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Papers by the Scientific Group and its partners in support of the UN Food Systems Summit.

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THE TRUE COST AND TRUE PRICE OF FOOD

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ABSTRACT

Ensuring sustainable food systems requires vastly reducing its environmental and health costs while making healthy and sustainable food affordable to all. One of the central problems of current food systems is that many of the costs of harmful foods are externalized, i.e. they are not reflected in market prices. At the same time, the benefits of healthful foods are not appreciated. Due to externalities, sustainable and healthy food is often less affordable to consumers and profitable for businesses than unsustainable and unhealthy food. Externalities and other market failures lead to unintended consequences for present and future generations, destroying nature and perpetuating social injustices such as underpay for workers, food insecurity, illness, premature death and other harms. We urgently need to address the fundamental causes of these problems. This brief sets out the results of an analysis to determine the current cost of externalities in the food system and the potential impact of a shift in diets to more healthy and sustainable production and consumption patterns. The current externalities were estimated to be almost double (19.8 trillion USD) the current total global food consumption (9 trillion USD). These externalities accrue from seven trillion USD (range 4-11) in environmental costs, 11 trillion USD (range 3-39) in costs to human life and one trillion USD (range 0.2-1.7) in economic costs. This means that food is roughly one-third cheaper than it would be if these externalities were included in market pricing. More studies are needed to quantify the costs and benefits of food systems to support a global shift to more sustainable and healthy diets. However, the evidence presented in this brief points to the urgent need for a system reset to account for these 'hidden costs in food systems and calls for bold actions to redefine food prices and the incentives for producing and consuming healthier and more sustainable diets. The first step to correct for these 'hidden costs' is to redefine the value of food through true cost accounting (TCA) to address externalities and other market failures. TCA reveals the true value of food by making the benefits of affordable and healthy food visible and revealing the costs of damage to the environment and human health. The second corrective step is true pricing: incorporating externalities in prices to align market incentives with social values. Appropriate safety nets to boost consumer purchasing power and the enforcement of rights and regulations should also be part of true pricing to ensure that affordable and healthy food is accessible to all. Such actions will conserve the environment and simultaneously meet fundamental universal human rights and accelerate progress towards achieving development goals.

1. INTRODUCTION

The vision of the UN Food Systems Summit is to "launch bold new actions, solutions and strategies to deliver progress on all 17 Sustainable Development Goals (SDGs), each of which relies on healthier, more sustainable and more equitable food systems" (UN, 2020). The Summit seeks to transform the way the world produces, consumes and thinks about food build a just and resilient world where no one is left behind (UN, 2020). In various Summit platform discussions, questions have arisen relating to (a) the true cost of the food we eat, (b) what costs would be involved in shifting to more sustainable patterns of production and consumption, (c) who would bear the cost of these changes and (d) what the implications are for the poorest consumers. Addressing these hidden externalities would be a significant, bold action.

Ensuring sustainable food systems entails ensuring that food systems provide affordable and healthy food to all people while respecting planetary and social boundaries. Current food systems are not sustainable. They generate substantial environmental, social and health costs while failing to provide affordable food to all (FAO et al., 2020). For example:

- The emissions associated with pre- and post-production activities in the global food system are estimated to be 21-37% of total net anthropogenic GHG emissions (IPCC, 2019),
- The majority of the global working poor work in agriculture (World Bank, 2016),
- 690 million people were undernourished in 2019 (FAO et al., 2020), and
- More than 10 million lives are lost annually due to unhealthy eating patterns (GBD, 2019).

A transition to sustainable food systems will reduce their environmental, social and health costs while making healthy food affordable to all. Researchers have only recently begun investigating what dietary changes will be necessary to keep food systems within planetary boundaries (Herrero et al., 2017, Rockström et al., 2009). Even more recently, the question has arisen of how changes in the food system and their resultant impacts on environments in which consumers acquire foods (food environments) affect our health, particularly the incidence of obesity and non-communicable diseases (Willet et al., 2019). For example, the EAT-Lancet report estimated that a transformation to healthy diets by 2050 would require substantial dietary shifts. This will include reducing the consumption of:

- Foods with added sugars (including harmful non-nutritive sweeteners);

- Refined grains (that can cause diabetes);
- Added sodium (that can cause hypertension);
- Harmful fats (especially harmful trans fats, and to a lesser degree, other solid fats linked to cardiovascular disease); and
- Processed meats (associated with cancer).

Increasing the consumption of healthy, protective foods such as fruits and vegetables, legumes, nuts and seeds (Willett et al., 2019) will address multiple health-related issues. These protective foods are needed for their phytochemicals and fiber that may be absent from other foods. Often unhealthy foods displace healthy alternatives (such as fruit, legumes, nuts, seeds and vegetables and beneficial forms of primary processing such as fermentation) that may be less convenient (Masters et al., 2021) and less marketed and therefore under-consumed.

Effective game-changing strategies[1] to achieve sustainable food systems should arguably not ony treat the symptoms of the problem. Solutions should also address the root causes of why food systems impose environmental and health costs and fail to provide sufficient quantities of beneficial foods in the first place. One major root cause is that these costs and benefits of production and consumption are externalized due to how markets are designed. These externalities are not reflected in market prices (Baker et al., 2020) and have no economic 'currency'. As a result externalities are hidden effects of choices of market players, and make sustainable and healthy food less affordable for consumers and less profitable for producers. Historically the choices of all stakeholders and business profits have been based on market prices and recorded in economic statistics such as gross domestic product (GDP). External costs and benefits can also be documented in statistics on mortality and disease, climate change and pollution. However, the link between market activity and those social or environmental harms is not directly visible or reflected in the incentives that drive economic systems. As a result, the economic value of food, which drives economic choices by businesses, consumers and governments, is highly distorted. By providing distorted information and perverse (often unintended) incentives against affordable, sustainable and healthy food, externalities constitute a significant barrier to attaining sustainable food systems. Moreover, even with a full cost approach, there are likely trade-offs across the health and sustainability considerations. There is considerable diversity in regional food systems and their externalities.

First, internalizing the externalities of the food system requires redefining the value of food by measuring and costing these externalities through 'True Cost Accounting' approaches. Secondly, the economics of food needs to be redesigned to explore pathways to internalize these externalities in prices, namely through true pricing. A price-based adjustment would be more inclusive than imposing third-party harm (abatements) or penalties. When combined with public funding mechanisms, true pricing could make sustainable and healthy food affordable and profitable.

At the request of the Scientific Group of the UN Food Systems Summit, a working group set out to investigate the true costs of food and propose possible actions to address the problem. This brief aims to inform food system stakeholders about how they can grasp an opportunity based on the most recent scientific insights in this young and emerging field of analysis. Section 2 summarizes the problem of externalities. Section 3 describes how TCA can be used to redefine the value of food. Section 4 sets out how true pricing can be used to redesign the economics of food. Section 5 provides an analysis of the current true environmental and health costs of food at the global level based on research from the working group. Section 6 outlines the potential benefits of dietary transitions. Section 7 discusses the implications of the analysis for the design of true pricing mechanisms. Section 8 concludes and presents recommendations.

2. THE EXTERNALITIES AS BARRIERS TO SUSTAINABLE FOOD SYSTEMS

Externalities refer to "situations when the effect of production or consumption of goods and services imposes costs or benefits on others which are not reflected in the prices charged for the goods and services being provided" (OECD, 2013). Externalities can arise when people are affected by market choices of others that they have no say in (Laffont, 2008). For example, greenhouse gas emissions from one person's actions affect people far away and future generations who have no say in those decisions. Externalities can

1 The UNFSS definition of a 'game-changing and systemic solution' is a feasible action, based on evidence, best practice or a thorough conceptual framework that would shift operational models or underlying rules, incentives and structures that shape food systems, acting on multiple parts of – or across – the food system, to advance global goals which can be sustained over time. The key criteria that a 'game-changing and systemic'

also be beneficial, such as disease prevention that reduces health care costs. There are other price-related market failures, that cause prices to lead to inefficient allocation of resources. In addition, to monopoly and monopsony, a lack of information or behavioral biases, for example around health effects can lead consumers to ignore costs and benefits of their decisions (Gruber & Kőszegi, 2001; Wang & Sloan, 2018). Due to missing markets, the well-being effects of affordable healthy food on the poor will not translate to higher prices and drive the supply of more healthy food (UNLPE, 2012).

Externalities arise from several elements in the food system (see Table 1). The boundary between social and human capital is defined differently across frameworks and health externalities can also be classified as human capital (TEEB, 2018; IIRC, 2006). Health externalities can also be classified as human capital (TEEB, 2018; IIRC, 2006). There is a considerable variation in costs between food products and regions (see Wageningen University (2017) for examples of variation in animal value chains). In some cases, traditional practices of animal husbandry can have positive effects on natural capital (Baltussen et al., 2019). Commodities involving production by smallholders in developing countries (such as cocoa or coffee) tend to have higher external social costs, including underearning for farmers (IDH, 2014).

Externalities create significant problems in food systems. The first problem is that externalities prevent societies from achieving their full potential by distorting the information about the value of food conveyed by market prices (Gemmill-Herren, 2021). The market price of products does not reflect its true costs and benefits. Furthermore, the value of companies and their decisions reflect expected future profits - the difference between the sum of the cost of outputs minus the sum of the cost of all inputs, including labor (OECD, 2002), all valued at market prices. If a company contributes to climate change, underpays workers or enables healthy and affordable food, this is not reflected in its profit (Serafeim et al., 2019). As the financial returns of companies are based on their (expected) profits, the financial value of investments does not reflect the actual value that these investments benefit society (Serafeim et al., 2019). The economic value of the food sector is measured by its contribution to GDP, which the sum of all companies' value-added - the value of

Table 1 Summary of the key externalities in food systems

Type of externality	Examples of externalities	Endpoint impact(s)
Environmental[1] (effects on natural capital)	Air, water and soil pollution GHG emissions Land use Overuse of renewable resources Soil depletion Use of scarce materials Water use	Contribution to climate change, health effects, depletion of abiotic resources, depletion of biotic resources including ecosystem services and biodiversity.
Social[2] (effects on social rights and human & social capital)	Animal welfare Child and forced labor Discrimination and harassment High and variable prices Training Underpayment and underearning	Poverty, well-being, food security and human skills.
Health[3] (effects on human health)	Antimicrobial resistance Undernutrition Unhealthy diet composition Zoonoses	Human life (mortality and the quality of life), Economic (medical costs, informal care, lost working days)
Economic[4] (effects on financial, manufactured and intellectual capital)	Food waste Tax evasion	Increased food demand, and a decrease in public funds

Sources:
[1] FAO, 2015; NCC, 2015; Baltussen et al., 2016; Allen & Prosperi, 2016; Nkonya et al., 2016; TEEB, 2018; 2019; Dalin & Outhwaite, 2019; FOLU, 2019; Galgani et al, 2021.
[2] Baltussen et al., 2016; Westhoek et al., 2016; IDH, 2016; WBCSD, 2018; Jaffa et al., 2019; True Price, 2020a, Galgani et al, 2021.
[3] Wageningen University, 2017; FOLU,2019; TEEB, 2018; GBD, 2019; FAO et al., 2020.
[4] FAO, 2015; TEEB, 2018; 2019; Impact Institute, 2020; FAO et al., 2020.

output minus the value of intermediate consumption measured at market prices (OECD, 2001). Hence, the degree to which the food systems contribute to climate change, deforestation or poor health is not factored into crucial economic indicators for policy-makers (Stiglitz et al., 2018), and externalities, therefore, lead countries to have lower average living standards than would otherwise be possible.

A second problem with (negative) externalities is social injustice. The existing arrangement of property rights, institutions and infrastructure were constructed over time, reflecting past choices of those in power who sometimes neglected or actively harmed marginalized groups, including women and girls, indigenous and minority populations, migrant workers and other communities. Environmental harm such as air and water pollution are often concentrated in places inhabited by marginalized groups. Unhealthy products are often marketed most intensively to vulnerable populations such as children.

The result is a variety of involuntary harms that may include severe rights violations: forced labor, harassment of women or underpayment in the agricultural sector and breach the rights of people making our food. A lack of affordable food is also a breach of the right to food for consumers. The erosion of natural capital breaches the rights of future generations to decent livelihoods (United Nations, 1972).

The third problem with externalities is that they inadvertently reward unsustainable, unaffordable and unhealthy food production and consumption. As natural, health and social costs are externalized, it is more profitable to produce unsustainable and unhealthy food. Child labor, forced labor and underpaid workers represent cheap labor, consuming natural resources without replenishing those provides cheap inputs and not containing pollution saves costs. At the same time, adding calories, salt, poor quality fats, sugars and harmful sugar alternatives to food items and promoting such foods can increase sales despite the negative effects on health (Stuckler et al., 2012). Food safety adds to the harmful effects on health, especially in developing countries (Devleesschauwer et al., 2018). One reason is that there is neurobehavioral evidence that some unhealthy foods elicit higher reward responses in the brain than healthy foods (Banerjee et al., 2020).

In the same way, encouraging high levels of food waste, e.g. through appealing packaging, can increase sales. Moreover, firms have no incentive to make healthy food affordable. Businesses set prices to optimize their business profit (Laffont, 2008), sometimes using inflated prices as signals of healthy food (Haws et al., 2016). As a result, sustainable and healthy food is more expensive to buy than unhealthy food (Stuckler et al., 2012).

Given that global capital markets allocate capital based on financial returns, most capital will flow to the most successful companies in externalizing costs to optimize profit (Serafeim et al., 2019). In an economy where consumers maximize purchasing power, businesses maximize profits. In addition, investors maximize returns, leading to the underproduction of food leading to waste, overuse of natural resources and overconsumption of unhealthy food (Gemill-Herren et al., 2021).

In summary, externalities form a significant barrier to the transition to sustainable food systems. It is difficult to imagine how policies aiming to foster sustainable food systems will be successful in an economic system where the erosion of natural capital, breaches of human rights, and unhealthy food are permissible and strongly incentivized.

3. TRUE COST ACCOUNTING: REDEFINING THE VALUE OF FOOD

A first step to address externalities is to expose them and redefine the value of food. This can be realized by True Cost Accounting (TCA), a tool for the systemic measurement and valuation of environmental, social, health and economic costs and benefits to facilitate sustainable choices by governments and food system stakeholders (Baker et al., 2020; Gemmill-Herren et al., 2021). TCA can serve different purposes, where different actors have different applications (Baker et a.l, 2020):

- *Governments* can integrate TCA into local, national or regional policy and budgeting. For example, Brazil, China, Columbia, India, Indonesia, Kenya, Malaysia, Mexico, Tanzania, and Thailand have applied TCA through the TEEBAgriFood framework's participatory process to bring stakeholders together to identify agricultural land-use policies that would benefit from the valuation of ecosystem services (Baker et al., 2020). An interim TCA assessment in Indonesia contributed to agroforestry being included in the country's 2020 five-year development plan (Baker et al., 2020).
- *Businesses* can use these structured assessments to minimize negative impacts and enhance positive benefits across value chains (Serafeim et al., 2019; WBCSD, 2021a). Companies can use TCA to produce impact statements or impact weighted

accounts (monetized, multi-capital, multi-stakeholder accounts of all material business impacts, including true costs and benefits) (Baker et al., 2020) and manage their externalities (NCC, 2016; Impact Institute, 2020) .
- *Financial institutions* use TCA for reporting, impact investment and risk assessment (WBCSD, 2021; Impact Institute, 2020), and obtain assurance on their published impact statement (Schramade, 2020).[2]
- *Farmers* can use TCA as a means to account for the costs and benefits of their agricultural practices (Jones, 2020). Various initiatives recognize farmers, peasants, indigenous peoples, pastoralists, and other food producers as important stewards of biocultural landscapes (Baker et al., 2020; Gemmill-Herren, 2021).
- *Consumers* can use TCA to become aware of the environmental and social externalities embedded in the food they buy (Lord, 2020). Many labelling schemes incorporate TCA information to strengthen the transparency they provide to consumers (Gemmill-Herren, 2021).

TCA recognizes that the economy's productive assets extend beyond the assets currently accounted for and include natural, social and human capital (TEEB, 2018; Dasgupta, 2021). A TCA assessment can be done at different levels: a food system, a policy, a region, an organization, an investment or a product (Baker et al., 2020). An overview of the approach and tools available is presented in Annex 1.

A TCA assessment typically starts by identifying the goal and scope of the assessment, establishing the unit of analysis and the system boundaries. Then various externalities are assessed (qualitatively or quantitatively), valued and aggregated (NCC, 2016; TEEB 2018; Impact Institute 2019). It should be noted that the maturity of methods and data to measure, value and attribute externalities varies greatly. The quantification of carbon emissions is relatively mature, whereas the quantification of health externalities is quite young and involves substantial uncertainty (Gemmill-Herren, 2021).

There is limited information available at this scale due to the young nature of TCA, the complexity of food chains and the large variety of disciplines and data required. Although TCA results will never be perfect or entirely objective, TCA provides actors in the food chain with much better information about the value of food than they currently have. However, given the ubiquity of externalities, the complexity of TCA, and the significant interests involved, actors in food systems need an abundant supply of affordable, comparable and reliable TCA information.

Available estimates (FOLU, 2019) approximate the external costs of the global food system due to GHG emissions at 1.5 trillion (2018) USD, other 'natural capital costs' at 1.7 trillion USD and "Pollution, Pesticides & Anti-Microbial Resistance" at 2.1 trillion USD. The 2019 FOLU study estimated health costs due to obesity at 2.7 USD in that study. An exploratory calculation by van Nieuwkoop (2019) estimated the annual external costs of the food system to be at least 6 trillion USD. A study by FAO (2015) estimated the natural capital costs of crop production at around 1.15 trillion USD. The results of other available estimates are presented in Annex 2.

4. REDESIGNING THE ECONOMICS OF FOOD: TRUE PRICING

Once we understand the true cost of food, food system transformation requires a redesign of the economics of food through true pricing - the integration of externalities in prices. An effective redesign of the economics of food based on TCA should address market and policy failures. True pricing addresses market externalities and is an essential complement to other policies such as social protection needed to remedy other market failures. True pricing complements other public policies (such as redistributive systems) by limiting the harm caused by negative externalities. True pricing can incentivize the private sector to provide more beneficial externalities from healthy, sustainable food production and consumption. True pricing can also limit social injustice and address some of the causes of cultural and political conflict. In addition to true pricing, active management by governments of systemic public goods, such as food security, infrastructure, the total stock of biodiversity, and stability, is needed.

A major challenge is putting theory into practice: how to reliably measure, trace and account for externalities

2 A report by the Harvard Business School found that by 2019, at least 56 companies worldwide had disclosed monetized information about their impact, of which five were in the food sector (Serafeim et al., 2019). By 2021, around ten food multinationals are members of the Capitals Coalition (CC, 2021b), and various leading multinational participate in WBCSDs True Value of Food project (WBCSD, 2021b).

throughout the entire value chain of food products. For a long time, this was simply impossible. For more than a century, economists have recognized that the solution to externalities is their internalization in prices (Pigou, 1920; Laffont, 2017). However, in practice, internalizing externalities has been elusive to economists and policy-makers due to the impossibilities of (i) quantifying and pricing externalities, (ii) creating political support for pricing externalities and (iii) measuring and accounting for externalities (Gemmill-Herren, 2021).

However, modern advances in technology have changed this by expanding the options and reducing the costs to store, communicate, validate, and process information (Gemmill-Herren et al., 2021). Recent advances in digital technology, environmental science and economics may allow businesses and governments to apply TCA and true pricing. This presents a major opportunity to support the transition to sustainable food systems. Some of these advances include:

- TCA has provided the science to quantify and price externalities, albeit with uncertainties, as discussed in the previous section.
- Key advances in technologies to measure environmental observables have increased the availability of up-to-date primary data about the effects of economic activity on environmental resources. For example, with satellite technologies, it is possible to monitor deforestation (Finer et al., 2018) or agricultural irrigation water use (Foster et al., 2020) in near real-time.
- Modern sensor technologies, in principle, allow for ubiquitous, low-cost automatic measurement of emissions (Maag et al., 2018).
- The tracing of primary non-financial information across the value chain has been facilitated by widely accessible information technology and can currently be done through identity preservation, segregation, mass balance and book-and-claim traceability systems (Mol & Oosterveer, 2015).
- Distributed ledger technologies have the potential to address both traceability and control by providing in real-time a clear and immutable audit trail for externalities data in a blockchain network shared by all actors in the value chain (Demastichas et al., 2020). Over 50 blockchain studies in agriculture and foods from bananas to salmon and pork are now available. Demastichas et al. (2020) found over twelve commercial solutions in a recent review.
- 'Big data' technologies – primarily leveraging existing scientific and statistical models with more significant memory and computational capacity – are currently being used to estimate externalities (Song et al., 2018), leading to various databases (UNEP, 2020). As primary data is currently still very scarce, developing the technologies and building databases are essential in the near future. Nonetheless, they will require an unprecedented level of international cooperation, including both public and private sectors.

Scientific insight corrects long-standing tenets that pricing externalities reduce purchasing power and that consumers and citizens are not interested in externalities. Citizens and consumers are interested in externalities. Modern research in behavioral economics and consumer science shows that the majority of people are not selfish but have (conditional) pro-social preferences (Fehr & Fischbacher, 2003) and are interested in sustainability, but price plays a foundational consideration in consumption choices (White et al., 2020; PwC, 2020). In addition, recent political science research is uncovering empirical evidence that revenue recycling could lead to majority support for environmental taxation (MacGrath et al., 2019). By better aligning taxation and subsidies with externalities, true pricing can reduce distortionary taxes and make subsidies more efficient (Freire-Gonzalves, 2018).

As a result of the scientific and technological progress, cases of true pricing by market players have emerged in the past years:

- Various food producers, traders and farmers have used it to make their production more sustainable and involve their customers in the price implications (Eosta 2017; Tony's Chocolonely, 2018; True Price 2020c).
- A small number of retailers have used it to provide transparency (Penny's, 2020) about the true price or even charge for it (Time, 2021).
- A fairtrade certifier uses true pricing to improve its value chain (Fairtrade International, 2019).
- Even governments have started to use it. For example, the Dutch Competition Authority allows true pricing as a criterion to justify sustainability collaborations (ACM, 2020).

These cases show that true pricing is possible but represent a small number of early adopters. For true pricing to actually solve the global problem of true costs, it should be implemented at scale throughout global food systems.

Table 2 Pathways for true pricing

Pathway type	Pathway
Market-based	1. The provision of transparency about true prices of products by businesses. 2. The purchase of products with lower true costs due to sustainable consumption. 3. The reduction of true costs by businesses through more sustainable production. 4. The payment of environmental costs by market players to restore damages to natural capital. 5. The respect by businesses of human rights and remediation of breaches where they occur.
Regulatory policies	6. Mandatory transparency of externalities of food products enforced by governments. 7. The incentivization of healthier and more sustainable food through taxes and subsidies by governments to incentivize businesses to produce sustainable products and enable consumers to buy them. 8. The enforcement by governments of the restoration of natural capital and the respect of human rights along the value chain of food products.
Income policies	9. The establishment and enforcement of labor prices (living wages and income) and minimum income (such as a basic income) that guarantee access to healthy and sustainable diets for all. 10. Ensuring an equitable distribution of the collective benefits of true pricing, including savings in public expenditures on healthcare and environmental mitigation.

Various pathways can be identified for its implementation (True Price 2020; Gemmill-Herren, 2021). Market-based pathways can significantly internalize externalities by enabling the expression of pro-social preferences in market choices and creating endogenous market incentives. See Table 2 for some of these pathways. Nonetheless, given the profit motive of businesses, consumers' budgetary constraints and the conditional nature of pro-social preferences, government intervention and international frameworks and agreements are likely required to fully internalize externalities.

Governments can establish 'first-best' true pricing mechanisms, which are welfare-efficient and equitable in the long term. First-best mechanisms would entail an optimal combination of regulatory and income policies. Regulatory policies would have a primary purpose to provide incentives and safeguards for market-based pathways. However, international trade regulations are a constraint to such change. The World Trade Organisation (WTO) rules impose economic competition strictly based on prices and do not consider externalities.

Income policies would ensure that people have sufficient income to buy healthy diets and no significant inequalities arise by the shift in production and consumption patterns. However, current trends in inequalities show this is unlikely without structural changes (transitioning from low productivity and labor-intensive economic activities to higher productivity, sustainable and skill-intensive activities) across all sectors, far beyond changes in food systems only. Moreover, there are numerous factors in current food systems which need to be considered, including agricultural specialization with some regions having converted to cash crop monocultures and others to intensive livestock, large dependencies in the access to modern agriculture. Agroecological systems are more likely to provide diversified food (contributing to healthy diets) with a lower environmental footprint. However, in some cases, organic farms have relatively large emissions of GHGs per unit product. True pricing would need to be deployed with strong policies supporting large structural changes in agriculture.

First-best true pricing mechanisms could support fully sustainable food systems:

- affordable, healthy diets with a small environmental footprint;
- all people participating in the economy would have access to healthy food baskets; and
- human rights would be respected and nature would be conserved.

However, there remain substantial technological and political constraints to implement first-best mechanisms (e.g. OECD, 2006). Applying the first-best true pricing mechanisms also requires:

- building technological infrastructure to collect and trace externalities along the value chain,
- modernizing the implementation of fiscal systems,
- integrating true pricing into international trade agreements and
- creating popular understanding and support for true pricing.

Therefore, governments could adopt pragmatic 'second-best' true pricing policies that take these constraints into account in the short run. Second-best policies effectively incentivize sustainable, healthy and affordable food without imposing significant administrative burdens or complexities. The most suitable mechanism for each country will also be context-dependent and country-specific. Some examples of potential policies that create smart incentives are the following:

- Subsidize healthy and sustainable food products for consumers, financed by eliminating distorting or inefficient subsidies or a carbon tax on carbon emissions by businesses.
- Stimulate true pricing through public procurement, prioritizing foods with low external costs.
- Integrate true pricing in risk and capital regulation by central banks.

A recent study by the World Bank found that agricultural subsidies were 30% of the total agricultural value-added, only 9% of which explicitly supports environmental conservation in OECD and eleven major developing countries (Searchinger et al., 2020). Afshin et al's. (2017) meta-study on studies in high-income countries found that, on average, a 10% decrease in price increased the consumption of healthful foods by 13%. In addition, there is recent evidence that fiscal incentives decrease the amount of cognitive control required to buy healthier food, suggesting it is possible to "titrate the amount of tax reductions and rebates on healthy food items so that they consistently become more preferable than unhealthy foods" (Banerjee et al, 2020). Given that price elasticities are much higher for low-income households and countries (Muhammed et al., 2017; Sassi et al. 2018), the effects of price reductions are expected to be much more extensive for low-income countries and lower-income individuals in advanced economies.

Both the design of pragmatic second-best and optimal first-best true pricing mechanisms need to be informed by data. The findings of the working group's analyses are presented in sections 5 and 6 already as an exploratory illustration of how such mechanisms could work.

5. ESTIMATING THE TRUE COSTS OF FOOD SYSTEMS IN THE CONTEXT OF THE UNFSS ASPIRATIONS

A novel analysis was conducted by a working group of the UNFSS Scientific Group to estimate the true costs of the current food system and estimate the costs of changes towards a more sustainable food system. The work brought together diverse sources of data and approaches. The core unit of analysis was the global food system, consisting of global food consumption and production, divided by country and food group. The environmental and health externalities (listed in Table 3) were estimated based on the externalities for which data were available at this scale and level of granularity. The current analysis excluded economic externalities, social externalities, some environmental externalities (soil degradation, depletion of non-renewable resources, land use other than cropland, overuse of renewable resources and other air pollutants than NH3), and health costs such as antibiotic resistance, zoonoses and undernutrition as well as productivity losses due to disease. Although these are important sources of externalities, time, data availability, data coverage and compatibility limited the inclusion of these costs. In particular, the requirement that data be available per food group excluded many externalities.

The value chain scope for environmental externalities was primary production, feed for animal products, inputs such as nitrogen and phosphate. Transportation, processing and food preparation costs were not considered in the analysis. Previous studies have shown

Table 3 Data included in the study

Type of externality	Externality	Endpoint impact(s)
Environmental	GHG emissions Nitrogen water pollution Phosphorus water pollution Scarce blue water use Land use Air pollution (NH_3)	Contribution to climate change Biodiversity loss Biodiversity loss Depletion of scarce water Biodiversity, ecosystem services Mortality and disability
Health (Human life)	Contribution to cardiovascular diseases Contribution to diabetes mellitus type 2 Contribution to neoplasms (cancers)	Mortality Mortality Mortality
Health (economic costs)	Contribution to cardiovascular diseases Contribution to diabetes mellitus type 2 Contribution to neoplasms	Medical costs, informal care, lost working days Medical costs, informal care, lost working days Medical costs, informal care, lost working days

the vast majority of environmental externalities are in the primary process (FAO, 2015; Baltussen, 2017).

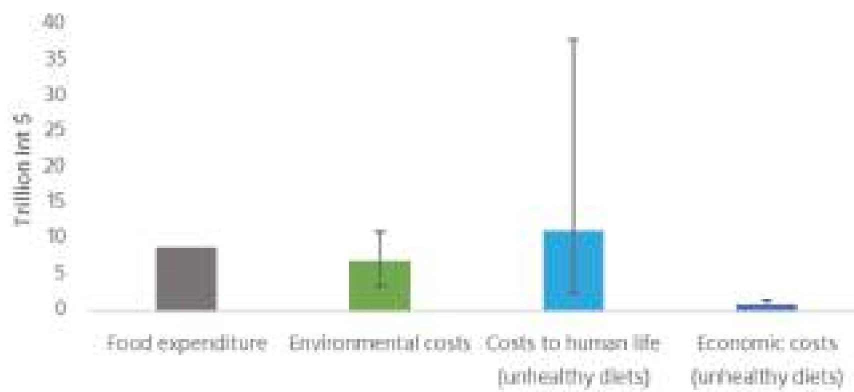
Many data sources and methods were used to quantify the externalities, including Afshin et al. (2019) and Springmann et al. (2018a) to quantify the health impacts and Pozzer et al. (2017), Schipper et al. (2018a), Willet et al. (2019) and WWF (2020) to quantify the environmental impacts. The effects were modeled per food group as set out in Willet et al's. (2019) health reference diet. Consumption per food group was based on expenditure. Production was based on production data per country and food group but is presented here as an aggregate for the world. The environmental effects of imports were based on a global average of the environmental effects of exports per food group.

The monetization of environmental externalities was based on country-level monetization factors for restoration and compensation costs. The methodology adopted has been described by Galgani et al. (2021) and True Price (2020b). A single median global value was used to monetize the loss of human life, based on a meta-study by the OECD (2012) on the value of a statistical life. An average value was used to estimate the direct and indirect economic effects of health loss.

The true annual cost of food was estimated to be around 7 trillion USD (range 4-11) for environmental costs, 11 trillion USD (range 3-39) in costs to human life and 1 trillion USD (range 0.2-1.8) in economic costs (Figure 1). The annual estimate is based on the most recently available data.

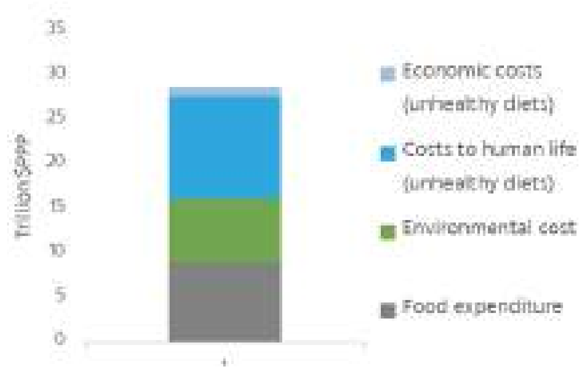
Figure 2 shows that the mean estimate for the total cost of food was 29 trillion USD per year. Given that the current cost of food at current market prices is 9 trillion USD, the results show that the true cost of food is disproportionally high. There is substantial uncertainty in the estimates, particularly for the health costs as impact pathways have not been extensively studied. The counterfactual is not self-evident and externalities relate more to diets than to products. In addition, it should be stressed that this is not a complete picture, as some relevant externalities are not yet included, as indicated above.

Figure 1 The annual true cost of food for the globe



Note: the bar represents the range of possible costs.

Figure 2 Mean estimate of the total annual true cost of food including the external costs in scope of the analysis



Note: This estimate excludes relevant externalities and estimates of included externalities include uncertainty.

Among the highest environmental costs are GHG emissions leading to climate change, land use and land use change leading to loss of ecosystems and biodiversity, and air pollution leading to, among others, loss of biodiversity and human health (Figure 3).

Figure 4 shows the breakdown of the diet-related deaths related to unhealthy food systems, which drives both loss of human life and economic costs of healthcare. The most considerable contribution is due to cardiovascular diseases. Note that the health costs are borne by the current population, whereas a significant part of the environmental costs will be carried by future generations (IPCC, 2014).

These findings align with previous studies in terms of order of magnitude, including those of the FOLU (2019) study. A major methodological difference with the FOLU (2019) outcomes is that the FOLU (2019) study was based on global estimates of the food sector. In contrast, the current analysis is based on a breakdown per country and food group. Van Nieuwkoop's (2019) estimate included fewer impacts and impact pathways than used in this study and intended to provide a first estimate of a lower boundary of the external costs. The current results for land use change align with the FAO (2015) estimate of natural capital costs of crop production (although the scopes are somewhat different).

It should be noted that there is substantial uncertainty in these as well as other existing estimates of the external costs of food, due to (i) an incomplete coverage of impacts, (ii) major uncertainties in primary data, (iii) uncertainties in trade data, (iv) uncertainties in the modeling of impact pathways and (v) uncertainty in the monetization of external costs. An uncertainty range was created for the results based on footprint and valuation uncertainty. Given that not all uncertainties can be captured and not all sources quantify their uncertainty, the ranges should be interpreted comparatively.

Figure 3 Breakdown of the annual environmental cost of food systems

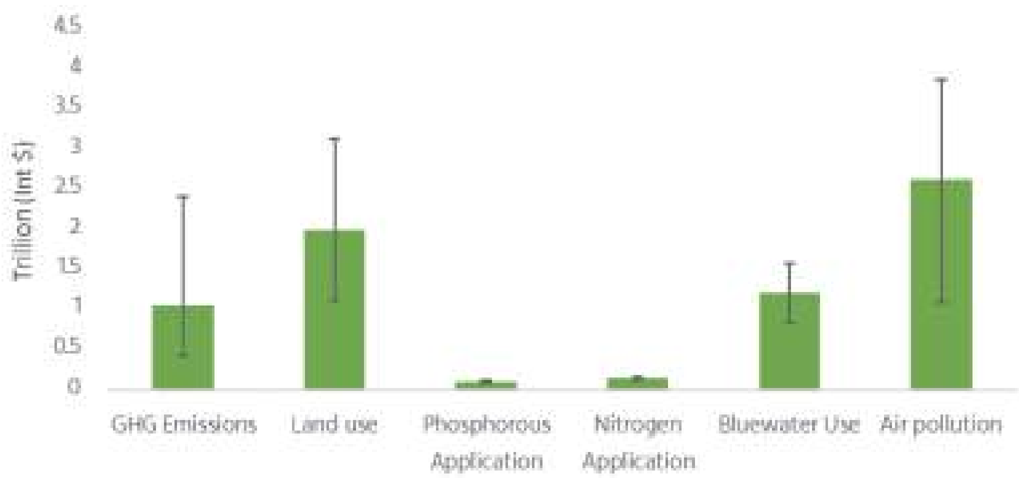
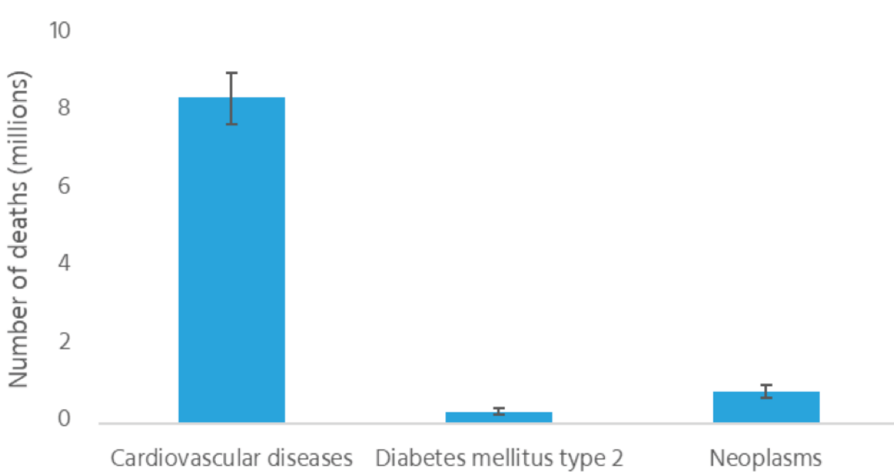


Figure 4 Breakdown of annual diet-related deaths



Environmental impact pathways that have high uncertainty include biodiversity and pollution. Quantifying and valuing the health impacts of diets is a novel field, and methodological choices around attribution, the rationality of consumers, the reference scenario and the valuation of a statistical life affect the estimates. No quantified dietary guide is currently available to support the analysis of achieving the ambitions of the UNFSS. This is an area that requires more attention and quantification.

Further research is required to include relevant externalities related to undernutrition (which ultimately affects human productivity and incomes), zoonoses, antimicrobial resistance (AMR), productivity losses due to diseases, soil degradation, land use other than cropland, and depleted resources. In addition, it is important to add social costs such as underpayment of workers, underearning of farmers, child labor and harassment throughout the value chain.

6. POTENTIAL BENEFITS OF TRANSITIONS TO MORE SUSTAINABLE DIETS

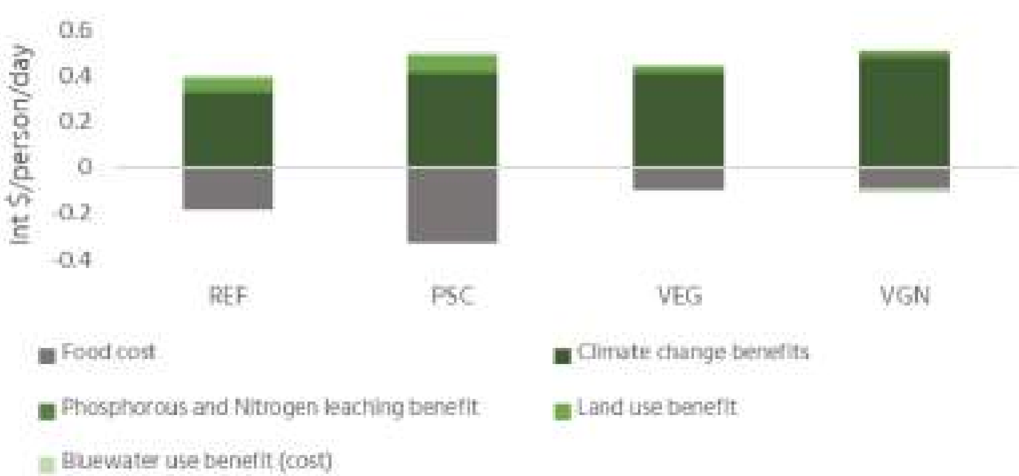
Effective policy interventions to redesign the economics of food also require an understanding of the effects of possible transitions on environmental and health externalities as well as affordability. Such interventions involve realizing multiple goals and making trade-offs, which can be managed by developing well-planned transition pathways, careful monitoring of key indicators, and implementing transparent science targets at the local level (Herrero et al., 2021).

Hence, in addition to estimating current global external environmental and health costs of food, the working group also explored the potential benefits on health and environment of dietary shifts and their implications on affordability. Due to a lack of availability of recent international dietary guidelines, the analysis used the only available EAT-Lancet alternative diets (Springmann et al., 2018). The working group in no way promotes these as recommended diets. The EAT-Lancet's recommended dietary patterns were based on the assumption that plant food production is more environmentally sustainable compared to animal food production, primarily based on considerations of land and water use, energy conversion and greenhouse gas emissions. However, these recommended diets do not consider differences in protein quality and nutrient bioavailability (Moughan, 2021). Nonetheless, the EAT-Lancet pescatarian, vegetarian and vegan diets offer a comparison to a healthy reference diet.

For illustrative purposes, the analysis of shifting consumption patterns to align with these four dietary alternatives showed that significant gains could be achieved in reducing environmental and health costs (Figure 6). However, these shifts do increase the average cost of food, albeit at a small fraction of the gains.

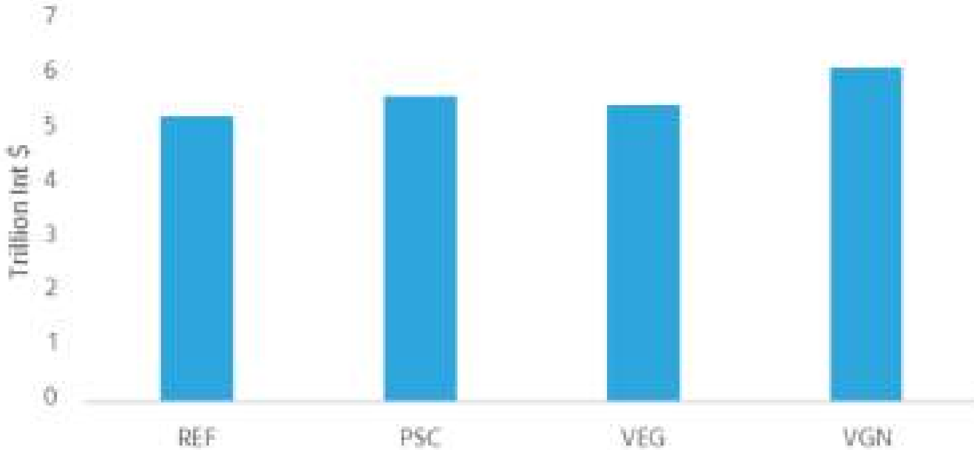
The health benefits of global dietary shifts are potentially substantial (Figure 7). Ensuring the affordability of (healthy) food for all requires detailed analysis about how any interventions affect the poorest groups in society. The current analysis does not cover the distributional effects of dietary shifts. This represents a critical area for future research.

Figure 6 Costs and benefits of potential dietary shifts



REF= Healthy Reference diet, PSC = pescatarian, VEG = vegetarian and VGN = vegan diets.

Figure 7 Health benefits of potential dietary shifts



REF= Healthy Reference diet, PSC = pescatarian, VEG = vegetarian and VGN = vegan diets.

7. STUDY LIMITATIONS

The methodology applied to estimate the true costs of the global food system and alternative diets has the following limitations:

- The environmental cost of dietary shifts did not take household food waste into account. The results were based on dietary guidelines for consumption.
- All scenarios were based on the environmental footprints per kg of product in the current system. Potential reductions in footprints due to a change in cultivation techniques were not taken into account.
- For the land use of animal products, pastureland was not included. The biomes used for growing the feed and the mean species abundance of the land used were determined from global averages of these data for products frequently used as feed (mainly cereal products). For processed food products such as vegetable oils and sugar, the biomes used and the mean species abundance were estimated by averages within the country.
- Air pollution emissions referred to the agricultural sector as a whole, and not only food production.
- The impact of food safety on human health and food waste has not been considered but is a cause of significant disease and mortalities.
- The effect of food production on AMR was not covered in the analysis. According to the AMR review (O'Neill 2016), each year at least 700,000 deaths are caused by AMR, which corresponds to a cost of 2.3 trillion USD using the same valuation approach as for other health impacts in this study. A substantial part of this should be due to food production, but it is currently unclear how much.
- The bioavailability and quality of protein and nutrients were not considered in the dietary shifts but is an important consideration for future research.

8. TOWARDS SCIENCE-BASED AND PRAGMATIC TRUE PRICING MECHANISMS

In a fully sustainable food system, all people can afford healthy and sustainable food. If the damage to nature is paid for and restored in a sustainable food system, food production costs will increase. Internalizing the environmental costs would significantly reduce the environmental footprint by providing an incentive to avoid or reduce such costs in the first place, albeit at a cost to producers. A corrected price mechanism may nudge producers and processors to produce food in a more sustainable way to the benefit of the producers themselves. Those stakeholders that are already more sustainably producing healthy foods will have a comparative competitive advantage.

In addition, paying minimum wages and ensuring adequate incomes for all workers in the food value chain would further increase the cost of food. At the same time, the realized benefits in human lives would be around 5 trillion USD and the economic savings, mainly through public health care expenditures, around 0.5 trillion USD. With true pricing, substantial savings in public expenditure can be realized through lower health care costs, avoided environmental mitigation measures (such as climate change) and the reduction of subsidies. These savings could be sufficient to make food cheaper than it is now, even after environmental and social costs are internalized, although further research is required.

There are currently substantial constraints to realizing the first-best true pricing mechanisms (see Table 2). More fundamental and applied research must include all aspects of externalities and generate appropriate data to do these analyses. Therefore, efforts should focus on supporting market-based pathways and pragmatic second-best true pricing policies in the short term. These policies effectively incentivize sustainable, healthy and affordable food without imposing enormous administrative burdens or complexities. Nonetheless, they also need to support structural changes in agriculture, food industries and international trade.

Suppose governments would like to incentivize a transition to the reference diet analyzed in 5 and 6 to reap the environmental and health benefits. In this case, the reference diet would, on average, be 6% more expensive than the current global consumption pattern and less affordable for many. A second-best true pricing mechanism could focus on making this diet 10% cheaper. In global terms, this would cost at most 1 trillion USD. This could, for example, be financed by a carbon tax on businesses or partly funded by reducing existing inefficient or less efficient subsidies.

Such a policy change may not cost taxpayers anything while making healthy diets more affordable and contributing to the achievement of the Paris agreement. Depending on the success in shifting dietary patterns, the shift could reduce the environmental costs of the food sector by 0.1- 1 trillion USD per year and create health savings of 0.7-5 trillion USD. It should be noted that these are speculative estimates and further research should explicitly model behavioral, market and ecological effects and interactions. In addition, any policy should be focused on country-level data. Nonetheless, substantial benefits can be realized with a relatively simple intervention that (i) does not require measuring all externalities of food products in the short run and (ii) would presumably be popular as it reduces the price of healthy food.

9. RECOMMENDATIONS

Given the high costs to the environment and human health presented in these findings, it is essential that UNFSS stakeholders actively identify externalities that represent ‘hidden costs’ in the food system and those that ignore or incentivize unsustainable and unhealthy food systems. These costs need to be quantified through TCA practices and pathways identified to reduce or eliminate these externalities through policies that: (i) internalize externalities and (ii) sanction those food system stakeholders who do not take appropriate steps to reduce and internalize these costs and/or incentivize those who do. Estimating the full scope of these costs is a priority to determine if such an adjustment to the food system would increase food prices to a point where a reassessment of poverty lines is necessary to ensure access to healthy diets for the poorest.

In the short term, policy-makers can remove the barriers for stakeholders to engage in TCA and use TCA data to redefine the value of food to reflect its true costs and benefits. In particular, governments and other UNFSS stakeholders can:

- **Foster internationally accepted harmonized TCA principles across all applications.** Together experts, practitioners and stakeholders from all fields in food and agriculture harmonized TCA principles can be developed to ensure validity and comparability of results and alignment between the various levels.
- **Educate and build capacity among professionals in business and government about TCA.** Build the new discipline of TCA it is important. Harmonized principles are necessary to bring experts and practitioners from all fields together. In addition, TCA can be integrated into educational systems and current food professionals in government, civil society and business can be educated in TCA.
- **Provide professionals in business and governments with concrete tools to facilitate TCA.** Lowering the entry barriers of professionals to the complex field of TCA can be facilitated by providing practical skills and approaches (toolboxes) for analysis.

In the medium and long term, governments can look at ways to integrate TCA in economic metrics at all levels systematically:

- **Integrate TCA into National Accounts and GDP.** This can provide a standardized account of how much inclusive welfare (realized welfare and changes in wealth) was created. This would provide a much better view of how the food sector contributes to welfare.
- **Integrate TCA into business sustainability reporting and controls.** By adding TCA information into their internal and external financial reports, businesses can compile impact-weighted accounts and impact statements, enabling them to report and manage the value they create to all stakeholders via all capitals.
- **Integrate TCA into product labeling.** Products can show their true costs to their customers (in monetized terms), as well as their true value (in monetized terms or otherwise).

In the short term, policy-makers could redesign the economics of food via true pricing by focusing on:

- **Supporting market players to engage in true pricing, enabling** the expression of preferences for sustainable and healthy food into choices, and creating endogenous market incentives
- **Pursuing pragmatic second-best true pricing approaches** that create smart incentives that significantly correct the price signal without increasing food prices or imposing high administrative costs.

Governments and other stakeholders of the UNFSS could enable both market-based and second-best government-led true pricing pathways, policy-makers and other food stakeholders can work together to:

- **Establish an international measurement standard for true pricing** based on a scientific consensus process and in alignment with governments and stakeholders.
- **Develop a global true pricing** database with the true prices and true costs of food products consolidating existing scientific knowledge, providing reference values and benchmarks for the most important externalities for each agricultural and food product and each country.
- **Support SMEs and smallholder farmers** who want to sell their products at a true price to businesses and consumers.
- **Create a policy toolbox for governments** to implement short term true pricing policies based on feasibility and impact studies of various second-best true pricing policies.
- **Create a modeling toolbox** to estimate the effects of short term true pricing policies on the environment, health and affordability.

Finally, policy-makers can start to explore how first-best mechanisms for the medium term:

- **Develop science-based first-best true pricing** mechanisms based on integrated TCA assessments of the food system and sustainable mechanism design.
- **Generate a global agreement and create public-private partnerships around a roadmap to realize the SDGs by 2030 and reach fully sustainable food systems by 2050** with affordable and healthy food without environmental, social and health costs.
- **Create a technological alliance to Invest in affordable, traceable, sustainable, reliable and fair technologies to allow all market players, big and small, to implement true pricing in practice.** This includes technology, science and inclusive governance to (i) measure primary environmental, health and social impacts and (ii) reliably trace and account for the true price of food products along the entire value chain.

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ANNEX 1: HOW DOES TRUE COST ACCOUNTING WORK?

A TCA assessment can be done at different levels: a food system, a policy, a region, an organization, an investment or a product (Baker et al, 2020). For each type of analysis, various frameworks exist. A major system-level framework is TEEB for Agriculture and Food (TEEB, 2018). Recently Lord (2020) also published a methodology for food systems analysis. These frameworks can be applied at other levels. At the regional level, the UN System of Environmental-Economic Accounting provides a mature framework for natural capital valuation (SEEA, 2021). For other aspects, few well-accepted frameworks exist (Hoekstra, 2019), although inclusive wealth is a promising approach (Dasgupta et al, 2021b). Various TCA frameworks are being developed for the organizational level, often focusing on corporate reporting (Natural Capital Coalition, 2015; Value Balancing Alliance 2021; Impact Institute, 2019; HBS, 2020). Also, frameworks have been developed specifically for products such as coffee and bananas (True Price, 2020; Serafeim and Trinh, 2020; Galgani et al 2021) and investments (Addy et al, 2019; Olsen, 2020; Impact Institute, 2020).

A TCA assessment starts by defining the goal, scope and unit of analysis ('functional unit'). Consequently, the relevant externalities have to be identified. Once these externalities have been identified, they have to be assessed, qualitatively or quantitatively. Quantification starts with measuring or assessing inputs and outputs, the direct measurable effects of production and consumption (Impact Institute, 2020). These inputs and outputs can be measured using primary data. In practice, inputs and outputs often have to be estimated with macro-level models through (environmentally) Extended Input-Output and Computable General Equilibrium models (Malik et al., 2018), micro-level models such as Life-cycle accounting (LCA) (Hausschilds et al., 2018) and social LCA (Huertas-Valdivia, 2020), or through hybrid approaches (Nakamura & Nansei, 2018). Consequently, these outputs have to be translated to impacts via impact pathways (Impact Institute, 2019).

For many environmental externalities these there are databases for such pathways such as those based on Recipe (Huijbregts et al, 2016), although pathways for ecosystem and biodiversity are more complex (TEEB 2018, Dasgupta, 2021). Impact pathways for social and in particular health externalities are less mature. If the functional unit is a product, investment or organization, the final quantification step is the attribution of impact to the functional unit (Capitals Coalition, 2021; Impact Institute, 2020; VBA, 2021). This process yields quantified impacts in natural units such as CO2 equivalents, liters of scarce blue water extraction or loss Mean Species abundance for environmental externalities, full-time equivalents (FTE) of child labor, FTE of forced labor and underpayment for social externalities, and disability adjusted life years (years of life lost + years lived with a disability) for health externalities (True Price; 2020).

After externalities have been quantified, they can be valued, in monetary terms or otherwise, so that they are expressed in a common unit. To capture value not reflected in market prices, a TCA assessment requires an (implicit or explicit) measure of welfare. Although terminology differs widely in the literature, there is a wide recognition that multiple dimensions exist (Stiglitz et al., 2018) and common welfare dimensions include:

- The preference satisfaction or well-being of people (Stiglitz et al., 2018; TEEB, 2018; Dasgupta, 2021; Impact Institute, 2020).
- An equitable distribution of income and other resources (Stiglitz et al., 2018).
- Adherence to social limits such as a living wage, labor standards and the right to food security, which can be derived from human rights. (TEEB 2018; True Price 2020).
- Adherence to environmental limits, such as the conservation of climate, abiotic resources and biodiversity. These limits can be derived from planetary boundaries for a livable planet (Rockstrom et al, 2009; Stiglitz et al., 2018), the intrinsic value of nature (TEEB, 2018) and/or the rights current and future generations (True Price, 2020).

The first dimension generally coincides with traditional measures of ordinal or cardinal utility economists have used to measure collective welfare (Van Praag 1991; Galgani et al 2021). The second dimension is linked to traditional measures of income inequality such as the GINI coefficient (Bowles & Carlin, 2020). Nonetheless, these measures cannot accommodate central issues in sustainability, such as biophysical limits, human rights, social equity and intergenerational equity (Dore & Burton, 2003; Gowdy & Erickson, 2005). Hence, the valuation of environmental and social damages has met with resistance from non-economists, policy makers and civil society (McCauley, 2006). As a result, in TCA, additional welfare dimensions emerged (Stiglitz et al., 2018; TEEB, 2018; Impact Institute, 2020). Depending on the welfare dimension, different valuation methods, such as cardinal utility, abatement costs, shadow pricing or remediation costs are used (Galgani 2021). A relevant discussion point is to which degree externalities can be summed and netted. Economists would traditionally sum all positive and negative externalities into one number, whereas some TCA frameworks hold that welfare dimensions ought to be considered separately (Stiglitz et al., 2018; Impact Institute, 2019) and human rights violations or deforestation cannot be offset by an equal amount of profit for example (Capitals Coalition, 2021; True Price, 2020).

ANNEX 2: SUMMARY OF ESTIMATES OF PREVIOUS STUDIES FOR EXTERNALITIES AND FOOD SYSTEMS CHANGES

Problem	Estimated costs of current externalities	Estimates of magnitudes of change
Food systems as a whole	Inefficiencies and environmental and health social costs of the global food system $11.9 trillion vs an estimate of the market value of the global food system $10 trillion in 2018: • $1.5 trillion from greenhouse gas emissions • $1.7 trillion from natural capital loss • $2.7 trillion from obesity-related costs • $1.8 trillion from under-nutrition-related costs • $2.1 trillion from pollution, pesticides and antimicrobial resistance • $0.8 trillion from rural welfare losses • $1.3 trillion from food loss and waste and fertilizer leakage (FOLU, 2019)	
Biodiversity loss	• Food production contributes to 60%-70% of total global biodiversity loss (Baltussen et al., 2016, Westhoek et al., 2016). • The loss of wetlands since 1970 has been estimated at about 35% globally (Darrah et al., 2019). • Food systems have created about 24% global forest disturbance (Curtis et al., 2018).	
Depletion of fish stocks	• Commercial fishing is estimated to deplete fish stock by 61% (Westhoek et al., 2016).	
Emissions of greenhouse gases such as carbon dioxide, nitrous oxide and methane	• 13 percent global emissions from agriculture, other than from land use change (Nkonya et al., 2016) and cost USD 0.27 trillions or 49.1 GT CO2 at $ 40/ton (van Nieuwkoop, 2019). • The diet-related social cost of GHG emissions related to current food consumption patterns are estimated to be around USD 1.7 trillion for 2030 for an emissions-stabilization scenario (FAO et al., 2020). • The social cost of carbon is USD 128 per ton CO2 (Baltussen et al., 2016). • Less than one-third of the costs are associated to CO2-eq emissions (Lord, 2020).	• Adoption of organic agriculture, vegan and vegetarian diets to reduce greenhouse gas emissions possibly by 41-74% in 2030 (Marchetti et al., 2020; FAO et al., 2020).
Food loss and waste	• Food waste contributes to about 3–5 % of global warming impacts, more than 20 % of biodiversity pressure, and 30 % of all of the world's agricultural land (Allen & Prosperi, 2016). • Food loss and waste greenhouse gas emissions of meat (poultry, bovine, goat, mutton, and swine) is estimated at 34–38% of all agricultural production-phase greenhouse gas emissions (Porter et al., 2016).	• Environmental and social externalities attributed to the production and purchasing of food that is not consumed (food loss and waste) estimated 1 trillion per year at 2012USD of financial losses and estimated external costs from the lost and wasted food as USD 700 billion for environmental externalities and USD 900 billion (b) for social externalities per year – including USD 394b from GHG emissions, USD 396b from conflict and 333b in lost livelihoods (FAO, 2014).
Food safety (including antimicrobial resistance) and poor food quality	• Economic loss due to insufficient food safety equates to 0.11 (USD trillions)per annum (Jaffee et al., 2019).	

Problem	Estimated costs of current externalities	Estimates of magnitudes of change
Inadequate diets and malnutrition (undernutrition, micronutrient deficiencies and overweight and obesity)	• Globally, diet-related health costs are projected to reach USD 1.3 trillion per year in 2030 (FAO et al., 2020). • More than half (57 percent) of these are direct healthcare costs as they are associated with expenses related to treating the different diet-related diseases (FAO et al., 2020). • In the UK, every £1 spent on food products generates 50 pence in externalities on healthcare systems alone (and £1 in total external costs) (Sustainable Food Trust, 2017). • Current food consumption patterns, health costs are projected to reach an average of USD 1.3 trillion in 2030. 43 percent accounts for indirect costs, including losses in labor productivity (11 percent) and informal care (32 percent) (FAO et al., 2020).	• Springman et al. (2016) estimated the economic benefits of improving diets to be 1–31 trillion US dollars, which is equivalent to 0.4–13% of global GDP in 2050. • Adoption of global dietary guidelines (HGD) would result in 5.1 million avoided deaths per year [95% confidence interval (CI), 4.8–5.5 million] and 79 million years of life saved (CI, 75–83 million) (Springman et al., 2016). • Transitioning towards more plant-based diets that are in line with standard dietary guidelines could reduce global mortality by 6–10% and food-related greenhouse gas emissions by 29–70% compared with a reference scenario in 2050 (Springman et al., 2016). • Using the cost-of-illness approach, we estimate that the health-related cost savings of moving to the diets based on dietary guidelines (HGD) from that assumed in the REF scenario will be 735 billion US dollars per year ($735 billion·y−1) in 2050 with values in the range [based on uncertainties in the cost transfer method (Methods)] $482–987 billion·y−1 (Fig. 2). (Springman et al., 2016). • About two-thirds of the savings (64–66% across the non-reference scenarios) were due to reductions in direct health care-related costs, one-third (31–33%) to less need for unpaid informal care (although this figure is an underestimate because we were unable to obtain estimates of the indirect costs of diabetes), and a small fraction (3–4%) to reduced productivity from lost labor time (Springman et al., 2016). • Transformation to healthy diets by 2050 will require substantial dietary shifts, including a greater than 50% reduction in global consumption of unhealthy foods, such as red meat and sugar, and a greater than 100% increase in consumption of healthy foods, such as nuts, fruits, vegetables, and legumes. However, the changes needed differ significantly by region (Willett et al., 2019). • If any of four alternative diet patterns (FLX, PSC, VEG, VGN resented in the FOA et al., 2020 SOFI report) are adopted, diet-related health costs decrease by USD 1.2–1.3 trillion (95% of the diet-related health expenditure) by 2030 (FAO et al., 2020). • Adoption of any of the four alternative healthy diet patterns set out n FAO et al., 2020) that include sustainability considerations could potentially contribute to significant reductions of the social costs of GHG emissions, ranging from USD 0.7 to USD 1.3 trillion across the four diets (41–74 percent) in 2030 (FAO et al., 2020).
Land degradation	• Food systems contribute to 33% of degraded soils (Westhoek et al., 2016). • Cropland soils have lost 20-60% of their organic carbon content due to land degradation; land degradation affects 1.3 to 3.2 billion people living in poverty in developing countries (Dalin & Outhwaite, 2019). • The annual total natural capital cost of livestock systems in terms of resource use and pollutant emissions is as follows: beef production is USD 1.5 trillion, dairy milk production USD 0.5 trillion and poultry meat production is USD 0.26 trillion (Baltussen et al., 2016).	

Problem	Estimated costs of current externalities	Estimates of magnitudes of change
Land use change	• Land use and land use change, including peatland degradation and deforestation lead to greenhouse gas emissions of 8-10% (FAO et al., 2020). • Average Ecosystem Service Value lost per hectare converted to beef production estimated at USD 1,837 per hectare (Baltussen et al., 2016). • Economic loss due to land use and land cover change in terrestrial ecosystems equates to 0.33 annually (Nkonya et al., 2016) and 0.41 percent of 2018 global GDP (van Nieuwkoop, 2019). • 25 percent of land was degraded due to poor management practices (Nkonya et al., 2016, #) equating to USD0.20 trillions or 0.25 percent of 2018 global GDP (van Nieuwkoop, 2019). • Carbon emissions due to land use changes are estimated to range from US$ 15-24 billion (Baltussen et al., 2016).	
Soil degradation and erosion	• Accelerated soil degradation has reportedly affected as much as 500 million hectares (Mha) in the tropics, and globally 33% of the earth's land surface is affected by some type of soil degradation. • Approximately 33% of soils are moderate to highly degraded due to erosion, nutrient depletion, acidification, salinization, compaction and chemical pollution (Westhoek et al., 2016).	

This Report was prepared by members of the Scientific Group and members of its Research Partners.