Environmentally-Adjusted Total Factor Productivity: the Case of Carbon Footprint

An application to Italian FADN farms

Keywords: Total Factor Productivity, GHG emissions, FADN

Abstract

Agricultural production growth can be generated in two ways: increasing productivity or increasing resources input (land, irrigation or input intensification per hectare). Though it played a major role over the last century, the latter solution does not seem viable without incurring major environmental consequences. Therefore, in the long-term the increase of agricultural productivity should be regarded as the only feasible response to the increasing global food demand also because a more efficient use of agricultural inputs saves resources available for the non-agricultural sectors of the economy and is consistent with environmental requirements. As matter of fact, over the last decades the strong increase of agricultural productivity, arising from innovation and changes in technology, has been already recognized as the most important source of growth of agricultural supply (OECD, 1995; 2011a; 2011b; Latruffe, 2010; Fuglie, 2012). Recently, however, several studies and authors have pointed out that in many developed countries (USA and EU, in particular) agricultural productivity growth started slowing down while, on the contrary, the larger contribution to the constant productivity gains worldwide actually now comes from developing or emerging countries (Fuglie, 2012).

The need for a new impulse to productivity growth in western modern agricultures was one of the motivation that led the European Union (EU) to launch the EU Innovation Partnership for Agricultural productivity and Sustainability (EIP-AGRI) in 2012 (European Commission, 2012). EIP pursues the mission of building a bridge between science and the practical application of innovative approaches, with the aim of addressing the most fundamental challenge faced by European agriculture in the early 21st century: how to increase production in order to respond to the significant growth in global food demand while preserving natural resources and the environment.

Despite this political intentions, assessing to what extent EU agriculture is really moving along this innovative path and, therefore, to what extent EIP-AGRI can really contribute in this direction of, at once, higher productivity and higher sustainability (i.e., better economic and environmental performances), remains a complex methodological challenge. Productivity gains are typically

measured as Total Factor Productivity (TFP) growth (OECD, 2001; European Commission, 2013). TFP measures the ratio of total commodity output (crop and livestock products) to total inputs used in production (i.e.: land, labor, capital, and materials). TFP improves when total output is growing faster than total inputs. Hence, an increasing TFP implies that more output is being produced from a given bundle of agricultural resources (Fuglie, 2012). However, a major drawback of conventional TFP measures is that they only account for those inputs and outputs for which there are observable market transactions, while non-marketable resources or outputs (e. for goods, or "bads", which private markets do not exist or are poorly functioning), are not accounted for. This could lead to a systematic bias in productivity calculations and incorrect policy conclusions, mostly for the agricultural sector, which has a peculiar relationship with non-marketable goods (OECD, 2010). Among these non-marketable goods we should consider, on the input side, the use of natural/environmental resources by agricultural activities, and, on the output side, the production of environmental damages (e.g., pollution).

These environmental effects can be captured and measured by appropriate environmental indicators that accompany the conventional economic indicator (TFP) to provide a multivariate/composite representation of the combined economic and environmental performance of agriculture. However, as the EIP-AGRI views productivity and environmental sustainability as an unique major objective for the EU agriculture of next decades, it would particularly helpful to have an unique indicator of these joint performances. This can be achieved with an Environmentally-Adjusted TFP (EATFP). In principle, such an EATFP is considered one of the key indicators for monitoring progress of green growth in agriculture (OECD, 2014). In practice, achieving a proper, viable and largely agreed measure of the EATFP is still empirically challenging.

One possible way to meet this challenge is to rely on the concept of joint production. Negative (undesirable) externalities associated to agricultural production (from groundwater and air pollution to biodiversity loss) are disregarded in conventional TFP calculations while, on the contrary, costs incurred to reduce them or mitigate their effects are entirely taken into account resulting in a misleading representation of agricultural performance and technological level. However, incorporating environmental effects in traditional TFP measurements involves challenges of both conceptual and practical nature, such as the availability of data (for instance, the lack of market prices for these environmental goods) and the proper representation of production technology incorporating these non-conventional goods.

In the theoretical and empirical literature produced on this topic so far, three different approaches are put forward to measure such EATFP: treating pollutants as an additional input or undesirable output variable (environmentally adjusted production efficiency models); the frontier eco-efficiency models; and the materials (nutrients) balance-based models (see Tyteca, 1996; Allen, 1999; Scheel, 2001; Zhou et al., 2008, for a review of this literature).

The main objective of the present paper is to explore and illustrate the feasibility of such EATFP calculation in the specific case of Italian agriculture. Among the several environmental implications (and negative externalities) that could be taken into account in performing this calculation, here the emphasis is agricultural (farm-level) emission of greenhouse gases (GHG), here considered as a a joint badput (or negative output) of some agricultural activities. The choice of this kind of environmental externality is made both for the relevance of the climate change mitigation objectives in the international (Gerber, 2013) and EU arena (both for climate and agricultural policy: European Commission, 2011 and 2012; European Council, 2014) and for the well-established international criteria and protocols to achieve a proper-farm level indicator of this environmental performance, the farm-level Carbon Footprint.

Agricultural GHG emissions are reconstructed at the farm level for the balanced sample of Italian FADN farms observed over years 2003-2007. Official UNFCC/IPCC (IPCC, 2006) methodology is here adapted and applied using country-specific emission coefficients (ISPRA, 2013), when available, to reconstruct methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) at the farm level (Coderoni *et al.*, 2013; Coderoni and Bonati, 2013). One of the novelty of the approach is the use of farm-level/micro data to reconstruct GHG emission from the following source categories: livestock production, crops, land use, fuel and fertilizers. These different farm-level GHG emissions are then summarized into a unique indicator, the farm Carbon Footprint. This non-conventional output (which is, in fact, a negative output) can be then included in farm-level EATFP calculations.

The EATFP performance is thus observed across the FADN balanced sample and compared with the conventional TFP measure to highlight the main differences. Possible determinants of these differences are also investigated by comparing such performance across farms' typologies, specializations and sizes, as well as across regions. Results indicate that the adjustment of the traditional TFP growth measure when the environmental performance (GHG emission, in this case) is considered may be relevant under specific circumstances.

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