisingly, it is not straightforward to measure either one. Both conceptual issues and practical difficulties arise. A prior challenge is to define a farm. This is difficult simply because there is no clear-cut threshold at which a garden becomes a crop farm, nor is there some point at which a household that keeps a few chickens turns into a poultry farm. In many developing countries, almost all rural households produce some food, and even many urban households may keep animals or maintain kitchen gardens. In rich countries, too, data often reveal a large number of very small production units, well below the size threshold at which they would represent a primary source of livelihood for an individual or a family. Without defining a farm, however, it is not possible to discuss the distribution of farm size. In turn, any discussion of the relationship between farm size and productivity must account for the differing definitions of farms, the various ways of measuring farm size, and the challenges of assessing productivity.

2.1 Defining a farm or agricultural holding

For the purposes of discussing farm size, there needs to be some way of defining or characterizing a farm. Many households produce agricultural goods, but not all of them would sensibly be characterized as farms. Even in developing countries, survey data often reveal that many urban households produce some agricultural goods. There may also be legal or tax advantages, in some countries, for households or landowners to claim that they are engaged in agriculture. (For instance, agricultural households may receive various subsidies or benefits from the government, or they may be subject to land taxation at a different rate.) Political leaders and government departments may also find it useful to draw on particular definitions of farms. For instance, in many rich countries, agricultural ministries find it convenient to claim large numbers of very small farms as part of the agricultural sector, since it allows them to claim larger constituencies – and correspondingly protects them from the perception that they are advocating for a small number of large producers.

In the United States, for example, the United States Department of Agriculture (USDA) defines a farm as “any place from which US\$1,000 or more of agricultural products were sold or would normally have been sold during a given year” (Hoppe, 2014), a generous definition that leads to a massively skewed size distribution of farms, with nearly 60 per cent of the 2.1 million total farms designated as “retirement farms” or “off-farm occupation farms.” These 1.3 million farms account for only 6.6 per cent of total production value (Hoppe, 2014, **table 1**, p. 11). Including these farms in measures of farm size or productivity will have substantial implications, quantitatively speaking. To see this, consider United States crop farms. In 2011,

the median size of a United States crop farm was 18 hectares, and over 15 per cent of crop farms were smaller than 4 hectares (MacDonald et al., 2013). However, these very small crop farms accounted for small fractions of total output. The USDA uses a definition of a “midpoint” measure of farm size, which is the farm size, such that half the cropland is on larger farms and half the cropland is on smaller farms. By this measure, the midpoint crop farm in 2011 was nearly 450 hectares.

Similar issues arise for defining and measuring farm size in the context of European agriculture. The European Union counted just over 12.2 million “agricultural holdings” in its 2010 agricultural census, of which 49 per cent were smaller than 2 hectares, when measured in terms of land area; fully 80 per cent were smaller than 10 hectares. However, a small number of holdings (under 3 per cent) accounted for over half of the farmed area in the European Union, reflecting the skewed size distribution. The European Union statistical approach to farm size measurement also uses a measure of “standard output” (SO), which is defined in terms of “the average monetary value of the agricultural output at farm-gate price, in euro per hectare or per head of livestock.” This is based on the expected gross margin that a farm would receive based on its size and activity mix (where size is measured in area or other appropriate metric, such as the number of heads of livestock), adjusted by a regional coefficient intended to capture local variation in productivity and prices. By this measure, 45 per cent of agricultural holdings in the European Union had an SO of less than €2,000 in the 2010 agricultural census. Of the 6.8 million holdings with an SO of €2,000 or more, nearly two thirds (65.5 per cent) had an SO of less than €15,000.

The point here is twofold. First, farm size cannot be defined independent of a definition of a farm. Second, small farms are ubiquitous even in rich countries, with the United States and the European Union both characterized by large numbers of extremely small farms – admittedly accounting for relatively small fractions of land area, gross output value, and value added. Because of the strongly skewed distributions, neither the mean nor the median is a particularly useful statistic for characterizing the farm size distribution. The midpoint value (as defined above) is substantially more useful, as it is much less sensitive to the numbers of tiny farms included under any given definition.

2.2 Measuring farm size: conceptual issues

Farm size can be measured in a number of different ways, even once the “farm” itself has been defined as an entity. Much analysis focuses on the amount of agricultural land that is managed by the farm. This is often (but not always) a useful measure for crop farms, but it is substantially less useful for animal agriculture, for which land area is a poor measure of farm size in both extensive and intensive production systems. Even on crop farms, there is a great deal of variation in the intensity of production, with some crops (e.g. berries or vegetables) produced under far more intensive conditions than is true for other crops (e.g. grains and legumes). In the extreme case, greenhouse agriculture and hydroponic production systems may have very small spatial scale. Traditional measures of land area deal with this by considering the “area planted” or “area harvested,” both of which allow for multiple cropping. Thus, a greenhouse might be treated as a small land area that is planted and harvested multiple times in a single year. In the extreme, however, production cycles are continuous and the area under cultivation is not well defined.

The conceptual problems of measuring crop area are not limited to high-intensity systems in rich countries; similar issues also arise for some crops grown in low-intensity systems in developing country contexts. One well-known and problematic example is cassava cultivation, where individual cassava plants may be left to grow amid fields of other crops. There is no fixed harvest date, and indeed in some cases the cassava may never be harvested. (Cassava may be planted in some settings as a kind of “insurance policy,” but if conditions are sufficiently good, the policy is never cashed in.) Thus, the total area planted to cassava may be difficult to measure – or even to estimate. But cassava may also be harvested in a continuous fashion from the same plants, with leaves and/or tubers harvested as need arises or demand dictates. In this context, the quantity harvested and the frequency of harvest are endogenous.

A similar problem arises in developing country contexts with the measurement of cropland area for mixed farming systems – e.g. those that combine multiple crops, or those that combine crop agriculture with livestock production or aquaculture. In these production systems, the land area under cultivation may serve simultaneously to support several different activities, some of which are purely agricultural and some of which may involve non-agricultural components. For instance, an agricultural household may grow some food crops, produce fodder, keep cattle, and sell butter and cheese or other processed foods. In some sense, the entire farm income can be seen as the economic output of the land, and the area under cultivation is not a particularly useful measure of the size of the enterprise. Development economists have recognized for some time that agricultural households in developing countries are best understood as the operators of complex household enterprises. But measuring the size of this enterprise is neither simple nor straightforward, and the land area under cultivation may not capture it well.

As alternatives to measuring cropped area, farm size can be measured in terms of production value (gross or net), labour use or capital value. All of these are economic measures, rather than physical production measures, and they reflect the choices and constraints of the farm household. In this sense, they can be problematic as measures of farm size. For instance, a large commercial farm may use very little capital and a great deal of labour (e.g. a vegetable farm in a non-mechanized setting), or a lot of capital and little labour (e.g. a grain farm in a highly mechanized setting), or almost any combination of the two. The size ranking of these farms will depend on the measure being used.

Much of the literature on farm size and productivity attempts to dodge the deeper questions here by focusing exclusively on crop agriculture and using land area as the measure of farm size. This indeed simplifies the analysis, but it raises a number of questions about whether the observed relationships between farm size and productivity are actually based on sensible comparisons of like with like, or whether the analysis omits important differences in land quality, market access and other variables.

2.3 Measuring farm size: practical issues

Beyond these purely conceptual issues in measuring farm size, there are numerous issues that arise in the actual collection of representative data on farm size. One of the main problems is related to sampling. Both large and small farms can be difficult to capture adequately in standard survey designs. This may be less of a problem in advanced countries, where administrative data may lend themselves to the construction of a full census or a sample based on the census of farms. Even in this setting, however, the census data may miss small

farms that are on the cusp of the classification. For instance, in the United States context, there may be small farms that could, in principle, meet the threshold of selling US\$1,000 of produce in a typical year, but some of these operations may not choose to register with the USDA, and indeed some of them may simply not participate in the agricultural cash economy.

In the context of developing countries, the corresponding problem is typically with capturing large commercial farms in the data. Much of the agricultural data that we have for developing countries is based on household surveys. These do a good job of capturing family farms – and even the relatively small garden plots and animal-keeping activities of urban households. But household surveys are not designed to account for large commercial farms, so these data sources are not particularly helpful for providing information about plantations or large farms.

An alternative to household surveys is the use of geographic sampling frames (or “area sampling frames”), in which (for example) the sample is of representative blocks of land (Gallego, 2015). This approach is more likely to capture large farms, but it may be administratively more difficult and costlier to conduct than a household survey, especially in a developing country where plots are small and where an individual household’s plots may be spatially dispersed around a village. In such a context, there may be a large number of households associated with any given block of farmland, making it challenging to collect useful socio-economic data for each household. A number of recent studies have sought to use remote sensing to estimate farm size, but this is problematic if individual farms are divided into multiple non-contiguous plots, as is commonplace in many developing country contexts. In settings like these, remote sensing may do a reasonable job of estimating the distribution of *plot* size, but this is different from farm size.¹

2.4 Measuring inputs: land

Given a farm, it seems relatively straightforward to measure the land area. But, as with everything else, the issue is more complicated in practice. A first challenge is to work out the full set of plots associated with a particular farm household. This may be complicated, however; individual household members may have overlapping rights to land with members of other households. For instance, a woman may have some rights (and obligations) that involve farming a plot of land that is jointly owned with her brother, who lives in a different household – and even in a different village. A plot of land within one village may be shared by multiple households. Within the same household, different individuals may farm different plots of land. What is a “farm”? Should we think of all the landholdings farmed by a particular manager? Or those owned by the individuals who make up a specific household? Issues such as this have given rise to a wealth of analyses, and many household surveys now ask questions at a level of detail sufficient to allow the researcher to choose a definition that is useful for a particular purpose and a particular context.

Measuring land area itself can be done by asking farmers to self-report the size of their plots or else by using other measures, such as using a rope and compass to map each plot – a

1. It is also worth noting that techniques for identifying plots from remote sensing remain in their infancy, except for the relatively simple case of fairly large monocropped fields under relatively weed-free cultivation. In smallholder settings (e.g. in African conditions), remote-sensing methods remain rudimentary. One part of the problem is the required spatial, spectral and temporal resolution for the satellite imagery. The other part of the problem is developing reliable crop classification models that are calibrated for smallholder farming systems.

technique that is considered the most accurate method (Carletto et al., 2016). In recent years, many surveys have shifted to the use of handheld GPS devices for measuring plot area. The evidence suggests that GPS measurement can be an effective tool for assessing land area, although it requires careful training of enumerators and can be costly, as it requires the enumerators to visit every plot on the farm and to walk the perimeter of each plot. GPS measurement is subject to its own errors, for example, from enumerators cutting off the corners of plots to save time or to avoid walking through wet areas or thickets. Kilic et al. (2017) discuss the biases introduced by missing data in GPS-based land area measures in large-scale household surveys, but they argue that careful multiple imputation of values for the missing data can work effectively to overcome these biases.

A more consequential issue, perhaps, than the area of land is the quality of land. For the purposes of agricultural production, land quality matters along many dimensions and in complex ways. Some land characteristics are observable – at least in principle. For instance, many surveys collect data on soil type, slope and topography. But there are many other potential dimensions of land and soil quality, and these may also interact in complex ways with other variables – for example, weather – making it difficult to control effectively for land quality in standard productivity analyses. The observable components of land quality are not the only relevant dimensions, however; Gollin and Udry (2017) argue that unobservable heterogeneity in land quality is quantitatively important in accounting for differences in productivity across farms. Gollin and Udry (2017) show that individual farmers frequently obtain very different levels of physical productivity on different plots on which they cultivate identical crops. Some of the differences in output reflect shocks to production, such as late-season losses to weather or pests. However, there is also evidence that farmers themselves are aware of subtle differences in land quality and are choosing inputs to optimize production in relation to this heterogeneity.

What this means is that simple comparisons of output per unit of land across farms or households must not be taken as clear evidence for differences in productivity or efficiency. To the extent that the intrinsic properties of the land differ, one should be cautious in treating land area – however well measured – as the correct way to quantify the land input. In some sense, what we need for productivity analysis is a measure of “effective land units” rather than a crude measure of land area. Collecting data on observable characteristics of land is helpful; as noted by Gollin and Udry (2017), the measured observables are overwhelmingly significant, individually and jointly, in explaining output. But the observable characteristics of land quality have little quantitative ability to account for differences in productivity at the farm level. By contrast, unobservable characteristics appear to be quantitatively very important (Gollin and Udry, 2017).

Meaningful comparisons of productivity across farms of different sizes will need to account properly for land quality as well as land area. Many studies that have supported the existence of an inverse relationship have relied on within-country comparisons of farm size and productivity that do not account carefully for differences in land quality. To the extent that large farms tend to be found in areas of low inherent land quality, where land is cheaper and less desirable, these calculations may be conflating the poor quality of the land with the productivity of large farms. The quantification of land inputs thus remains a challenging area for productivity measurement. Both land area and land quality may be challenging to measure and to translate into economically useful terms.

2.5 Measuring inputs: labour

Other than land, labour is the most significant input into agricultural production. It is also the most difficult to measure, for both conceptual reasons and practical reasons. Early productivity studies simply attempted to quantify the number of people working on a farm, perhaps assigning different weights to adults and children (or, in many cases, adult men, adult women and children). To the extent that rural households engage in non-farm activities, however, it is important to account for the hours worked in agriculture, as opposed to time spent in non-agricultural market activities, home production and leisure. This has led to a new standard approach in household surveys of asking individuals about the total hours of labour used on each of a household's plots – including both hired labour and family labour. In the most detailed surveys, data are collected on the specific tasks carried out on each plot, such as land preparation, planting, weeding and harvesting. The new approach allows for the construction of aggregate labour measures on each plot – through applying some kind of weighting to the labour of different household members – as well as for an account of hired labour.

In principle, an approach of this kind should capture the full use of farm labour. In practice, however, the results appear to be quite sensitive to the frequency with which households are asked to report, the particular individual(s) who are asked to report, the season at which the report takes place, and the length of the recall period. An interesting experimental approach (Arthi et al., 2018) shows the extent to which the form of the survey affects conclusions about total farm labour use; the authors find that asking Tanzanian farmers, at the end of the growing season, to provide an estimate of their hours worked on the farm leads to a very large overestimate of agricultural labour relative to what is calculated by adding up the responses to more frequent queries covering shorter recall periods. A similar data experiment in Ghana also finds that end-of-season recall methods overestimate total labour uses, but by smaller amounts (Gaddis et al., 2017).

What is less clear is whether a plot-by-plot and week-by-week summation of hours worked on the farm is an adequate measure of agricultural labour. Some farm work does not take place on any plot, for example, purchasing inputs in town or marketing output. Both of these are, in principle, activities that should be attributed to the agricultural enterprise. Maintenance of tools and equipment, storage of harvested crops, and acquiring information about markets (and even talking with other farmers about technologies and markets, which may be difficult to distinguish from leisure) should all, in principle, be counted as part of farm labour, but none of these will necessarily be captured by a plot-by-plot record of time use. Many agricultural households also carry out non-crop activities that are done in small units of effort: feeding the chickens as part of the morning routine or collecting their eggs, or gathering forage from the roadside for the family cow, for example. To the extent that many of these activities are carried out by women – who may not even perceive them as “farm labour” – their omission in “summation-based” estimates of agricultural labour may systematically understate the contributions of women (Palacios-Lopez et al., 2017) and may also understate the total amount of household labour used in agriculture (Doss, 2018).

Time use data also do not distinguish levels of effort or skill, both of which in some sense should be quantified in our measures of “effective labour units.” We know that there are important differences across individuals in both effort and skill; hired labour is typically

reserved only for certain tasks where effort and skill are easily monitored. Families typically assign different individuals to different tasks, presumably reflecting perceptions of skill and comparative advantage. Seymour et al. (2017) discuss some of the other challenges of measuring labour input through time use surveys.

We also know that an hour of labour, carried out on the same plot by the same individual, will have a very different marginal product at different moments in the growing season. An hour of weeding just after the first rains may make much more difference for yield than an hour of weeding at the end of the season. Many tasks, such as land preparation and planting, are extremely time-sensitive. An hour at the right point in time may have a far higher value than an hour spent in futility after the appropriate window has closed.

Current research is attempting to measure labour effort through activity trackers and similar “objective” measures of physical effort (Akogun et al., 2017). However, the key determinants of labour effectiveness may depend on timing, knowledge, skill and attentiveness – qualities that are far more difficult to assess through external monitoring or tracking.

How does the difficulty of measuring agricultural labour affect our understanding of productivity differences on large and small farms? To the extent that very large farms may use hired labour, the total labour input may be quite easy to capture. In fact, the more hired labour that a farm uses, the more easily the labour input will be measured, at least conditional on effective record-keeping. On small farms, where most (or much) of the labour is provided by family members, and where farm tasks may be difficult to discern from leisure and off-farm activities, current summation-based methods of estimating farm labour may tend to undercount the labour inputs into agriculture and hence to overstate the average labour productivity of small farms relative to large farms or non-farm activities. Alternatively, if we believe that the summation-based measures are accurate, then self-reported measures of labour use probably overstate actual labour use and hence underestimate labor productivity on small farms.

In fact, where farming is essentially a full-time activity, the old aggregate measures may actually be a fairly useful measure of labour input. Individuals who are full-time farmers throughout the year should probably be understood as providing a person-year of farm labour. For many purposes, it is not clear that it is feasible or useful to break this down into a specific number of hours worked. Consider a farmer who wakes up in the morning listening to the farm report and the weather forecast on the radio, spends the morning cleaning out the grain store and setting traps for rats and other rodents that eat the grain, then travels in the afternoon to a farmer field day conducted by the local extension officer, stops at the agri-dealer to purchase medicine for the family cow, and returns home in time to feed the chickens and close them up in the hen house for the night. By the summation-based measures, this farmer has supplied zero hours of agricultural labour. It is surely more useful and more informative to say that this individual, as a full-time farmer, is supplying a person-day of agricultural labour.

A final note is that summation-based measures, which are typically linked to crop agriculture and plot-level activities, tend to overstate seasonal differences in agricultural labour use. Farming systems typically allocate a number of non-plot-level farming tasks to off-season parts of the crop calendar. This may include some animal agriculture activities (often not counted in summation-based measures) and many other non-specific farm activities and

rural household activities. Conclusions about the total labour use in agriculture and about seasonal patterns of labour slackness should recognize that summation-based measures tend to omit these activities.

2.6 Measuring inputs: intermediates

Many farmers in poor countries, such as those of sub-Saharan Africa, use few intermediate inputs. Some will purchase seed and/or fertilizer; for certain crops and contexts, other agricultural chemicals are used. The quantities and purchase prices of these intermediate goods are often recalled by farmers with a reasonable degree of accuracy. In this sense, there are fewer measurement issues than with land and labour. However, an increasing body of evidence suggests that farmers who purchase intermediate inputs do not necessarily get what they think they are purchasing (Ashour et al., 2016; Bold et al., 2017; Michelson, 2017). Analysis suggests that the quality, purity and composition of fertilizer and herbicide may differ from what farmers believe they are purchasing. In a similar vein, methodological survey experiments that have been supported by the CGIAR Standing Panel on Impact Assessment (SPIA) and that have tested the feasibility of using DNA fingerprinting for objective crop variety identification have revealed, in the context of a wide range of crops and countries, that farmers are frequently either misinformed or uninformed (Kosmowski et al., 2018).

Typically, intermediate inputs are included in productivity analyses either as controls (e.g. a binary dummy variable indicating whether or not a household reports using improved seed or fertilizer) or as measured input quantities or values. Either way, the measurement of these inputs will be important for productivity calculations. A plausible conjecture – not yet tested systematically – is that the problem of counterfeit or incorrectly labelled inputs may be a particular challenge for small farmers, who do not buy in bulk. Farmers who purchase small amounts of “fertilizer” taken from open bags may be more likely to get an adulterated product than those who can afford to purchase a whole bag in its original packaging. Similarly, larger farmers may be more likely to purchase seed from reputable dealers – again, sealed in original packaging – where small farmers may purchase seed from bulk supplies that are of lower quality. Even if there is no deliberate adulteration of the seed or fertilizer, these bulk supplies may have been stored with less care and may have become contaminated or diluted through oversight or poor management.

As a result, it is not unlikely that intermediate input quality varies between smallholders and large-scale farmers. If these conjectures are correct, they would tend to make smallholders appear less productive in terms of their effective use of inputs, and their profitability may also be negatively affected.

2.7 Measuring output

Measuring the physical output of agriculture ought to be straightforward, in the sense that the output is physically observable, potentially even in terms of quality as well as quantity. The gold standard for measuring crop output for cereal grains is the crop cut, in which grain is harvested, dried and weighed on a representative sample of plots, typically in randomly selected square subplots (e.g. 2 m × 2 m or 4 m × 4 m, but seldom larger than 10 m × 10 m). Even crop cuts have measurement issues, though: standard practice calls for

avoiding field edges, which may lead to non-representative measures on small plots that have proportionately large edge areas. More significantly, however, crop cutting is costly to administer on a large scale and difficult to implement in a survey. For instance, crop cuts necessarily need to take place at harvest time, which means that they must be carried out within a narrow window of time.²

The challenges to carrying out crop cuts on a large scale are compounded by the difficulty of measuring output on crops that are harvested continuously (e.g. vegetables such as tomatoes, or fruits) or intermittently and irregularly (e.g. cassava). For these crops, measures of yield must depend on the aggregation of harvest over some period of time – and then generalizing to a time period such as a year. This is a process that raises many more measurement questions. Should the output measures include, for example, the tomatoes that spoil on the vine and are never harvested by farmers? Should the cassava harvest be defined by what farmers actually harvest? Or by the quantities that they *could* harvest? What is the relevant measure for productivity? These are conceptual issues that do not have clear answers.

A similar set of concerns arises in relation to measuring yields from animal agriculture. For a few animal agriculture technologies, there are analogs to yield, in the sense that output can be measured consistently. For example, milk output is consistently weighed and measured. Meat production is more difficult to measure and is typically estimated based on the number of animals slaughtered and an assumption of meat offtake per head slaughtered. These coefficients obviously introduce a measurement problem in terms of quantifying output or productivity. For small stock, such as poultry, it is difficult to estimate even the quantity of animals produced or slaughtered; the same may be true for pigs. Other animal outputs, such as draft power, are much harder to quantify. What is the productive output of donkeys in East Africa?

Partly because of the difficulty, cost and limitations of these direct measures of agricultural output, a common practice in household surveys is to rely on farmer reporting of quantities produced. Self-reporting is based on some recall period. Farmers are asked about the quantities of different commodities that they have produced, typically both in physical output units and value terms. Although this is a relatively low-cost way to collect output data, there are numerous measurement concerns. One relates to the ambiguity of units. Farmers typically report production in bags or other units that may not be precise measures. Indeed, the same unit may translate into different quantities of more standard units (for example, kilograms) in different locations within a country. Farmer reports may also not account very carefully for differences in the moisture content or quality of output. Recall measures are also susceptible to a variety of recall biases.³

Recent research has shown that farmer recall is not only subject to a variety of errors, but may also be systematically biased across farm size (Desiere and Jolliffe, 2018; Gourlay et al., 2017). Comparisons of crop cuts with farmer reports suggest that small farmers may systematically over-report yield and production. Gourlay et al. (2017) find in data from Uganda that maize yields are systematically over-reported on small plots, as given by comparison of crop cut data with farmer self-reporting; the same result holds for a subset of plots where yield measures are based on measuring the entire plot harvest. Similarly, Desiere and Jolliffe (2018) find similar results in data from the Ethiopia Socioeconomic Survey on a large number of crops. Neither of these studies systematically deals with farm size; in both

2. Some of the challenges of implementing careful crop-cutting procedures are discussed in detail in Gourlay et al. (2017).

3. There are also issues with the non-standard measurement units in which production and consumption are often reported (Oseni et al., 2017).

cases, the finding is that farmers over-report yield on small *plots* rather than small farms. To the extent that small farms are characterized by small plots, these two papers support the finding that farmer self-reporting may overstate output and yield on small farms. It is worth noting that Gollin and Udry (2017) find a similar inverse relationship in the LSMS-ISA data between plot size and plot yield; but they also find that farmers report high labour-intensity on small plots – and, perhaps more surprisingly, that farms with more plots, holding total land area constant, display higher consumption expenditure, suggesting that small plots are in fact more productive than larger plots.

2.8 Prices

Productivity comparisons across space and time require some adjustment for price differences, and where farm households produce multiple outputs, it may also be necessary to use a common vector of prices (a “base price”) for aggregation purposes. There are numerous challenges that arise in measuring prices, in addition to the conceptual and theoretical difficulties that are well documented in the literature on index number theory. The theoretical literature tells us that relative productivities will, in general, be sensitive to the choice of prices used for these comparisons. Even the *ranking* of productivities may change with a different base price. In other words, under a particular base price, Farm A may appear to have higher productivity than Farm B, but under a different base price, the reverse may be true. There is no “correct” base price, and although there is an extensive literature suggesting different approaches to minimizing the problem (using, for example, chain weights or other price indices), these cannot make the underlying problem disappear.

Beyond the theoretical issues, however, there are also a number of measurement problems. Households are typically asked to state the prices at which they bought or sold different commodities. (They may instead be asked for both the physical quantities and the values; unit values are backed out from these two responses and are often treated as prices.) In practice, however, the answers given to these questions often result in unit value reports that vary wildly within communities, even for what appear to be identical crops. As a result, a common practice among researchers is to abandon these household-level “prices” and to substitute something like a community price. This is often estimated as the median unit value for a commodity that has been reported by the households in a community, although sometimes community prices are taken from separate market surveys. In either case, the end result is to create a potentially consistent bias across households. For instance, those households that are (in fact) farther away from a market or community centre will face higher input costs and lower output prices than those that are more central. Their optimizing choices will reflect this price structure. For instance, they will apply inputs (including labour) at lower levels of intensity than farms that face higher output prices and lower input costs. When these farms are compared, however, with a constant set of prices, the more remote farms will appear to be less efficient and/or productive. To the extent that remote farms tend to differ in size from farms that are in close proximity to markets, this will affect our perceptions of a relationship between farm size and productivity. It is not clear in which direction this bias will operate, however. In some contexts, remote farms will be small relative to those closer to community centres and markets – e.g. where remoteness limits commercial opportunities and leaves households in subsistence, and where “close” farms can take advantage of scale economies. In other contexts, however, especially where land in remote areas is less desirable and less

productive, remote farms may actually be larger. In either case, we must be aware of the ways in which remoteness affects measured productivity levels through price mechanisms. Note that these cases, the *true* physical productivity across farms may be identical. The point here is that using a constant set of prices for spatially dispersed households will affect *measured productivity* in ways that can create systematic biases.

2.9 Which productivity measure?

Much of the literature from agricultural economics and agricultural development focuses on crop yields (output per unit of land) as the key measure of productivity. Comparisons of large and small farms often rely on comparisons of the crop yields attained on farms of different sizes. For example, a common approach to assessing the inverse relationship between farm size and productivity is to regress crop yield on farm size (typically a measure of area), along with some vector of controls – typically in a linear or log linear structure. In more complicated settings, where farmers grow multiple crops, the dependent variable may be farm profits per hectare or even gross farm income per hectare. For many reasons listed above, we might worry about measurement and specification problems here that could lead to misleading results. But a different question is whether this is even the most useful or relevant measure of productivity for us to consider.

Outside the agricultural economics literature, economists tend to think about productivity primarily in terms of output per worker, or output per unit of labour (i.e. average labour productivity), or, better still, value added per worker. Average productivity is seen as having some relationship to income, since, in many environments, the marginal product of labour will be closely related to the average product. The average product of labour is a useful indicator of how much value a typical worker produces, with that value presumably being shared between workers and the suppliers of land and capital. For this reason, labour productivity seems like a more useful measure than land productivity.

In general, the same factors that Sen (1962) identified as leading to the inverse relationship – namely, the tendency in an environment of poorly functioning land and labour markets, for smallholder farm families to use family labour at very intensive levels on their limited landholdings – will lead to high crop yield but low output per unit of labour on small farms. This result is, in some sense, just an arithmetic corollary to the inverse relationship between yield and farm size. But where yields vary relatively little across farms of different sizes, labour productivity can vary enormously, due in particular to the substitution of capital for labour. The key insight here is that land per unit of labour varies tremendously across countries – far more than output per unit of land. Mechanization is the key factor driving the differences in land per unit of labour. Where farmers work only with hand tools, there is a biophysical limit to the amount of cropland that a single person can productively cultivate.⁴ But animal traction – and, even more so, mechanical power – can extend this limit.

A third measure of productivity, beloved by economists but somewhat less transparent for non-economists, is total factor productivity (TFP). This is a measure of output per unit of total inputs. The idea here is to see how output varies in relation to changes in multiple inputs. For instance, an increase in the use of capital will, in general, lead to an increase in output per unit of land and a similar increase in output per unit of labour. But economists

4. Where land is abundant, the way to extend the spatial scope of farming is through reliance on livestock – especially ruminants – which can graze a large area under the supervision of a single herder. This allows agricultural households effectively to bypass the limits of scale that they would face in crop farming.

would still tend to visualize this as an increase in output that is driven by an increase in inputs. Comparing output across two farms, or two moments in time on the same farm, a TFP measure would seek to assess how much change there is in the output per unit of total inputs. This measure has a useful interpretation as a pure productivity gain. We expect to see TFP increases from improved technologies – or, similarly, from improvements in efficiency. TFP increases have a parallel interpretation as decreases in the unit cost of production; a TFP increase is essentially a change that allows us to produce the same output with fewer inputs (and therefore at lower cost).

There are many challenges, however, to measuring TFP growth. One is that TFP measurement requires highly accurate and detailed measures of all inputs and all outputs. It is thus a data-demanding measure. In many contexts, the data are not available at a sufficient level of detail to provide accurate TFP estimates. A second problem with TFP measurement is that it requires the economist observer to know with confidence the way in which different inputs are combined to generate output. Because TFP is, in a sense, based on a comparison of an output index to an input index, it is quite sensitive to the construction of the two indices. Most economic analyses construct measures of TFP (or change in TFP) by assuming knowledge of the specific production function. However, production function estimation is itself a challenging exercise, and TFP calculations may be quite sensitive to the assumed specification and functional form. Comparing TFP across farms of different sizes – whether within countries or across countries – is also subject to the concern that the production function itself is likely to vary across farm size categories. When we compare the TFP of a large mechanized farm in the United States or France with the TFP of a small semi-subsistence farm in Mali or Mozambique, it will be difficult to disentangle the technological differences from the massive disparities in inputs. Figuring out which farms are more productive (in TFP measures) may be quite challenging in the face of such enormous variation.

3 Farm size and productivity: data and patterns

In this section, we leave behind the conceptual issues and the practicalities of measurement to discuss some of the recent evidence on farm size and productivity. There is a rich recent literature on this topic, both from the macro and micro perspectives.

3.1 Cross-country

We begin by looking at the cross-country differences in crop agriculture productivity and overall agricultural productivity. This is a topic explored recently by Adamopoulos and Restuccia (2014) and Gollin et al. (2014a, 2014b), among others. Even a cursory analysis suggests that the big differences in crop agriculture across countries come from differences in farm size.

To see this, consider **table 1**. This shows the available hectares of arable cropland divided by the economically active population in agriculture for countries at different levels of income per capita. The top 10 per cent of countries in the income distribution have approximately 30 times more cropland per worker than the poorest 10 per cent of countries. This does not reflect a difference in natural endowments; instead, it reflects the fact that far fewer people work in agriculture in rich countries.

Next, consider the differences across countries in output per unit of land for major grain crops. **Table 2** shows that for rich countries, yields of the major grain crops are 2.5 to 4.7 times higher in the world's richest countries compared to the poorest.⁵ The resulting differences are large, to be sure, but these differences pale in comparison to the differences in land per worker. A similar finding comes from analysis of cross-country micro evidence in Adamopoulos and Restuccia (2018).

Table 1 Land per agricultural worker by country income group

	Hectares per worker
Top 10 per cent of global income distribution	44.6
Top quarter of global income distribution	23.9
Bottom quarter of global income distribution	1.3
Bottom 10 per cent of global income distribution	1.4
Ratio of top to bottom 10 per cent	31.2
Ratio of top to bottom quarter	18.0

Notes: From FAOSTAT. Land is measured as hectares of arable land.

5. The comparison here is based on the top decile of countries in the world income distribution and on the bottom decile.

Table 2 Physical productivity of staple grains by country income group

	Average yield (tons/ha)		
	Maize	Rice	Wheat
Top 10 per cent of global income distribution	9.2	8.1	4.9
Top quarter of global income distribution	8.2	6.8	4.8
Bottom quarter of global income distribution	2.4	3.2	2.1
Bottom 10 per cent of global income distribution	2.0	2.9	2.0
Ratio of top to bottom 10 per cent	4.7	2.8	2.5
Ratio of top to bottom quarter	3.4	2.1	2.2

Note: Data from FAOSTAT.

Taken together, these data imply striking differences across countries in output per unit of labour. Whereas crop yields are moderately higher in rich countries than in poor ones, the physical units of crop output per unit of labour are massively higher. Consider **table 3** and **table 4**, which show the differences in output per hour worked – where output is measured in physical units of production (rather than value) and labour is measured carefully in hours (rather than in person-days). We can do this for a number of settings in which the data can be consistently compiled. The remarkable finding is that output per hour of labour effort varies by a factor of more than one thousand (for maize) and around five hundred (for rice). Output per hour is consistently higher in settings where farm sizes are large, presumably reflecting both the differences in production technology and the capital intensity of production.

Table 3 Maize output per hour worked

Country	Year	Yield (kg/ha)	Hours	Output (kg/hour)	Source
Kenya	1997	908	963.9	0.9	Suri, 2011
Kenya	2004	1 415	1 164.3	1.2	Suri, 2011
Malawi (1)	1989-90	745	306.0	2.4	Smale et al., 1995
Malawi (2)	1989-90	1 264	348.0	3.6	Smale et al., 1995
Malawi (3)	1989-90	2 774	372.0	7.5	Smale et al., 1995
Malawi	1995-2000	1 342	504.0	2.7	Edriss et al., 2004
South Africa	2003-04	1 060	249.0	4.3	Gouse et al., 2006
United States	2001	8 473	6.3	1 318.9	Foreman, 2001
United States (Iowa)	2011	10 395	7.0	1 470.6	Plastina, 2017

Notes: (1) local varieties unfertilized; (2) local varieties fertilized; (3) hybrids fertilized.

Table 4 Rice output per hour worked

Country	Year	Yield (kg/ha)	Hours	Output (kg/hour)	Source
Java†	1875-78	1 600	1 350	1.19	Barker et al., 1985
Java‡	1875-80			0.66	Van der Eng, 2004
Java†	1920-30	1 800	1 224	1.47	Barker et al., 1985
Java†	1968-71	2 700	948	2.85	Barker et al., 1985
Java†	1977-80	3 700	864	4.28	Barker et al., 1985
Java‡	1987-92			3.15	Van der Eng, 2004
Burma†	1930s	1 548	282.6	5.48	Barker et al., 1985
Thailand (northeast)†	1960s	1 321	339	3.90	Barker et al., 1985
Sri Lanka (Kurunegala)†	1972-73	2 917	972.6	3.00	Barker et al., 1985
Philippines (central Luzon)†	1974-75	2 449	489.6	5.00	Barker et al., 1985
Taiwan (central)†	1926-27	2 500	576	4.34	Barker et al., 1985
Taiwan (central)†	1936-37	3 100	756	4.10	Barker et al., 1985
Taiwan (central)†	1961	4 100	828	4.95	Barker et al., 1985
Taiwan (central)†	1972	5 200	504	10.32	Barker et al., 1985
Indonesia (E. Kalimantan)*	1980-85	2 020	1 110	1.82	Padoch, 1985
Nigeria (upland)	2002	1 900	1 284	1.48	Erenstein et al., 2003
Nigeria (lowland)	2002	1 700	936	1.82	Erenstein et al., 2003
Nigeria (semi-irrigated)	2002	3 700	1 350	2.74	Erenstein et al., 2003
China (Zhejiang)	1998	6 820	1 074	6.35	Huang et al., 2000
Bangladesh	2000	5 630	726	7.75	Husain et al., 2001
California (Sacramento Valley)	2015	9 527	11.2	850.6	Espino et al., 2016
United States††	2000	7 734	11.1	696.8	Livezey & Foreman, 2004

Notes:

† Assumes six hours per day of labour.

‡ Assumes eight hours per day of labour.

* Assumes six hours of labour per day; uses an approximate midpoint for the estimated labour use of 178-192.5 person-days; p. 282.

†† Data for mid-cost category and actual (rather than expected) yield.

Consider the simple decomposition of average labour productivity into two components: crop yield (output per unit land) and labour intensity (land per worker):

$$\frac{\text{output}}{\text{worker}} = \frac{\text{output}}{\text{land}} \times \frac{\text{land}}{\text{worker}}$$

The data suggest strongly that the differences in land per worker dwarf the differences in labour intensity. Yields differ by a factor of six, at the maximum. But hours worked per unit of land (i.e. the inverse of land per worker) vary by a factor of several hundred. The central lesson is that an understanding of productivity differences across countries needs to address the differences in land per worker – which reflects a combination of farm size, capital-labour substitution, land market institutions and other factors. Data on average farm size across countries give a clear picture: the overwhelming pattern in the cross-country data is that rich countries have both higher productivity (by almost any measure) and larger farms. But is this relationship causal? The same relationship could simply reflect differences in (relative) land abundance. To the extent that rich countries also have access to better technologies and/or more capital, the relationship might also reflect simply a complementarity between abundant land and these improved technologies.

The cross-country data are thus highly suggestive of a relationship between farm size and productivity per unit of labour. This relationship may not be direct, and it may not be fully causal. But it is not difficult to understand that where farmers command larger amounts of land – and have access to both the capital and the technology to use it productively – they are able to produce more output per worker. The question becomes simply whether the land rents are sufficient to make capital investments (such as mechanization) profitable.

3.2 Within country

In comparisons of farm size within countries, long-standing literature has supported the notion that there is an inverse relationship between farm size and productivity in developing countries. This literature has been extensively surveyed, including in a useful critical review by Eastwood et al. (2010). Following Sen (1962) and the near-contemporaneous work of Mazumdar (1965), a large literature documented an inverse relationship across numerous within-country studies in Asia and Latin America. Numerous theoretical explanations for the relationship have been advanced and discussed, for example, Barrett (1996), Barrett et al. (2010), and Feder (1985).

The general approach in much of the literature has been to look for evidence of the inverse relationship in data collected across farms, often within relatively narrow geographical areas, but occasionally in nationally representative data. The usual empirical approach is to regress yield on farm size, including a number of controls. A statistically significant negative coefficient on farm size is then interpreted as evidence for the inverse relationship. A problem here is that farm size itself may be endogenous (e.g. to land quality) so that farm size may be small precisely where the land is most productive. If so, the yields may be high on small farms because of land quality differences – not because of farm size. Concerns over the econometric identification of this relationship have been expressed since Carter (1984). A further set of concerns have been raised for many years over measurement error,

heterogeneity and other issues limiting confidence in the empirical findings. In a literature dating back more than twenty years, researchers have expressed concerns that the apparent inverse relationship within country is an artifact of measurement errors of various kinds; see, for example, Benjamin (1995), Mundlak (2000), or Assunção and Ghatak (2003). Newer literature, much of it focused on African farms, has also challenged the inverse relationship, citing measurement problems in farmer-reported production and yield relating to farmer reports of land area, yield and other variables, for example, Gourlay et al. (2017), and Desiere and Jolliffe (2018).⁶

Even where the relationship shows up in a statistically significant fashion, it may be too small to be economically very meaningful. Variation in observables does not typically account for a very large fraction of yield differences across plots or farmers. Gollin and Udry (2017) show for three African countries (Ghana, Tanzania and Uganda) that the dispersion of measured plot yield around the mean is wide even after controlling for a very large set of plot characteristics and household observables. Indeed, they find large variation even across plots of the same crop, farmed by the same individual, in the same season. This suggests that yields are highly sensitive (as, indeed, any farmer knows) to weather shocks, pest shocks and idiosyncratic variations in the production environment; in addition, measurement error introduces another source of dispersion in yield.

A major concern is with the failure of the data to capture in any adequate sense the *change* in productivity that one might expect to observe if existing small farms were consolidated into larger farms. Such changes would presumably be accompanied by corresponding changes in the technology and capital used in production. But we do not generally observe what happens to the productivity of agriculture under conditions of changing farm size. Moreover, many of the existing within-country studies tend to sample existing farms. This approach ends up comparing tiny farms with those that are only slightly less tiny. Much of the literature focuses on these kinds of comparisons, often between farms that are between 0 and 5 hectares in size. It may be the case (and probably is) that the smaller farms have higher crop yields. But the real question that we care about is whether there is a consequential loss in productivity as farm size increases in a qualitative sense – from 1 hectare to 10 hectares or even 100 hectares. The within-country data say little about these differences in most developing countries.

3.3 Discussion of patterns

The patterns that emerge are relatively clear. There seems to be – at low levels of farm size – a relatively clear inverse relationship between farm size and crop yield, although this does not typically hold when we switch to measures of labour productivity instead of land productivity (Fan and Chan-Kang, 2005). These patterns hold at quite low levels of farm size, but they subsequently disappear with larger farm sizes, as evidenced by the increasing upward trend in farm size in the United States and European Union. They also do not hold for studies that use crop cuts to measure yield. Foster and Rosenzweig (2011) describe a U-shaped relationship between farm size and productivity that applies, when a much larger range of farm size is included in the analysis. On this basis, Foster and Rosenzweig (2011) estimate that the scale of farming in India is inefficiently small, with far too many small

6. Bevis and Barrett (2016) point to another potential source of measurement error in productivity, related to “edge effects.” They argue that farmers may be more likely to farm intensively (leading to higher yields) on those plots with a high ratio of edge to area. Since farmers tend to walk around the perimeter of their fields, they are more likely to notice problems and to respond to them if the problems are easily visible from the edge of the plot.

farms operating, given the potential scale economies through mechanization. Their work points out the value of looking at farm size in contexts where the support of the farm size distribution is quite wide and where commercially oriented farms can be seen operating at different scales, using different technologies.

One striking finding is that the variation in yield due to farm size is relatively small. Yields differ by a factor of around two between the lowest-yield and highest-yield farm sizes in India. This is not a trivial difference, but the corresponding differences in profits are almost certainly smaller. This means that farm size is not a particularly major determinant of yields. Within-country variation in yields is heavily due to location-specific factors (such as those captured with community fixed effects), whereas observable land and farm characteristics have relatively low explanatory power. This suggests that a focus on farm size as a source of yield gains and losses may be misplaced. What is abundantly clear, however, is that there are very large differences in *labour productivity* in relation to farm size. The overwhelming finding here is that large farms generate higher average labour productivity than small farms, perhaps unsurprising given the arithmetic relationships. Thus, any focus on farm size should pay attention to the labour productivity differences across the size distribution, or perhaps the profitability of farms of different sizes, rather than to yields.

4 Policy implications

Government policies around the globe have long targeted farm size for a variety of issues relating to efficiency and equity. Eastwood et al. (2010) survey the range of policies, which range from support for consolidation of farms (e.g. in places where land fragmentation is perceived as a problem or a barrier to the take-up of new technologies) to programmes of land reform and redistribution that are intended to limit the maximum farm size. We consider these briefly here.

4.1 Distortions to land markets

At present, one of the most significant areas of land policy relates to titling and tenure security. This has been a significant area of focus for international institutions in recent years. An extensive literature addresses the conjecture that formal land titling may be a necessary condition for increasing investments in land and the efficient allocation of land. On the first point, there is a sense that titling encourages farmers to feel secure in their ownership rights and thereby incentivizes them to make long-term investments in productivity; see, for example, Besley and Ghatak (2009), Galiani and Schargrodsky (2010), Ali et al. (2011), Deininger and Feder (2001), Deininger and Jin (2006), and Jacoby et al. (2002). Evidence of a relationship between tenure security and productivity also emerges from analysis of informal institutions, for example, in Goldstein and Udry (2008). A general finding of this literature is that tenure security does have a positive impact on long-run investments in land quality (e.g. in the use of trees and in measures that promote long-term soil fertility), but not much impact on short-run productivity. There is little evidence that formal land titling is essential for tenure security, however. Many farmers with informal tenure appear to feel highly secure, and in some cases titling may actually create threats to tenure security.

Restrictions on land sales and rentals, and on the maximum size of farm holdings, have the potential to be far more significant. A number of recent papers have examined the aggregate cost of misallocations created through restrictions of this kind, for instance, Adamopoulos et al. (2017), Adamopoulos and Restuccia (2015), and Restuccia and Santaella-Llopis (2017). A particular concern is that restrictions on the maximum size of farms may have the effect of taking land away from the management of particularly efficient farmers and de facto reallocating it to less efficient farmers. Quantitatively, the analyses mentioned in this paragraph find large impacts of the efficiency losses that result, with agricultural gross values reduced by as much as two thirds or three quarters in some contexts. Papers in this literature acknowledge that there may be equity goals of policies that restrict farm size or that otherwise limit land transactions. But it is clear that there can be real efficiency losses from such policies. It is important to note that in many cases, the inverse relationship has

been invoked as a potential justification for placing limits on maximum farm size. But if this inverse relationship is questionable, then this particular claim – of an efficiency bonus accompanying the equity benefits of land reform – may be flawed.

It is worth noting that Gollin and Udry (2017) argue for caution in applying the methods used in some of the analyses, and they also question some of the more extreme results. But there is no question that land market failures represent a potentially important source of inefficiency in agriculture, and the costs of this inefficiency may be large; see, for example, Foster and Rosenzweig (2011, 2017).

5 Conclusions

To summarize, small farms remain a ubiquitous feature of the agricultural economy, even in rich countries with active land markets. Small farms will not disappear from the agricultural landscape any time soon. Particularly where there are market niches that make sense for small farms to exploit (e.g. specialty markets) or opportunities to produce high-value outputs on small spatial footprints (e.g. horticultural crops), small farms will persist. They will also persist in locations where off-farm employment opportunities are good and where farming can become a part-time source of employment, or as an additional source of livelihoods for semi-retired people or those who enjoy rural lifestyles. In developing countries, the sheer momentum of rural population growth will drive shrinkage of average farm size, given the limited supplies of agricultural land. Many of the world's poor are small farmers, and for this reason, too, smallholder agriculture will necessarily remain at the centre of development strategies and programmes for many decades to come.

The pertinent question for policy is not whether development strategies need to recognize the existence and persistence of small farms; it is, instead, whether strategies based on smallholder agriculture offer a particularly valuable way to generate agricultural development. There are surely equity reasons to focus on smallholders – for poverty reduction, for food security, for employment, and for nutrition. Given the likely long-term trajectories, in which hundreds of millions of poor (and marginally non-poor) people are likely to remain in smallholder agriculture for many decades, these are sufficient reasons to take smallholder agriculture seriously. There are also reasons to focus on smallholder agriculture because of the vulnerabilities of people supported by these farms to climate change and other environmental stresses – and also because of the importance of smallholder activities for the sustainable management of natural resources and the environment. The world's future will be affected deeply by the ways in which smallholders manage land and soil, trees and water, and genetic diversity and wildlife, to name a few of the resource issues that arise.

The more challenging question, however, is whether smallholder agriculture offers long-term solutions to poverty, or whether on the contrary it may be a source of persistent poverty. A related question is whether national and international agricultural futures should be encouraged or incentivized to focus on smallholder agriculture and to resist or limit the emergence of large-scale agriculture. These issues relate to perceptions of the productive potential of smallholder farming. To the extent that the inverse relationship holds – i.e. that small farms are more efficient or more productive than large farms – this relationship could be seen as supporting the idea that future agriculture should be channelled into smaller farms. This paper argues that an accumulating body of evidence challenges the quantitative importance and policy relevance of the inverse relationship – even if there remains some support for the inverse relationship in a qualitative sense. By this, I mean that there may be

evidence that yield is slightly negatively related to farm size over some range. But yield is not necessarily the right measure to use in thinking about farm income or productivity. The evidence is very strong – and has never really been contested – that output per unit of labour rises quite consistently with farm size. This is surely the point that is relevant for discussions of farm size, both in a positive sense and in a normative sense.

In the long run, the incomes of the poor depend on the returns to the factors of production that they control. These are essentially labour, land and capital. Labour has two components: raw labour and skill. Land has (perhaps) three components: area, quality and location. Most smallholders have relatively low skills and little capital. This means that their incomes will normally be determined by the amount of land that they farm and the quality and location of their land. There is not much potential for increasing the income of farmers, in an absolute sense, by increasing the output of one or two hectares of relatively unimproved land. There is some scope to improve the quality of land. And some farmers will be lucky as to location. For a relative handful of the world's smallholders who live in prime locations, there may be huge location rents to be earned – either from selling their land for housing or other non-agricultural purposes, or from taking advantage of a market niche that is related to location. For instance, being well connected to urban markets may allow farmers to switch from staple grain production to high-value animal, dairy or horticultural production, all of which might allow them to earn good livings from small landholdings. Some smallholders will similarly win the agroecological lotteries that allow them to produce commodities with very high returns and limited geographic domains – wine, or truffles, or avocados, or poppy. But for those farmers unlucky enough to have little income from location rents or quality rents, a smallholding will not – and arithmetically cannot – earn a middle-class living. Two hectares of maize and cassava cannot, regardless of yields, produce enough income to afford a farmer the same living standard that will accrue to an urban worker. The inevitable (positive) consequence of this is that people will leave smallholder agriculture as opportunities emerge in other sectors for more productive work. In other sectors, their labour can be matched to reproducible capital, which can grow over time, rather than to land which is fixed. This is the long-run experience of economic growth through capital deepening.

The movement out of smallholder agriculture may take decades, and as noted above, it does not mean that the sector should be ignored or smothered. As Keynes notably said, in the long run, we are all dead, but this is not a reason to smother those who are living. Smallholder agriculture can – to some extent – be made more productive and more efficient. But it may also be sensible to think about policies that reduce the frictions to mobility out of smallholder livelihoods. This may involve measures that support the working of formal or informal land markets, reduction in barriers to land consolidation, support for internal migration, attention to the rural non-farm sector, and a myriad of other activities. Many types of public investments in rural areas may also be valuable: rural roads and infrastructure, irrigation and electrification, and public administration in various forms. As pointed out, traditional agriculture is generally efficient, given the constraints and resources and technologies that farmers face. Improving the well-being of smallholders will require changing their constraints and technologies, since land and capital resources are difficult to increase. Schultz (1964) would also have emphasized the importance of investing in people, and here, too, the lessons remain valid. Investing in smallholders will in many cases imply preparing young people to leave agriculture and to compete effectively for jobs in other sectors – and possibly in other

locations. It is not that young rural people will all become computer programmers; some of the preparation that they will need is not “hard skill” so much as it is information and “soft skill.” Interesting work points to the importance of aspirations, beliefs in self-efficacy and other behavioural attributes.

Supporting movements out of smallholder agriculture does not imply undermining or diminishing those who remain. Smallholder farmers should be recognized for the value that they contribute to society and for the work that they do. It cannot help to refer to smallholders as backwards or unproductive – a language that persists disturbingly in many policymaking circles. The overwhelming evidence is that smallholders do a reasonable job of optimizing their choices under extraordinarily difficult conditions. But the reality is that smallholder livelihoods, in most locations and for most farmers, will be very limited. Smallholder agriculture can produce more commodities in developing countries, but it is not clear that it can produce middle-class incomes, except where the smallholdings win a geographic lottery that allows farmers to take advantage of rents to land quality or location. Alternatively, smallholder farming can produce middle-class incomes in contexts where large capital investments are available to farmers. These change the game by enabling farmers to produce very intensively on small spatial footprints. But these exceptions will sadly not apply to most smallholder farmers in sub-Saharan Africa and South Asia. For them, smallholder agriculture will remain a fact of life, rather than a development strategy or a growth strategy.

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