1. Background on the TFPEN Network

1. The OECD launched a Network on Agricultural TFP and the Environment in 2017, where experts gather together to share experiences and best practices, and aim to develop a framework for cross-country agricultural TFP comparisons. While traditional total factor productivity (TFP) indicators measure the ability to use less input to produce a given quantity of output, "environmentally-adjusted" TFP or "EATFP" also accounts for the fact that, keeping the level of input and output constant, a reduction in negative externalities, or an increase in positive externalities or non-marketed public goods, also results in an improved performance. The ambition is to incorporate environmental sustainability into the measurement of agricultural country performance, and, in due course, create a set of sustainable productivity indicators.

2. An important part of the network's activities has been to develop an approach that countries can use to construct productivity accounts for the measurement of agricultural TFP and EATFP trends. The OECD acts as a co-ordinator and facilitator to help convene people with common interest. The Network promotes and develops analytical approaches to key issues already identified such as land input and climate change. The agendas and summary records of the meetings can be found at http://oe.cd/eatfp. Its first output was planned to be the development of methodological and practical guidance specific to TFP and EATFP measurement in agriculture.

3. The book Insights Into the Measurement of Agricultural Total Factor Productivity and the Environment was published in June 2022. It builds on the OECD "Measuring Productivity" Manual and the existing international guidance such as the UN System of Environmental Economic Accounting (SEAA) that contains an agricultural component as a starting point. The book is a combined collection of the work undertaken by the Network and proceedings of its meetings, with each chapter or annex authored by a member of the Network. The content is under the responsibility of the authors, with the OECD having played the role of facilitator. Based on the work by the Network, the OECD's Joint Working Party of Agriculture and the Environment also published a non-technical document for policy makers: Agricultural Total Factor Productivity and the Environment: A guide to emerging best Practices in Measurement.

2. Objectives of the 7th meeting

4. The Declaration on Transformative Solutions for Sustainable Agriculture and Food Systems adopted on 4 November 2022 on the occasion of the Ministerial meeting of the OECD Committee for Agriculture, called the OECD to facilitate robust and comparable measurement of sustainable agricultural productivity growth. The next meeting of the TFPEN Network will take place on 5-6 December 2022 in Paris. The possibility of hybrid participation is envisaged. This will be a great opportunity to relaunch the social capital of the network and give new momentum and dynamics to our work. In particular, it will allow to define the priorities and a roadmap for the Network responding to this demand from Ministers. The Network will continue working in the following areas:

- Sharing methodologies and experiences on agricultural TFP measurement with a particular emphasis on incorporating environmental issues: sustainable productivity growth.
- Defining guidelines or references for international comparisons of productivity and sustainable productivity performance.
- Undertaking and promoting policy relevant analysis on sustainable productivity growth.

This document, as well as any data and map included herein, are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

3. Summary Record of the 7th meeting

Participation

5. The 7thº meeting of the Network on Total Factor Productivity and the Environment (TFPEN) took place on the 5-6 December 2023. The meeting was hybrid with 32 participants in person in Paris and another 60 virtually, including breakout sessions. Participants were experts and delegates from 17 different countries. The background of experts was broadened to include not only production economist and TFP experts, but also environmental economists and specialist on index numbers. The discussion was rich because of the diversity of perspectives.

Session 1: Stocktaking and priorities for measuring sustainable productivity

6. **Marion Jansen**, Director of Trade and Agriculture in OECD, provided the introductory remarks. The basic goal here is to do more with less to address the world challenges. OECD Ministers have asked the Secretariat to put together indicators of sustainable TFP. It is already a difficult task to measure productivity growth and to agree on comparable measures. Now there is the extra challenge of defining indicators that account for environment. There is nevertheless a urgent need to do so and there are high expectations on the work of this network

1.1 Defining the issue

7. **Spiro Stefanou** (Administrator of the Economic Research Service of USDA), highlighted that the ministerial meeting brought up the issues with TFP growth. What are the issues at stake for measuring sustainable productivity growth? Food security and improving global food availability among others. What is the value of TFP growth? Competitiveness, nutrition, allocation of inputs including land use. What do we need to measure and how? What are the indicators that allow to adjust for environment?

8. The U.S. is interested in sustainability with economic and social dimension, is there an agreement across countries. How can we generate sustainable TFP indices that are applicable across all countries? There are significant data issues including cross country comparisons. This is why we need to work on a consistent database of natural capital accounts, which raises the challenge of measuring environmental assets. The selection of assets, the consistency across countries are challenges. How do we make this useful for policy makers? The first target is to minimize the impact on environment. The second target is to foster growth. This is not necessarily a zero sum game, there are potential win win situations. Agriculture science is crucial but creative economics is also important, we need new instruments, new markets.

9. **Pierluigi Londero** (Acting Director. Directorate for Strategy and Policy Analysis. DG Agri) argued that TFP does not appear as an important indicator for policy makers compared to the role that is given to productivity by academics. From past experience in the EU, one can think of several possible explanations. First, skepticism regarding how a global indicator can tell you something on sectors that are that heterogeneous. Agriculture is complex, how can we make use of a simple indicator, and doesn't it simplify too much? Furthermore, some measures are already hardly comparable (e.g. measurement of labour). TFP combines difficulties in making data comparable

10. Second, ignorance of policy makers regarding the meaning and usefulness of TFP. Even though productivity is a ratio it is politically connotated as "producing more" and has had a bad press for that (especially in the years of overproduction in the 1980s). Productivity is associated in the general public to unsustainable practices, and to benefits for the few. Additionally, it takes time to collect data for meaningful TFP series. And TFP growth is influenced by past R&D. Policy

makers get the results of efforts from the past, but have little incentive to engage in efforts that will benefit their followers. These points should be considered when designing indicators that are of interest for policy makers.

11. **Jared Greenville** (Executive Director ABARES, Australia), tried to answer the question of What do policy makers need? Policy is moving much faster than methods/data is. Being able to keep up with those demands is going to be a major challenge. What has productivity been used for? Impact evaluations on policy changes, targets or aspirational variable, and measuring adjustment. In order to include sustainability in productivity measures, we need to consider consumer-led demands around sustainability communication. Trading relationships are following rapidly and are demanding a clear ability to communicate environmental sustainability. Finally, there is demand for improving accountability in policy programs.

12. Where can we move from here? A focus on inputs has led to a loss of effectiveness in communication in TFP/sustainability outcomes. We need to build from the less complex to the more complex. A mixed methods approach may be a good starting point. For example environmental accounting is a set of methods that are being developed with drastic shortfalls in data, yet they are forging ahead and creating the accounts in any case as a starting point.

13. The **discussion** brought other issues to the debate. There is lots of interest in farm data, particularly on natural capital, to support insights on 'sustainable' productivity. Farm level data can indeed play an important role. Valid comparisons (i.e. oranges to oranges) is very important. Because TFP has a negative connotation, there is a need to explain while TFP growth is different from production intensification and negative externalities. The Network's output (guideline to emerging best practices) provides useful elements that need to be publicized.

1.2. Stocktaking and framing the problem

14. **Jean-Christophe Bureau** (AgroParisTech, France) presented an update of previous results from the work of the Network. Reminder of the main ideas behind the Network. Recent works suggest that there has been a slowdown in global agricultural TFP growth in recent years. Not only would slower TFP imply more difficulty to fulfill the needs of a growing population, they would also imply pressure to bring more land into production and more agro-chemicals, with related consequences for greenhouse gases emissions, air and water quality, and biodiversity. Measuring TFP in a very precise way, and putting together the data that is needed to monitor growth in output, inputs and productivity is therefore of key importance. So is communication to policy makers.

15. *"Traditional" measures of TFP need to be adapted* to new issues and the need for the economies to remain in a "safe operating space". Productivity gains need to help mitigate and adapt to climate change and to address other environmental challenges, together with ensuring food supply. That is, TFP indicators must reflect that productivity growth sometimes reduce the negative environmental externalities produced by production as it reduces the amount of inputs needed to produce a given level of output. This requires to account for non-marketed inputs and outputs in economic indicators. One needs to reconsider economic measurement, growth accounting, and pretty much the whole national accounting framework that was largely designed in the 1960s and 1970s.

16. The Network covered many technical issues, from the use of simple indicators based on the growth accounting approach, to the need for investment in shared databases. The in particular in the valuing of primary inputs, the treatment of subsidies, etc. Some of these developments are now adopted by other Member states (e.g. accounting for land quality, for change in the composition of inputs over time, etc.). Data needs were identified to make TFP measures more comparable across OECD Member States. Some of the participating institutions and in particular the ERS/USDA have set the foundations for a comprehensive worldwide database using common standards and conventions.. The TFPEN provides the opportunity for improving such data. The different meetings of the Network showed that coordination efforts and the development of similar conventions and data across countries are still needed, particularly in the measurement of capital

(e.g. depreciation patterns and service life); in the pricing of land; in adjusting for quality and new products for outputs and inputs (e.g. chemicals); and in aggregating over different outputs.

17. The OECD Secretariat has engaged several works in *measuring environmentally adjusted TFP*. It has defined the Environmentally Adjusted Multifactor Productivity, or EAMFP for the general economy that accounts for a specific set of pollution (greenhouse gases, air pollution, etc.). In agriculture, the variety of negative as well as positive externalities requires special developments. The TFPEN Network, but also the OECD Farm Level Analysis Network and the OECD Agri-environmental indicators have joined forces to incorporate the costs and benefits of the environmental impacts of agriculture. As a result, work from the Secretariat combining economic and environmental indicators has already made it possible to assess sustainability performance in both the economic and environmental dimension (example on Norway, OECD 2021). Discussions within the TPEN Network showed that challenges were numerous when attempting to include environmental issues in economic indicators. For example, different, equally reasonable indicators can carry different messages (e.g. indicators of GHG/production and GHG/hectare).

18. The work of Kendrick, Jorgenson and others in the 1960s showed the importance of grounding economic measurement in economic theory and has led to a renewed approach in national accounting. For environmentally adjust TFP indicators, *solid theoretical foundations are also needed* so as to avoid running into unsolvable, paradoxes and ambiguity that arise from ad hoc indicators. The Network has paid a lot of attention to the collaboration between academics and nationally statistical agencies.

19. Academic research has been vibrant regarding methods that ensure that TFP measures adjusted for environmental by-products give theoretically consistent indicators. One area of particular relevance is *the need for improved estimates of "shadow prices"* for non-priced, non-commodity goods. Numerous estimates of such shadow prices have appeared in the literature. However, there is a need for clarification since those shadow prices relevant in TFP indicators are not necessarily those that environmental economist measure for other purposes.

20. The rigorous conceptual framework that has been the basis for including "bad" inputs and outputs in TFP indicators, based on production theory (assumptions on disposability and jointness of inputs and outputs) has also raised some debates. In particular questions arise regarding the difficulty to remain consistent with physical aspects of production (e.g. consistency between the number of animals and the level of manure produced). This is why the "material balance" issue will be discussed in today's meeting.

21. Some of the theoretically consistent measurement methods that were developed to adjust TFP indicators for the presence of desirable as well as undesirable by-products (e.g. directional distance functions, etc.) were sometimes at odds with the need for simple and transparent indicators. This raises difficulties in terms of ensuring routine implementation of environmentally adjusted TFP indicators by national statisticians.

22. In conclusion, there is no agreement on how to measure TFP, implementability, data, theoretical consistency. Growth accounting approach, index number indicators, ad hoc indicators combining traditional TFP and environmental indicators. Need to be open and explore different alternatives. Work with agri-environmental indicators and farm level data useful. OECD is a good place to discuss these issues.

23. **Nick Hanley** (University of Glasgow) made a screen presentation "Valuing externalities in agriculture", available on the Network web page, Nick Hanley discussed the different types of externality (positive and negative) which can result from farming activity. Amongst those discussed were impacts on farmland biodiversity, non-point source nutrient pollution and greenhouse gas emissions from livestock. Changes in farm production methods (eg from less intensive to more intensive grazing) or output choices (eg from arable crops to livestock), and changes in the area of land devoted to agriculture, will all have potential impacts on the size of these externalities. He then reviewed different methods available for estimating the non-market, economic costs or benefits associated with these externalities. These include revealed preference and stated preference approaches, and production function methods.

24. The discussion then focused on the problem of assigning economic value estimates to changes in biodiversity indicators resulting from farm production. A possible approach using stated preference choice modelling was outlined. Finally, Hanley discussed the idea of developing shadow prices for changes in natural capital stocks associated with farm production. He argued that the welfare economics basis behind these types of values might not sit comfortably with the exchange value centered approach of TFP accounting. Indeed, this is also a problem with how externalities are typically assigned an economic value, which also revolves around welfare economic principles.

25. **Daniel Gregg** (Heuris Pty. Ltd.) made an interactive presentation available in the Network webpage. The presentation is interactive with participants answering using Slido (www.slido.com). Participants are asked to rank methods for measuring TFP (i.e. Direct calculation using aggregate quantity indexes, Growth accounting, Econometric methods, Data Envelopment Analysis methods) on a variety of criteria.

26. The **open discussion** served to highlight that, while it is important to make it easy for policy makers to understand/communicate TFP, it is absolutely critical that we don't use wrong measures. As Bob Chambers put it, wrongness is more important (to avoid) than ease of use. In TFP measurement, shadow prices are closer to abatement costs than social values [Hervé Dakpo]. If you want to be consistent, look at the private costs of the bads [Frederic Ang].

27. For some, the issue is perhaps more complex [Jean-Christophe Bureau]. Indeed, the shadow prices in TFP indexes are more opportunity costs than a reflection of the entire set of social costs. However, it would be difficult to defend an indicator that values the cost of a major long lasting pollution (e.g. chlordecone pollution, that prevents selling agricultural products in large areas in the Caribean, for several centuries) simply by considering the amount of "good input" that needs to be sacrificed to reduce the emission of "bad output".

Session 2: Looking inside the box

2.1. Consistency of Environmentally Adjusted TFP (EATFP)

28. **Robert Chambers** (University of Maryland) made a presentation on how important is the material balance issue and how to deal with it? Historically, the main question with TFP has been what drives output? The focus will be then on productivity accounting and there is no single wrong or right approach, even if this does not mean to 'do nothing'. A far larger set of phenomena can be equated to the material balance than has been typically done in the literature. Usually material balance approaches focus on flow inputs (e.g. fertiliser). However, the material balance also applies to stock changes, such as for topsoil losses. These considerations are being accounted for in the natural capital approaches.An overall point is the importance of accounting for a large set of, largely environmental, losses that are currently missed out leading to likely upward bias in TFP growth and to incorrect policy inferences. The laws of thermodynamics apply, and what goes in needs to go out. The difference is, to quote Abramowitz, a measure of our ignorance.

29. A key point: what has not been done in TFP is to incorporate the ideas of Ayres and Kneese 1969, that the TFP differs from one only because the environment is free and we do not care about it. If one decomposes TFP growth into two categories of inputs (those that we measure and those that we do not measure) and two categories of outputs (idem), our current measures of TFP growth, such as growth rate of measured outputs (typically 178% in US agriculture between 1948 and 2019 according to USDA) minus the growth in inputs (typically 4%) provide a change in non measured outputs and inputs. And this amount of 178%-4% is probably close to the change in material balance: example: loss of soil in the Midwest (2mm of topsoil a year over the past century according to Thaler et al 2022). The challenge is to measure the growth in currently non measured inputs and outputs. "We should not be missing so many things". And at the end of the day "we should be able to explain all the changes in X and Y". The gap between the 178% and the 4% is mostly "stuff we missed", from human capital to degradation of environment.

30. **Chris O'Donnell** (University of Queensland) made a presentation on "How to Build Sustainable Productivity Indexes". He followed the OECD and defined measures of productivity to be measures of output volume divided by measures of input volume. He then built a sustainable productivity index in such a way that if volumes of inputs and good outputs remain unchanged, then productivity numbers will increase as volumes of bad outputs fall.

31. The first step involved measuring changes in volumes of inputs, good outputs and bad outputs. Many volume indexes are available, and the choice of index is a matter of taste. When choosing an index, the overriding consideration should be whether the index produces numbers that are consistent with measurement theory (i.e., whether the patterns in the numbers mirror the patterns in the volumes). Only proper indexes can do this. Proper indexes satisfy a number of basic axioms from index theory, such as proportionality and transitivity. Most economists and statistical agencies (including the OECD) use volume indexes that are not proper (e.g., the Tornqvist and Fisher indexes fail the transitivity axiom; the Chained Fisher, Chained Tornqvist and Caves-Christensen-Diewert indexes fail the proportionality axiom). The easiest way to construct proper indexes is to use fixed weights. Contrary to some claims made in the literature, fixed-weight volume indexes do not overstate or understate growth in volumes.

32. The second step involved combining the good output and bad output volume indexes into a total output index. In turn, this involved choosing the value of a parameter, alpha that measures the extent to which the output index accounts for bad outputs. In practice, the choice of alpha is again a matter of taste (or politics). If a decision-maker does not prescribe a value for alpha, then it can be estimated using regression methods (this requires no information about markets or production technologies). Another possibility is to use an estimate of the shadow value share of bad outputs (this involves estimating shadow prices and marginal rates of transformation).

33. The indexes proposed by Cardenas Rodriguez et al (2018) and by Pittman (1983) are not proper indexes (they fail the proportionality axiom). If a country used twice as much of every input to produce exactly the same outputs it had produced in an earlier period, then we would want all measures of productivity growth to say that productivity had fallen by 50%. The Cardenas Rodriguez et al (2018) and Pittman (1983) indexes will generally say something else.

34. The **discussion** focused on material balance issues. The main note was the need to move away from value-based weights as those do not reflect quantities in ways that allow for logical approaches to material balance (in addition these need to be based on the same units, such as kg mass). There is difficulty in breaking TFP measures into purely separable sector-based measures. There is substantial overlap between sectors, even ones that might not be regarded as similar or correlated (e.g. urban sprawl can severely impact agriculture but are not regarded as related sectors typically).

2.2. Examples of applications to environmentally adjusted TFP.

35. **Frederic Ang** (Wageningen University) builds on his presentation "N surplus and GHG emissions in a productivity framework: A case study of Dutch dairy farms". A first paper (Lamkowsky, M., O. Oenema, M. P. M. Meuwissen, and F. Ang 2021: "Closing Productivity Gaps among Dutch Dairy Farms Can Boost Profit and Reduce Nitrogen Pollution," Environmental Research Letters) quantifies possible TFP gains in monetary values; and to quantify possible reduction of N surplus at maximum TFP levels. The by-production approach is used in this latter issues, following Murty, S., R. R. Russell, and S. B. Levkoff (2012): "On Modeling Pollution-Generating Technologies," Journal of Environmental Economics and Management, 64, 117 - 135. Data envelopment analysis (DEA) is used on a sample of 341 Dutch dairy farms over the time period 2006 to 2017. Over this period the average economic productivity per farm increased by 48%; The average Nitroagen productivity increased by 192%, with large variations between firms. By closing the N productivity gap, farmers could on average reduce the annual N surplus by 50%, alleviating a major environmental constraints in the Netherlands.

36. The purpose of the second paper by Ang, F., K. Kerstens, and J. Sadeghi (2022): "Energy productivity and greenhouse gas emission intensity in Dutch dairy farms: A Hicks-Moorsteen by-production approach under non-convexity and convexity with equivalence results," (Journal of Agricultural Economics) is to evaluate performance in (1) the conventional technology and (2) emission-generating technology, using Hicks-Moorsteen formulations. DEA is applied to 1510 obs510 observations of Dutch dairy farms over the time period 2011 to 2019. The results show a positive association between energy productivity change and GHG emission intensity change, which calls into question the potential of on-farm, energy-efficiency-increasing measures to reduce GHG emission intensity. The approach shows that multi-equation modeling approach of Murty et al. (2012) is suitable for considering pollutants in a productivity framework.

37. **Raushan Bokusheva** (Zurich University of Applied Sciences, ZHAW) summarized in her presentation several aspects of relevance for integration into agricultural TFP measurement natural capital contributions (ecosystem services (ES)). So far, activities of the network were mainly focused on accounting for negative externalities from agricultural production. However, there exist a number of ES that are of immense relevance for agricultural production. Some examples are soil's ES (supply of organic matter and nutrients, protection from erosion, etc.), animal pollination, pest and disease control and flood control by wetlands. Accordingly, it is important to explore options for measuring these contributions. Given the complexity and amplitude of this task, it would be desirable to exploit synergies that may exist with the work of the UN SEEA EA on the economic valuation of ES.

38. An important aspect of measuring contributions of ecosystems to agricultural production is a consistent pricing of specific ES. In particular, the ES shadow prices derived using representations of production technologies formed by farms' short optimization decisions may be inadequate for measuring nature contributions to the TFP growth. Severe deficiencies in Institutional Resource Regimes (IRR) that govern the use and management of natural resources do not urge producers on the sustainable use of natural resources and, therefore, cannot prevent environmental degradation. This aspect is particularly important considering non-convexities and tipping points in ecosystems. Moreover, it questions the application of marginal productivity and substitution concepts in the economic valuation of ES. In this context, the evaluation of nature contributions to agricultural productivity growth should go beyond standard approaches for measuring contributions of different factors to the TFP growth and account for both relative and absolute scarcity of renewable natural resources. That is, to evaluate agricultural TFP growth on the subject of its sustainability, one needs to assess contributions of different factors of production to output growth considering their total societal costs i.e., costs enabling optimal allocation of renewable natural resources intertemporally.

39. Additionally, considering the strong dependence of agriculture on natural resources, it is illusory to believe that we would be able to substitute many of nature contributions to agricultural production by produced capital. Accordingly, the weak sustainability concept may only to a limited extent be applicable in the context of agricultural production.

40. **K. Fuglie** (USDA ERS) builds on his PowerPoint presentation "The value of irrigation water in world agriculture". The use of scarce surface and groundwater resources for irrigation is an important environmental resource in agricultural production. However, for many countries information on the quantities and values of irrigation water, and especially on how these have evolved over time, is incomplete. Moreover, markets for water are often poorly developed, if they exist at all. Even where farmers report costs incurred for water use, water for agricultural purposes may be heavily subsidized. For these reasons, water is often poorly represented in measures of agricultural total factor productivity (TFP).

41. In this presentation, Fuglie proposes using differences in land rental rates between irrigated and unirrigated cropland to derives estimates of the average shadow value of water by country. He first constructs estimates of irrigated area and water use by country over 1987-2017 drawing on data from FAO Aquastat and OECD Agri-Environmental Indicators databases. He then uses estimates of average regional productivity differences between irrigated and dryland agriculture and data on land cost shares from the USDA International Agricultural Productivity dataset to derive shadow values for irrigated water by country. The shadow value for irrigation

water varies widely across countries and has increased over time. Growth in agricultural TFP has in many cases raised the productivity and value of water used for irrigation. By 2017, the world-wide the shadow value of irrigation water was about $140 billion per year, or $48 per cubic meter.

42. The **discussion** focused on how to distinguish the value of water relative to the value of infrastructure and the value of land? Irrigation is part of investment plan and energy cost [Keith Fuglie]. In the case of a study on Egypt, public investment contributes to farm productivity, but is left outside TFP measurement. How to deal with conservation policies: e.g. land set aside is a negative productivity shock only if you set a zero value to the ecosystem services it provides? The large level of heterogeneity at the farm level could mask the productivity pattern.

Session 3: Looking outside the box

3.1. Approaches from other sectors and other methods

43. **Miguel Cardenas Rodriguez and Florian Mante** (Environment Directorate, OECD) made a presentation on including renewable natural capital inputs (e.g. cropland, pastureland, forestland, non-cultivated biological assets such as fisheries and timber, ecosystem services) in whole economy. GDP growth adjustments are being undertaken by the OECD - these include positive contributions of natural capital with EAMFP calculated as the residual. See the 2018 paper that describes the methodology (Cárdenas Rodríguez, Haščič and Souchier, Ecological Economics). MFP is an important macroeconomic indicator, it describes growth not explained by change in labour or capital, and is a measure of intangibles (innovation, education, market efficiency, organizational improvements, etc). EAMFP accounts for the use of natural resources and for the production of undesirable outputs. Provides insights about more sustainable long term growth, and is a starting point to analyses green growth. Complementary indicators derived from the measurement framework include the contribution of non-renewable and renewable natural capital to income growth, and the growth adjustment for pollution abatement.

44. The inclusion of natural capital is based on a wide array of environmental accounts from multiple data sources. Natural capital inputs include four types of fossil fuels, ten minerals, three land types, two biological resources, three ecosystem services and three renewable energy resources. Consistent with the literature, the value of natural capital is calculated using the unit rent of natural capital extraction following the producer's perspective, i.e. private costs for producers are used rather than the social value of environmental goods and services. Pollution is included in the growth accounting framework using their shadow prices, estimated econometrically. While there are important interactions of these environmental inputs and outputs with the agricultural sector, the EAMFP analysis of this paper is performed at the whole economy level, masking the direct contributions of individual sectors such as agriculture.

45. Results were presented on identification of sources of growth. The contribution of natural capital to income growth varies a great deal across countries, with high positive contributions in some countries such as Saudi Arabia, and negative in some countries decreasing their reliance on such resources (e.g. Norway). This is driven by the contribution of non-renewable natural capital, which is more prevalent than that of renewable natural capital, both in frequency and magnitude. There does not appear to be much in the way of contributions of natural capital to growth for most countries with it being 'visible' only for a small set of countries (e.g. Australia). The strong negative contribution to income growth of marine capture fisheries, suggests that sustainable resource management techniques are required to maintain growth rates over the long run. Overall, ecosystem services play a minor role in the generation of income growth. Watershed protection from forests is the ecosystem service with the largest contribution to output growth. Unit rents and the contribution of renewable energy sources to income growth turns strictly positive over time. Driven by decreasing technology costs, turning renewable energy profitable in several countries. Once pollution is included as an output, many countries show important downward adjustment to conventional GDP growth. Pollution effects are substantive for few countries - most importantly fast growing developing countries (e.g. India, China). Results should not be interpreted as sustainability indicators.

46. In the **discussion** one participant asked about the meaning of negative contribution for the stock of natural capital. Contributions are calculated using the private value of the resource and the growth rates of the quantity extracted/used over a year. Since private values of natural capital inputs are always zero or positive, a negative contribution indicates that the resource has been used less for production compared to the previous year. It does not inform per se in the level of the resource nor pollution, nor whether the extraction levels are sustainable. The interpretation of the sign of the contribution of non renewable capital is that a continuous increase in extraction is not sustainable in the long term both in the economic and the environmental sense. For renewable capital assessing sustainability is less straight forward, here we need complementary information on stocks, production/extraction levels, management techniques and the ecological value of resources.

47. How is the pollution series generated? The quantity of pollution is based on the level of production-based air emissions. The private valuation of pollution is estimated econometrically as the forgone GDP associated with a decrease in pollution. Attention is paid to avoid double counting among pollutants, and allow for country-specific shadow price estimates.

48. Does EATFP show a fast or slower growth rate compared to 'vanilla' TFP? EATFP and TFP do not use the same baseline as both input and output are different. Rather than comparing the two directly, comparing the dynamics of each can inform on productivity patterns and their relation with the environment.

49. How is trade/intermediate inputs included? These are taken out of the production estimates using value added approaches. Natural capital inputs are not double counted because they are only counted in the country of extraction/renewal. Here the concept is similar to GDP, all of what is produced in the country over a year regardless of where it is consumed.

50. Will the data series for shadow prices used here be published? Contribution of pollution abatement will be included in the paper and published in the statistical portal once the paper is declassified, while the estimated shadow prices can be provided upon request. Are the shadow prices being estimated using distance functions? No, shadow prices were estimated using a Random Coefficient Model, more details on the estimation method can be found on the previous paper (OECD version, journal version).

51. **Ben Henderson** (OECD TAD) presented ongoing work by the OECD that uses simple approaches to explore how the sustainability and productivity dimensions of agricultural performance are connected. This was done by combing data on TFP growth rates published by the USDA and changes in GHG emissions and N surpluses from the OECD AEI database, for a sample of 33 countries. The first part of the presentation focused on decomposing changes in GHG emissions into changes in TFP, output and the emission intensity of input use, in the context of decoupling emissions from output growth. Most of the sample experienced positive TFP growth and some form of decoupling (in absolute or relative terms), but the environmental performance of countries closely on the type of TFP growth experienced. For instance, input-saving TFP growth tended to be associated with emission reductions, whereas TFP growth dominated by output growth only helped to partially decouple emissions from production.

52. In the second part of the presentation the concepts of weak and strong sustainability were explained as aggregation rules for creating composite indicators. The weak sustainability concept (based the average of TFP and GHG per unit of output) was shown to be a special case of an environmentally-adjusted TFP index in which emissions are included as an input. This composite growth index was then compared the TFP growth index. It was shown that TFP scores could be adjusted downwards for different reasons: i) because emission reductions were lower than reductions in the standard input bundle, or ii) when emissions increase faster than the input bundle. On the flipside, GHG-adjusted TFP growth will exceed conventional TFP growth when: i) emissions growth by less than standard inputs, or ii) emissions fall by more than these inputs. This assessment was extended by incorporating changes in both N surpluses and GHG emissions in the environmentally adjusted TFP measure. This was shown to change rankings and increase the richness of the measures, but at the same time place greater demands on its interpretation.

53. In the **discussion** a question was raised by Keith Fuglie about whether leakage should be considered in either measuring or interpreting sustainable productivity measures such as those shown in the presentation. The implication being that countries with relatively low emission intensities for their agricultural products may only be partially decoupling their growth in output from emissions, but if they were not producing so much other less efficient countries would fill this gap and global emissions could be higher. These leakage implications certainly warrant further investigation. That said, the there is still a need for agricultural sectors in all countries to absolutely decouple some of their emissions from production to meet the mitigation targets of the Paris Agreement. It is unlikely that leakage considerations would change the calculation of sustainable productivity, but it may indeed change the interpretation of the measures.

54. A question was raised about the use of equal (0.5) weights and whether this meant that a 100% improvement in environmental performance can offset 50% of input growth? This is indeed the implication, but it should be emphasised that the weights are arbitrary in the presented assessment. The choice of weights for the series remains an open question. In the absence of concrete data to calculate appropriate weights (e.g. shadow prices) they could be treated as a sensitivity variable whereby a wide distribution of weights are used to understand their relative importance to country rankings. Here Francisco Areal contributed to discussion describing a method that he had developed for this type of sensitivity testing.

55. Tiho Ancev intervened to say that the weak sustainability aggregation method was a useful idea. He also asked if there had been consideration of using other data series (e.g. WB Adjusted Net Savings series) as inputs into the EATFP approach presented. The Secretariat is currently exploring this issue.

3.2. Parallel session: group 1. Analysis of productivity and sustainability performance and policy links. Facilitator: Jean-Christophe Bureau

56. On policy links, the Network needs to consider some of the issues raised by P. Londero, i.e. that there ignorance of policy makers of what TFP really is, i.e. potentially a reduction in “bad” outputs, that the indicator is seen as too global, too complex, and has a connotation (associated to intensification of agriculture).

57. Spiro Stefanou stresses that our job is to conceptualize the need to produce more for a growing population, the need for everyone to be able to buy it, and sustainability. How do we find that balance? Proposition: not to focus on specific number, but more on categories, with some kind of “fuzzy logic” approach, e.g. low, middle, high. And to have some input from policy makers not left to economists.

58. What would be interesting for policy makers would be pragmatic methodologies; how this could be used to compare different countries. Policy makers are particularly interested in connecting the work of the network to environmental indicators (e.g. attempts to “green” the EU Farm Accounting Data Network); and in measurement of environmental leakages (imported deforestation, etc.). There is also a strong interest in looking at the entire food system, including demand, i.e. food industry and consumers, and look at the consistency of the entire food system growth in production but also changes in consumption.

59. Interest in economic sustainability but also environmental sustainability in the sense of “will the resources still exist?”. Focus on ecological scarcity. Benchmarking important. Need to consider the social aspects of sustainability.

60. Policy makers will be interested on links with the different types of subsidies, such as those to positive externalities. There are two pockets of subsidies, those to R&D and those to the environment, that affect sustainable TFP. These are of direct interest for policy makers. Gathering data, making international comparisons possible can shed light on the linkage between these programs and TFP indicators.

61. TFP is a black box and needs to be made more transparent. Particular interest in the quality of outputs and inputs. Links with regional problems that are of prior interest for policy makers, e.g. lack of water.

62. At the same time, we need to maintain the focus on what the tool is. Paul Schreyer said it in a previous meeting, the problem is to measure output, output growth. Productivity cannot be everything because "policy makers do not like TFP". Bob Chambers stresses the need to "Keep it focused".

63. Miguel Cardenas: Indeed, need to keep it focused. Suggests three priorities: 1/ dada availability. There is a lack of data on freshwater, soils, etc. 2/Valuation of pollution, since the System of National Accounts does not provide a lot of information to value pollution; 3/ going beyond TFP, in terms of consumption, sustainability. For this there are several initiatives, such as Green GDP, concept of net saving developed by World Bank, etc. On consumption, TiVA (Trade in Value Added) developed by the OECD is another one. The concept of Environmental Policy Stringency.

64. One question is how to communicate. Policy makers think of social costs not producer costs. Might be the need to combine TFP with other environmental indicators.

65. There are complex interdependences, and policy makers will be looking at food for example as different attributes (medicine, health, fun), not only the ones covered by TFP.

66. An approach could be to define what would be the output supply for a particular objective and then derive a TFP measure. Possible approach with the model GTAP Invest. Could provide information to policy makers for a specific country

67. We need a definition of sustainability. Need to distinguish the private and longer-term aspects, but a clear definition of sustainable is needed. The wording is important: do not call it environmentally adjusted TFP but agricultural sustainability. Spiro Stefanou: there is a "branding" problem, and one might consider changing the name of the Network.

68. There is a fairly large literature on Green GDP accounting. One needs to separate TFP and analysis of sustainability. TFP was developed to look (and forecast) output growth. Having a TFP ratio of 1 is not a problem, if we need to explore growth.

3.3. Parallel session Group 2: TFP and alternative (pragmatic) methodologies to measure sustainable productivity. Facilitator: Daniel Gregg

69. Chris O'Donnell: There are also 3 other issues: Need to make adjustments for pollution abatement; To what extent is productivity coupled to GHG emissions; The use of growth rates rather than levels indicators of TFP.

70. Ben Henderson: The issue of weights and shadow prices has occupied the TFPEN for a long time and seems still to be largely unresolved. Chris has suggested that you can measure TFP without shadow prices at all. Can we do this?

71. Frederick Ang: Shadow prices are totally valid, and 'better' than using non price weights. The problem is around aggregation because we have things in different units. This becomes more problematic when we have things like pollution. TFP is a measure that is focused on the producer.

72. Response by Chris O'Donnell: The choice of weights is a matter of taste – taste that is related to the objectives of use of the measure. Governments are focused on community welfare outcomes from productive activities. Regardless of the weights you use, you need to use proper index approaches. So as long as you justify your weights choices, the matter is really to do with the index chosen. Response by Frederick Ang: The underlying assumption of productivity models is some sort of optimising behaviour. This is the justification for use of shadow prices in aggregation approaches for TFP measures. Response by Chris O'Donnell: Sure, but the index approach is still incorrect.

73. Arne Henningsen: Taking a simple productivity measure, using market prices as weights we have a profitability index. For farms maximising this is 'good'. But for politicians the aim is not profit maximisation at the firm level. Rather it is a social value. Bad outputs could also be put in the input side as costs.

74. Sun Ling Wang: There are a lot of different methodologies for index creation. But, for statistical agencies it is important that approaches are simple and straightforward. For example Ben Henderson's presentation a simple equal weights approach was used. This compares to the first presentation in which a range of shadow values were chosen and these approaches are sensitive to specification

75. Response by Ben Henderson to first point: the choice of an equal weight is just a start. It is arbitrary, but can help to start to indicate where important environmental issues/achievements may occur, and also a first step to consider simpler approaches to EATFP.

76. Maria Vrachioli: Social prices of bad outputs is a very complicated problem – more so at the national level where these have major local issues but be highly heterogeneous at the national level

77. Francisco Areal response: It's not that having an equal weight is 'bad'. It is that there are a large range of possible weights. Perhaps one way to integrate this 'distribution' of weights it to explicitly generate a distribution of TFP indices based on these weight distributions.

78. Chris O'Donnell response: It is unlikely (maybe impossible) to get agreement on weights for social/environmental factors. The people that can best choose these weights are likely to be the government. In the meantime, there may be ways of computing weights that don't involve any major assumptions. For example Benefit of the Doubt indices (make everyone look as good as possible). However, the idea of Francisco is interesting in that it may provide for a more general approach to weighting in which multiple viewpoints can be considered using distribution approaches. This might actually show some surprising outcomes – that some weights simply don't matter.

79. Frederick Ang: Confusion has arisen from a perspective that pollution has some value. Whereas from production economics perspectives, the focus is on trade-offs. Does this mean a single pollutant has some particular value or weight? Response by Chris O'Donnell: Yes this is completely correct. The production economics approach is important, but not for measuring TFP. Rather production economics approaches are important for explaining TFP patterns.

Session 4: Long Term priorities for the Network

80. **Group 1 reporting: summary by Hervé Dakpo**. Group 1 discussion focuses on the analysis of productivity and sustainability performance and policies links. The discussion centered around three key elements. The first one is about measuring. This part was about how to define sustainability (given that the concept implies accounting for complex interactions between systems), then how to benchmark sustainability change (for instance, social or private costs can be used to weigh environmental outputs), the required data (including the quality of the data). The second key element was monitoring and evaluating. One crucial feature accrued to agriculture is that it is different from many other sectors in that it works with subsidies (environmental or R&D subsidies). The question is, how can these policies be related to environmental outcomes, including TFP? Therefore, in terms of evaluation or monitoring, we must be able to go beyond the simple concept of TFP. Finally, the last key point is communication. It was all agreed that there is a huge branding problem regarding the term "productivity." A new brand maybe required, e.g., "agricultural sustainable productivity" or other. Moreover, we must go beyond the numbers. For instance, use categories or some classification to qualify the quantitative results. Another point raised was that communication experts should handle the communication part.

81. **Group 2 reporting: summary by Maria Vrachioli**. The discussion on Group 2 focused mainly on the different approaches that can be used to weight the components of an

environmental TFP composite index. Approaches such as growth accounting approach that account for uncertainty and/or heterogeneity and distance functions were proposed, as equal weighting may not be the right way to move forward. There was though a point that statistical offices prefer simple weighting methods rather than econometric approaches, such as distance functions that lead to shadow prices as a weighting mechanism. In addition, the use of shadow prices for bad outputs may not be an easy way forward as someone needs to consider both economic and social costs of these outputs. While a scheme with weights from public/governmental sources seems to be the least cumbersome from an application perspective, this approach may lead to biased results as the weighting could be skewed towards the directions of each government. Finally, while weights reflect trade-off from production perspective, they also reflect importance of certain pollutants from a policymaker perspective.

82. **General discussion.** The work of the Network is on TFP and environment but is actually close to sustainable growth. Is it the evolution the Network should take? OECD Member states demand to have indicators that can be tracked. In the mandate given to OECD, the term “sustainable productivity growth” is present: “comparable and robust” measurement.

83. Spiro Stefanou: Useful links with the sustainable growth coalition in the US, chaired by Elise Golan. Looking at the perimeter covered could be useful. One priority should be to develop data products that can be used for international comparisons.

84. Bob Chambers: When you measure something it is important to be consistent with the theory. This is still true if we need to expand the coverage of what we want to measure. Warning: keep doing it in a correct way.

85. Lionel Cosnard: The wish list for policy makers includes several aspects. One is providing information on sustainability in agriculture. There is a big lag between investment and productivity growth. Communication such as the one done by the network in the “Guide to emerging practices” is particularly useful to explain what policy challenges lie behind TFP.

86. Keith Fuglie: What we are after is why outputs grow faster than inputs, and one of the explanations, as pointed out by Bob Chambers, is that we have not counted environmental inputs. One objective is to close the gap between the “178% and the 4%” described by Bob Chambers, i.e. the growth in measured inputs minus the growth in measured inputs. In some cases, it is noteworthy that traditional TFP has grown while some resources have been saved, which suggests that the gap has expanded. One major objective is to measure growth that saves environmental resources.

87. Jesus Anton, Guillaume Gruere. There is a disconnection between what we do and the demand from policy makers. We need consistency with theory but also between indicators.

88. Miguel Cardenas: it is worth looking at the publication by Eco directorate on “main drivers”, to help define the perimeters of the TFP network roadmap

89. Simone Perali: idea of using productivity to evaluate what the government has been doing

90. Chris O’Donnel: a way forward would be 1/ to define what we mean by productivity and sustainable productivity; 2/ measure sustainable TFP that is consistent with theory (but not economic theory, index number consistency); 3/ use economics to explain determinants of TFP growth; 4/ identify the main drivers

91. Arne Henningsen : one question is whether and how much we include social sustainability.

92. **Roadmap for the OECD Network on Agricultural TFP and the Environment.** Jesus Anton: Several objectives and guidelines. We need to keep a direction compatible with the OECD mandate. Get focused on clear and well-defined objectives and not expand to broad and ill-defined ones.

93. First we need to define clearly what we want to measure: Environmentally sustainable productivity growth (SPG). Then, the Network must associate experts beyond TFP and production economics (e.g. Green accounting) to include environmental economists and experts on index

numbers. But not fall into a “cacophony” of indicators. If social sustainability is envisaged in the longer term, the diversity of expertise should also be expanded.

94. Second, we need to get indicators that are comparable across countries and usable for policy makers who ask for that. Participants are invited to look at the consistency of the figures they come up with and consistency across countries. The results of different indicators need to pass the test of theoretical consistency, but also of empirical meaningfulness for the policy debate. The network needs to engage in policy analysis and interpretation of the SPG indicators.

95. Finally, a single avenue or research is unlikely to solve the problem. We need to explore a diversity of methods and strategies, including the calculation of TFP with shadow prices (which ones?), the combination of TFP with agri-environmental indicators, and the use of index numbers that combine them. The networks should give space for this diversity of avenues.

96. **Next meeting:** After some consultation made January 2023, the dates of next meeting were decided to be 24-25 May 2023. It would be good to create different action tracks inside the network.