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REPURPOSING AGRICULTURAL POLICIES AND SUPPORT

Options to Transform Agriculture and Food Systems to Better Serve the Health of People, Economies, and the Planet

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REPURPOSING AGRICULTURAL POLICIES AND SUPPORT

Options to Transform Agriculture and Food Systems to Better Serve the Health of People, Economies, and the Planet

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ACRONYMS AND ABBREVIATIONS

AEZ	Agroecological zone
ALU	Agricultural production and land use
BCA	Border carbon adjustment
CAP	Common agricultural policy (European Union)
CES	Constant elasticity of substitution
CET	Constant elasticity of transformation
CFS	Committee on World Food Security
CGE	Computable general equilibrium
CO_2eq	Carbon dioxide (CO_2) equivalent
COP26	Twenty-Sixth Conference of the Parties of the UNFCCC (2021)
CoSAI	Commission on Sustainable Agriculture Intensification
CSA	Climate-smart agriculture
EC	Emission coefficient
EMDE	Emerging market and developing economies
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FOLU	Food and Land Use Coalition
FSIN	Food Security Information Network
GDP	Gross domestic product
GFR	Gross farm receipts
GHG	Greenhouse gas
GI	Green innovation
GNI	Gross national income
Gt	Gigatons
HLPE	High Level Panel of Experts (of the CFS)
IDB	Inter-American Development Bank
IFA	International Fertilizer Association
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change (United Nations)
IO	International Organizations Consortium
LES	Linear expenditure system
LUC	Land-use change
MAFAP	Monitoring and Analyzing Food and Agriculture Policies (FAO)
MToE	Million tons of energy use
NDC	Nationally determined contributions (UNFCCC)
NRA	Nominal rate of assistance
NRP	Nominal rate of protection
OECD	Organisation for Economic Co-operation and Development
PPP	Purchasing power parity
R&D	Research and Development
TFP	Total factor productivity
UNCAS	UN Climate Action Summit
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNFSS	United Nations Food Systems Summit
WDI	World Development Indicators
WTO	World Trade Organization

Note: $ refers to US dollars.

FOREWORD

Providing nutritious and affordable food for a growing global population while protecting the vital natural systems that sustain life is one of the critical challenges of our times. Current agricultural practices have yielded impressive productivity gains, but are increasingly associated with high greenhouse gas emissions, biodiversity loss, and chronic disease, while leaving many rural people who depend on farming in poverty.

How can agricultural support policies be repurposed to make the food system deliver better outcomes? This was the broad question the World Bank and the International Food Policy Research Institute (IFPRI) sought to answer in this study. The report finds that there are important current and projected trade-offs for policymakers to consider as they work to deliver on the promise of food systems for sustainable development.

All solutions are not equal when it comes to rethinking agricultural public policies and support. The report finds that greenhouse gas emissions would increase substantially in the future if current policies are untouched. Simply rearranging or even removing current support would not bring about the changes needed for sustainability. Nor would applying environmental conditionality to the support provided while relying solely on currently available technologies: While it could help reduce emissions in the short term, lower yields could induce farmers to expand land use for agricultural production. Both changes in incentives and investments in innovations that simultaneously pursue productivity enhancements and greenhouse gas emission reductions are needed in order to deliver broad and long-standing wins.

The report finds that repurposing a portion of government spending on agriculture each year to develop and disseminate more emission-efficient technologies for crops and livestock could reduce overall emissions from agriculture by more than 40 percent. Meanwhile, millions of hectares of land could be restored to natural habitats. The economic payoffs to this type of repurposing would be large. Redirecting about $70 billion a year, equivalent to one percent of global agricultural output, would yield a net benefit of over $2 trillion in 20 years.

Most importantly, repurposing would deliver large benefits to people. It would raise rural incomes, contributing to improved food security. It would substantially reduce the cost of healthy diets, contributing to better nutritional outcomes. And it would accelerate poverty reduction.

At a time when farmers bear the brunt of worsening climate change impacts, volatile food prices, rising input costs, and shifting consumer demand, government support is much needed and could be much better targeted. The report uncovers that for every budgetary dollar spent under current farm policies, only 35 cents end up with farmers. In rethinking agricultural policies, governments must be mindful of farmers' bottom lines and the particularities of country and even local contexts. Indeed, farmers' support for policy changes, incremental or otherwise, will be key to the success of reform efforts.

We hope readers will find that this report makes a useful contribution to a growing literature on how to repurpose current agricultural policies and drive reform, as the World Bank and IFPRI, together with other partners, including FAO, work with policymakers to reexamine their support programs and chart ways forward for food systems that better benefit people, the planet, and the world's economies

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OVERVIEW

KEY MESSAGES

- Current governmental support for agriculture provides incentives for unsustainable patterns of production and consumption, with agriculture and land-use change responsible for 22 percent of global greenhouse gas emissions (GHG).
    - *Given a "business-as-usual" scenario of unchanged support, GHG emissions from agriculture would increase by 58 percent, and 56 million hectares would be converted to agricultural land between now and 2040.*
- Current support for agriculture delivers low value for money as a way of helping farmers; for every dollar of public support, the return to farmers is just 35 cents.
- Simple reductions in or rearrangement of current support will not yield game-changing reductions in global emissions.
- Policy conditionality tying support to the adoption of environment-friendly but lower-yielding farm practices could potentially reduce emissions, but would entail tradeoffs for people, nature, and economic prosperity with lower agricultural production, higher poverty, higher agricultural land use and an increase in the cost of healthy diets.
- Concerted efforts to repurpose a part of current domestic support as incentives to develop and adopt green innovations that reduce both emissions and costs could potentially deliver substantial gains for the planet, the economy, and people.
    - *Simulation results suggest that investments in innovations designed to lower emissions and raise productivity by 30 percent could reduce emissions from agriculture and land use by more than 40 percent, returning 105 million hectares of agricultural land to natural habitats, while delivering substantial gains in poverty reduction, nutrition, and the overall economy.*
- There is a strong case for policymakers to scrutinize and rethink their current domestic policies. The biggest gains would accrue through a coordinated effort of all countries to reset their policies to address the global threat of climate change, and to better meet nutritional and social needs.

Securing affordable access to a healthy, nutritious, and safe diet for the growing world population in the face of climate change and wide-spread resource degradation is a major global challenge. Demand for food is expected to increase rapidly between now and 2050. The world's population is projected to reach almost 10 billion by 2050, and per capita incomes are rising rapidly. Agricultural performance in meeting the challenge of feeding the world over the past 60 years has been impressive, as food production has substantially outpaced population growth. However, continuing to meet global food needs successfully and sustainably is becoming increasingly difficult. Global hunger has been on the rise since 2015, and the growth in food output per capita has both decelerated and become more volatile (Figure O.1).

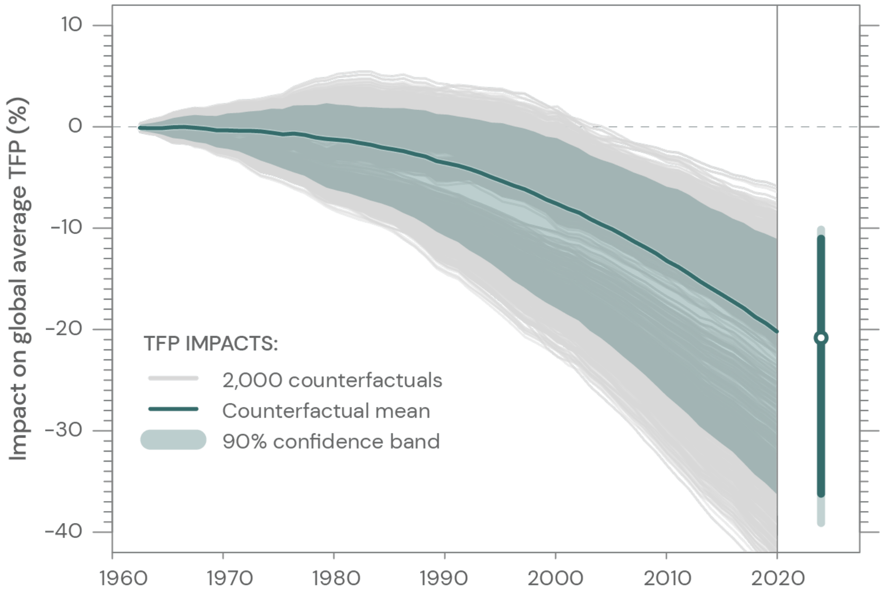
FIGURE O.1: Growth and Volatility Trends in Food Production Per Capita, 1980–2000

Source: FAOSTAT

Climate change is not a distant threat—it is already adversely affecting agriculture. Recent analysis indicates that since 1960 climate change has slowed productivity growth by 21 percent globally, and by as much as 40 percent in parts of Africa and other tropical zones. More worryingly, as shown in Figure O.2, this adverse impact appears to be intensifying, pushing the world more quickly toward a "tipping point" where climate change impacts will offset all productivity growth, and beyond which the economic and social consequences could be devastating.

While agriculture is highly vulnerable to climate change, it is also a major contributor to the problem. The agri-food system contributes about a third of the world's total anthropogenic GHG emissions. About two-thirds of these, or about 22 percent of the total, are generated on farms, from agricultural production and land-use change; the rest come from pre- and post-production activities in the broader agri-food system. Agriculture and food systems also generate other major negative externalities, including the loss of biodiversity, the degradation of natural resources, and the adverse effects on human health of costly nutrition-adequate diets.

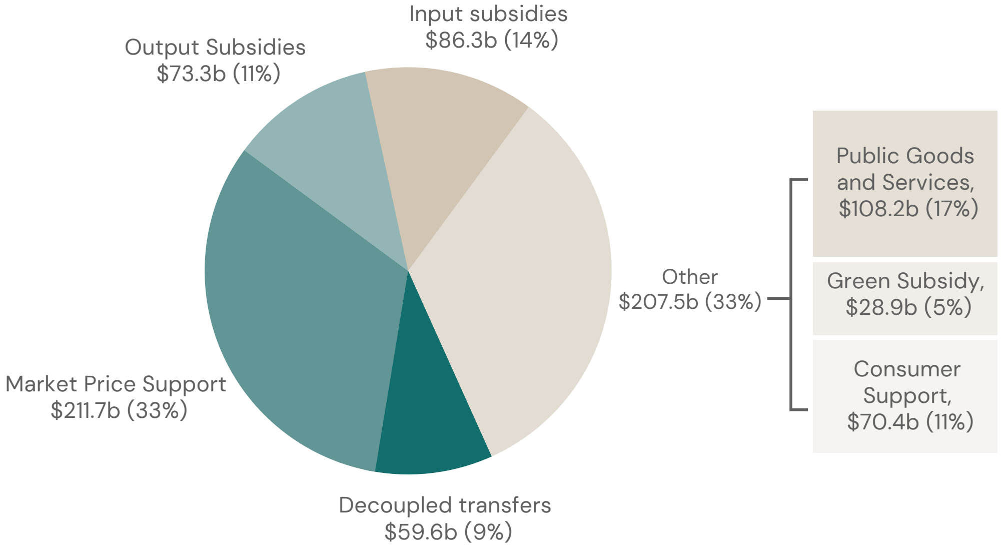
FIGURE O.2: Impact of Climate Change on Productivity, 1960–2020



Source: Ortiz-Bobea et al. 2021.

Building better food systems requires a fundamental change in incentives. This study finds that if countries continue on a "business-as-usual" path by keeping current policies in place, emissions from agricultural production would double by 2040, and an additional 56 million hectares of new land would be converted to agriculture between 2020 and 2040. These outcomes reflect the patterns of production and consumption that have emerged, influenced in part by incentives created through longstanding governmental measures taken to support agriculture. In 2016–18, the governments of the 79 countries for which data are available supported agricultural production and food consumption with measures that generated net transfers of $638 billion per year (Figure O.3). More than 70 percent of this total support, about $456 billion, consisted of support for agricultural producers, of which 82 percent was provided through measures that the Organisation for Economic Co-operation and Development (OECD) refers to as "potentially most distorting." These include subsidies linked to outputs, inputs, or production factors like land area (referred to as ***domestic support*** in this study) as well as market price supports provided through trade restrictions such as import tariffs and other border measures (referred to as ***trade barriers*** in this study). About 11 percent of the total support was provided to poor consumers, for instance through public food assistance or food distribution programs. Of the remainder, about 17 percent was for public goods and services like research and irrigation, and another 5 percent was "green" subsidies, that is, subsidies to support better environmental outcomes. Governments have been providing these broad types and levels of support to agriculture and food systems for a long time. This public support has helped to raise productivity and lower the price of food, especially of basic staples such as cereals; but it has also promoted the unsustainable patterns of production and unhealthy diets that characterize today's food systems.

FIGURE O.3: Total Annual Support to Agriculture Provided by 79 Countries, 2016–18 (in billions of current dollars and percentage share)



Source: Authors, using data from AgIncentives International Organizations Consortium.
Note: b=billion

Could the current support to producers be repurposed to deliver better outcomes? Given the scale and structure of the support to agricultural producers globally, this study assesses several options for repurposing current agricultural policies and support to achieve better economic, environmental, social, nutritional, and climate outcomes. The scenarios analyzed are:

0. ***Baseline:*** A business-as-usual (or "zero") scenario simulates a "no policy change" option that assumes current policies and patterns of producer support will continue unchanged.
1. ***Removal:*** Two scenarios consider the removal of two distinct forms of producer support:
   a. Remove the current domestic support provided to producers.
   b. Remove both domestic support and trade barriers or market price supports.
2. ***Restructuring:*** Two forms of restructuring domestic support that would rely on currently available technologies and practices are analyzed:
   a. Replace the current pattern of support, which targets certain agricultural products, with a uniform rate of support for all agricultural products.
   b. Target current domestic support to only low-emission intensity products.
3. ***Conditionality***: In this scenario, producer support would be conditional on farmers adopting emission-reducing practices, using currently available technologies.
4. ***Repurposing:*** In this scenario, a portion of current domestic support would be repurposed for increased spending on green innovations; that is, the development, diffusion, and adoption of new technologies that both reduce emissions and raise productivity. The remainder would be returned to taxpayers and would be potentially available to deliver as nondistorting transfers to producers and other stakeholders. This could be used to compensate them for potential losses due to this reform, and to spend on rural infrastructure and other essential public goods and services that are fostering agricultural and rural development.

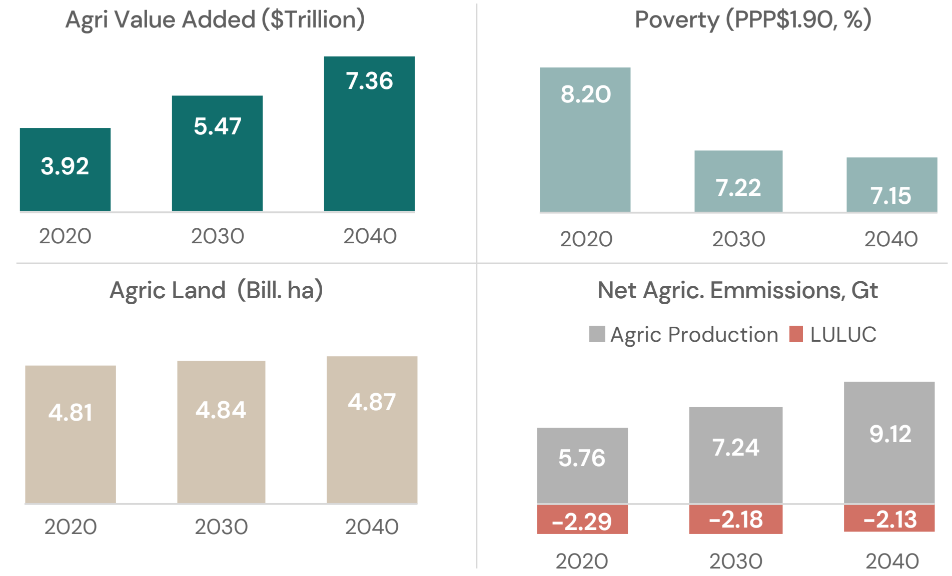
BOX O.1: METHODOLOGY

Using the International Food Policy Research Institute's (IFPRI's) global general equilibrium model, MIRAGRODEP, this study analyzes the likely impacts of several different policy options on the planet (that is, on GHG emissions and land use); the economy (national income); and people (poverty, food security, and the cost of a healthy diet). These scenarios assess the potential effects of removing, restructuring, attaching conditionality to, and/or repurposing current domestic producer support.

Our analysis assumes a phased implementation of reforms and focuses on longer-term outcomes rather than immediate impacts. In all of the scenarios, reforms are assumed to be implemented gradually over a five-year period (2020–2025), and impacts measured against a projected baseline for 2020–2040. This would allow the investment and consumption responses to changes in income resulting from the reforms to be fully incorporated when considering outcomes.

***0. Baseline.* A "business-as-usual" (or zero) scenario with unchanged policies projects a substantial increase in agricultural emissions by 2040.** Figure O.4 shows the projections for key outcomes. From 2020 to 2040, in line with past trends, agricultural value added would increase by about 3 percent per year, and emissions from agricultural production would double. In this business-as-usual scenario, agricultural land use is projected to increase by 1 percent, equivalent to drawing *56 million hectares of new land into agriculture from 2020–2040*. This expansion of agricultural land would increase losses in biodiversity and ecosystem services; increase emissions as a result of forest conversion to farmland; and reduce carbon sequestration capacity by 7 percent.

FIGURE O.4: Baseline Projections, 2020-2040



Source: Authors' baseline scenario projections.

***1. Removal:* What is current agricultural support "buying"?** This question is addressed by the first set of complementary scenarios (1a and 1b), which assume the removal of domestic support and of all producer support, including market price support (Figure O.5).

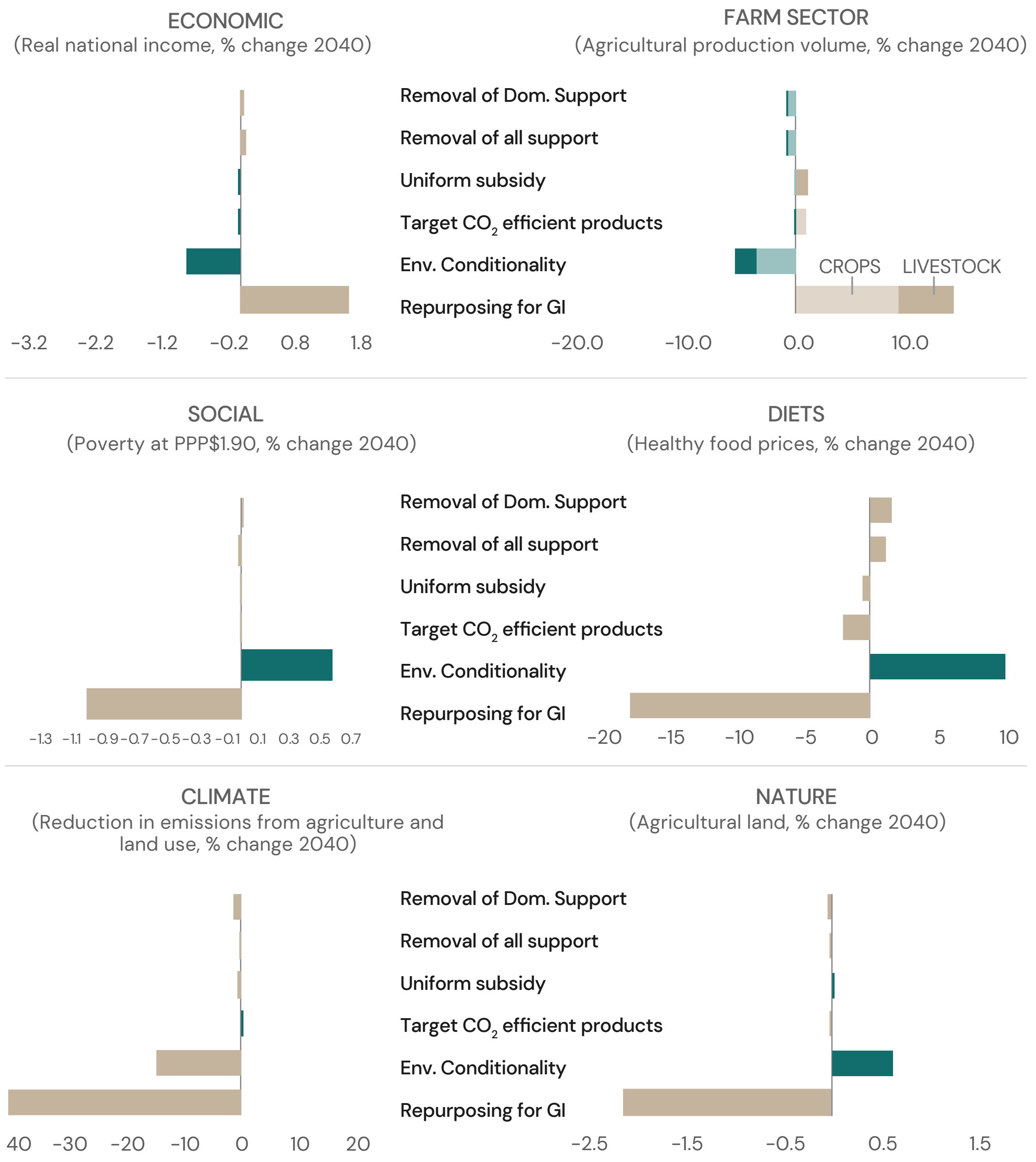
- ***A simple removal of domestic producer support would involve important trade-offs.*** Removing domestic support (Scenario 1a) would have small but favorable impacts on the climate and on nature by reducing agricultural GHG emissions by the equivalent of about 103 megatons of CO_2 (CO_2eq), or 1.5 percent of total agricultural emissions in the baseline, as well as reducing the territorial footprint of agriculture, saving 27 million hectares, or about 49 percent of the projected conversion of land to agriculture. However, these environmental gains are far short of what is needed to appreciably curb agriculture's contribution to climate change. Moreover, the economic outcomes would be mixed. On the one hand, removing distortionary domestic support would generate some efficiency gains, reflected in a small increase in real world income of $74 billion (0.05 percent) per year relative to the baseline projections for 2040. On the other hand, major political economy challenges would be likely to emerge as farm output and real farm income per worker would decline, reinforcing policymakers' concerns about food security and the welfare of farmers. *The current farm-support regimes were not designed to reduce poverty or to improve diets, but their abolition would likely increase food prices, contributing to more poverty (albeit marginally) and raising the cost of healthy diets.*
- ***This scenario also reveals that the vast public resources spent to benefit farmers is delivering very little "value for money."*** Domestic support to producers costs around 14 percent of agricultural value added but yields an increase in real value added of only 5 percent. If farm support is thought of as providing transfers to farmers, its implied *transfer efficiency is very low,* at only about 35 percent. In contrast, lump-sum transfers (that is, payments to producers that are not linked to inputs or outputs) would almost triple the gains to farmers, while avoiding the distortions created by current forms of support.
- ***Removing trade barriers as well as domestic support would yield somewhat greater income gains but would limit the reduction in emissions.*** Trade barriers in the form of import tariffs support production but tax consumption in protecting countries. Their removal (Scenario 1b) would thus have partially offsetting effects on supply and demand. Economic efficiency gains would be larger if both trade barriers and domestic support were reduced (which would be about $135 billion, or 0.09 percent in 2040), and global poverty would fall slightly. With a more muted decline in global agricultural output as compared to removing only direct support, however, this *more comprehensive reform would limit the reduction in global GHG emissions induced by the removal of domestic support* to about 39 megatons of CO_2eq, or 0.55 percent of total agricultural emissions in the baseline. This muted impact is explained in part by the effect of removing protection on food prices, which would fall in protecting countries, thereby increasing global demand for food and offsetting some of the decline in global production from the removal of domestic support.

Approaches that specifically aim to reduce emissions can be game changers for agriculture's impact on climate change; but they require careful consideration of current and projected trade-offs. The options for maintaining but redirecting domestic support to agriculture considered in this study are representative of a broad range of specific policy options that are conceptually similar but that need to be tailored to individual country contexts. The impacts of selected repurposing options are shown in Figure O.5 and compared with those of the previous scenarios involving the removal of current supports. These scenarios assume an international consensus, under which all governments would repurpose support toward common global objectives.

***2. Restructuring*. Maintaining support for agriculture at the current levels but restructuring it either by moving to uniform rates of assistance for all products, or by favoring low-emission products would yield surprisingly small economic, social, and environmental gains.** Replacing the current highly variable system of agricultural support with a uniform rate (Scenario 2a) mimics a shift toward decoupled transfers and would remove the present bias toward certain products. However, moving support away from high-emission to low-emission intensity products (Scenario 2b) would have surprisingly little impact on emissions. Paradoxically, transferring all subsidies to low-emission crop cultivation would actually *increase* global emissions by increasing demand for cropland and stimulating land-use change from forests, even though some pastureland would be retired as livestock production fell. These outcomes suggest that while this scenario is appealing at face value, merely shifting subsidies away from emissions-intensive commodities would do little in terms of overall emission reduction.

***3. Conditionality*. Making support "conditional" on reducing emissions would be positive for planetary health but could entail trade-offs for people and economic prosperity.** Promotion of production methods and practices that improve environmental outcomes but reduce the productivity of land (Scenario 3) could potentially deliver important reductions in GHG emissions; but it might also come with economic and social costs. Drawing on the literature on emission reductions and cost increases associated with existing policy proposals for this type of conditionality, an illustrative simulation makes farm support conditional on production techniques that reduce emission intensities by 10 percent, while raising costs by the same amount. This would reduce global GHG emissions from agricultural production by 19 percent through the reduction in emissions per unit of output, and a decline in global output. But this gain would be offset by increases in emissions from land-use change, because additional land would need to be brought into agriculture. The net reduction in emissions from agriculture and land-use change would be 15 percent. This gain would come at cost of a 0.8 percent decline in global income, and a drop of more than 5 percent in agricultural production, while poverty and the cost of a healthy diet would both increase. Decreased biodiversity would incur additional losses since an increase in the use of land for agriculture would result in the loss of forest habitat.

FIGURE O.5: Global Implications of Repurposing Domestic Support (Percentage Change Relative to Baseline Projections for 2040)



Source: Authors, using model simulation results.
Note: ***Brown bars*** indicate movement toward, and ***teal bars*** indicate movement away from achieving the related SDG(s). GI= Green Innovation.

***4. Repurposing for green innovation*. The repurposing option, which would redirect a part of domestic support toward targeted investments in technologies that are both productivity-enhancing and emissions-reducing, appears to hold the potential to deliver "triple wins" for a healthy planet, economy, and people.** The key point of departure in the final option considered (Scenario 4) is the focus on green innovation;

that is, *technologies and practices that would reduce emissions while increasing productivity***.** Recognizing that achieving this is not without cost, the focus of this scenario is on redirecting some of the domestic support currently provided to agriculture toward more public spending on research and development (R&D), and incentives for the development and adoption of green innovations. Some such innovations already exist or are emerging. Based on an examination of the literature on the potential of recent innovations to raise productivity and reduce agricultural emissions, this illustrative scenario assumes a 30 percent increase in production and a 30 percent reduction in emissions per unit of output. The literature on past agricultural productivity growth suggests that the cost of raising agricultural productivity by 30 percent on a sustainable basis would be roughly equivalent to one percent of the value of farm output. This scenario considers repurposing the equivalent of one percent of the value of farm output from the current domestic support for agriculture to invest in R&D, under the assumption that with reoriented R&D priorities, this level of research intensity would also apply to the generation of green innovations. The remaining domestic support would amount to a saving for taxpayers and would be potentially available to deliver as nondistorting transfers to producers and other stakeholders to compensate them for any losses they might incur due to this reform, and for spending on extension services, rural infrastructure, and other essential public goods and services that are fostering agricultural and rural development. The importance of green innovations in delivering these wins is clear from Figure O.5, which shows the results of the repurposing scenario.

- ***Global real income would be higher, reflecting large economic efficiency gains.*** In 2040, the projected world income would be 1.6 percent higher than the business-as-usual projection.
- ***Adoption of these improved technologies would deliver huge benefits for the climate and nature.*** Between 2020 and 2040, overall emissions from agriculture would fall by more than 40 percent, or nearly 2.8 Gt CO_2eq—avoiding nearly 80 percent of the incremental emissions expected under the baseline (business-as-usual) scenario. Productivity growth would also release production factors (for a given level of demand), including land. About 2.2 percent ***less*** agricultural land would be needed in this scenario, releasing about 105 million hectares of agricultural land for restoration to natural habitats, with potentially substantial biodiversity benefits. This approach would spare not only the additional 56 million hectares of land that would be transferred to agriculture between 2020 and 2040 under the baseline scenario but would also release another 48 million hectares currently being used for agriculture that could be restored as natural habitats.
- ***Productivity-driven growth reduces poverty and makes nutritionally adequate diets more affordable.*** In this scenario, global extreme poverty would fall by 1 percent, while the cost of a healthy diet would drop by a substantial 18 percent.
- ***Incomes of farm workers would increase, while farm employment would fall as part of structural economic transformation over the long term—between now and 2040.*** The repurposing of current agricultural support could facilitate farm labor moving into other parts of the economy, because some of this money could be spent instead on human capital and skills development, as well as on rural financing and infrastructure. Through structural transformation, farm labor could become more productive both within agriculture and in nonfarm work if governments invested more in the human capital of rural people.

Notwithstanding the substantial potential gains for people, the planet, and the economy that could result from the repurposing options discussed in this study, current agricultural support measures need to be carefully scrutinized in various country contexts. A key insight from this study is that current agricultural support is a very blunt instrument for fighting climate change and for addressing the challenges of global food security and nutrition. There appears to be great potential for achieving major gains on these fronts by repurposing support toward public investments that facilitate the widespread adoption of productivity-enhancing and emission-reducing technologies for agri-food systems. Further, these policies are likely to have strongly positive international spillovers. Innovations that reduce environmental impacts and raise productivity are likely to either be rapidly adapted in other countries, or to provide a basis for developing technologies for other agroecological environments.

Nevertheless, even the best-designed policy reforms will face political hurdles. Agricultural support policies are the prerogative of national governments. Overcoming national resistance to agricultural policy reform from affected stakeholders will be a huge challenge. National farm and agricultural policies have a long history in most countries and have developed well-established entitlements and vested interests. Recognition of the major private and societal gains to be achieved, and multistakeholder engagement to discuss the potential trade-offs associated with policy options and to devise acceptable strategies should help to earn political support for smart repurposing of existing support at the national level.

For reforms to foster sustainable global development, effective policy coordination and technological innovations that are attractive to both individual producers and governments are needed. At present, agricultural support is distributed unevenly across nations. Poorer nations have less fiscal space with which to provide agricultural support. Also, their national agricultural research systems generally have weaker resource capacity for developing high-productivity and sustainable farm technologies and practices relevant to the local context, and their farmers and other food producers face bigger obstacles in adapting those practices. Hence, to be most effective at the global level, a more even-handed diffusion of both technologies and financial resources is needed in order to allow countries to reap the benefits of agricultural policy reform and contribute most effectively to solving global challenges.

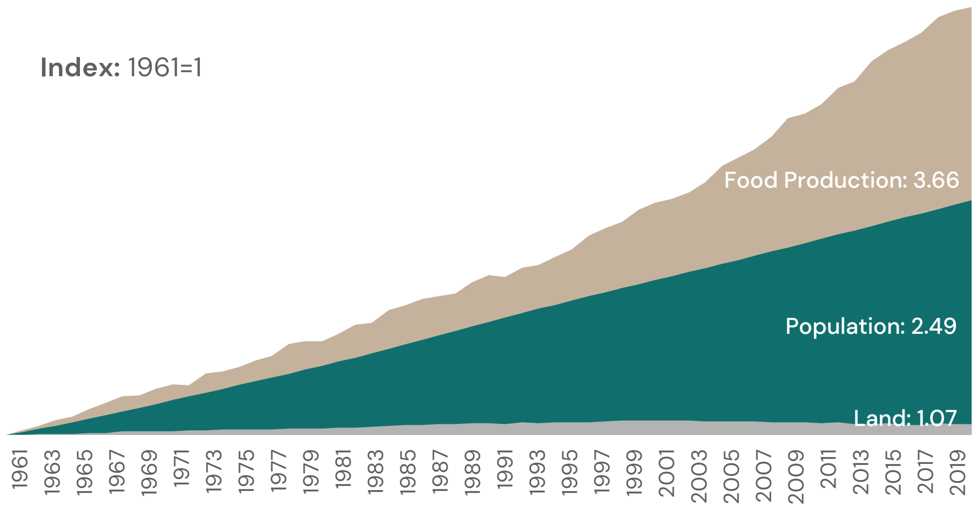
International coordination is vitally important to achieve the needed reductions in global emissions from agriculture. Climate change and environmental sustainability are global challenges that transcend borders, and national policies have strong international spillover effects. Policy-makers are well-placed to scrutinize and rethink domestic policies – but ultimately all countries need to act together to effectively address the global threat of climate change to our food systems.

1

INTRODUCTION

Remarkable progress has been made in increasing global food production over the past 60 years. The increase in the production of calorie-rich staples helped ward off the widespread hunger and famine forecast across much of the developing world in the 1960s and 1970s (Fuglie et al. 2020). Driven by an overriding focus on food availability, intense public support has helped cereal production more than triple since the early 1960s, outpacing population growth, which has increased about two and a half times since 1961 (Figure 1.1). Much of this increase is credited to productivity growth, with expanded area under agriculture contributing relatively less. Despite this progress, the world is off-track for meeting its Sustainable Development Goal (SDG2) targets, with hunger and food insecurity on the rise since 2014 (FAO et al. 2021).[1]

FIGURE 1.1: Increase in Food Production Per Capita, Population, and Agricultural Land, 1961–2018



Source: FAOSTAT

Looking forward, the world faces an even more daunting and complex task than it did in the 1960s: that is, ensuring that a growing population has access to affordable, healthy, and safe food in the face of climate change and the rapid degradation of natural resources. The world's population is projected to reach 9.7 billion by 2050, which together with rapid urbanization and rising incomes will increase the demand for food, especially for more resource-intensive animal-source foods, and fruits and vegetables. Efforts to successfully and sustainably meet this challenge are already encountering stiff headwinds. Growth in food production

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[1] FAO et al. (2021) estimates that as many as 811 million people faced hunger and nearly 2.4 billion people (or one in three people worldwide) were without access to adequate food in 2020, with the COVID-19 pandemic worsening trends that had been already deteriorating since 2014. Healthy diets were out of reach for 3 billion people in 2020 due to the high cost of healthy foods. Over 149 million children under 5 are estimated to be stunted, 45 million suffer from wasting, and 39 million are overweight.

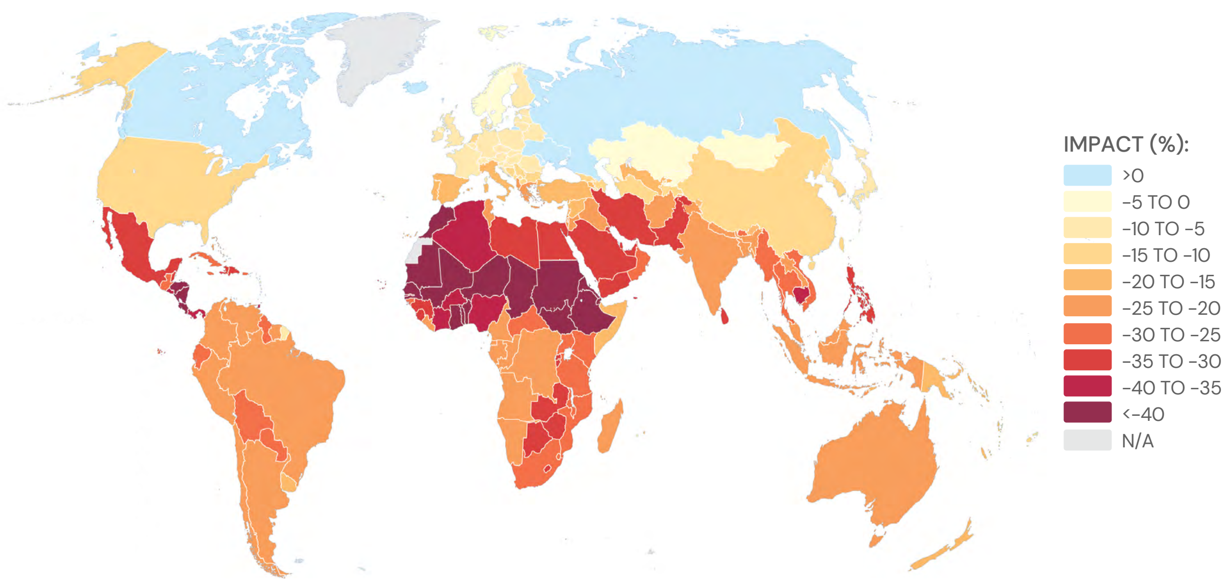
per capita appears to have been slowing since about 2010. At the same time, the long-term decline in the volatility of food production per capita appears to have reversed and has risen since the mid-2000s (Figure 1.2).

FIGURE 1.2: Food Production Per Capita: Growth and Volatility Trends, 1980–2000

Source: FAOSTAT

Climate change is no longer a distant threat; it is already adversely affecting agriculture. The trends shown in Figure 1.2 are indicative of this, and a rigorous new study establishes a concrete link between climate change and productivity (Ortiz-Bobea et al. 2021). This study estimates that climate change has reduced global agricultural productivity growth, as measured by the growth in total factor productivity (TFP), by 21 percent since 1961. This is the equivalent of wiping out seven years of productivity gains globally; in other words, neutralizing technologically driven productivity growth since 2013 (Ortiz-Bobea et al. 2021). Importantly, the impacts are more severe in tropical agriculture, with productivity growth falling by as much as 40 percent or more in parts of Africa and other areas (Figure 1.3). These impacts are already being felt through rising levels of hunger (FAO et al. 2021), and acute food insecurity across large swathes of Africa, Central America, and parts of South Asia and the Middle East that *overlap with the areas most affected by climate change* (FSIN 2021).

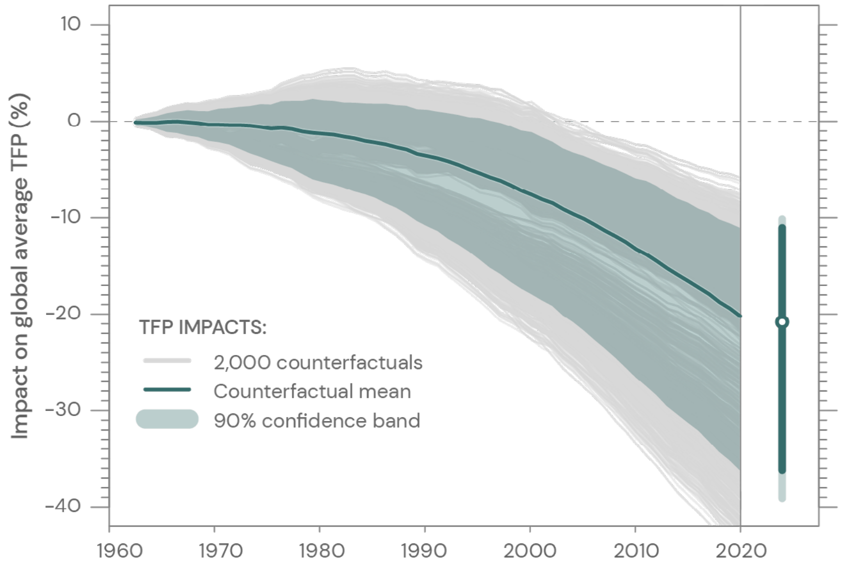
FIGURE 1.3: Global, Regional, and Country Level Impacts of Anthropogenic Climate Change



Source: Ortiz-Bobea et al. (2021). This map was produced by the Cartography Unit of the World Bank Group. The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of the World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries.

The impacts of climate change are also accelerating (Figure 1.4). If it is unchecked, it will be increasingly difficult to maintain the impressive rate of productivity growth seen over the past 60 years. Positive technological gains could be overwhelmed by worsening climate change, leading to an expansion in the amount of agricultural area needed to feed the growing population, and pushing the world more quickly toward an eventual "tipping point," with potentially enormous economic and social consequences (Johnson et al. 2021).

FIGURE 1.4: Impact of Climate Change on Agricultural Productivity, 1960–2020



Source: Ortiz-Bobea et al. 2021.

While agriculture is highly vulnerable to climate change, the way that much of it is practiced now is also a major contributor to climate change, and to degradation of the natural resource base on which it relies. The current agri-food system is associated with substantial "hidden costs" that are becoming increasingly apparent (WRI 2019; FOLU 2019). It contributes about a third of total anthropogenic greenhouse gas (GHG) emissions (Tubiello et al. 2021; Crippa et al. 2021; IPCC 2020). Clark et al. (2020) conclude that reducing GHG emissions from agriculture will be essential to meeting the IPCC targets of holding global temperature increases to 1.5° or 2°C. Agricultural production and additional land being brought into agricultural production have an outsized environmental footprint—they accounted for 22 percent of the total emissions in 2018—that is, two-thirds of agri-food emissions, with the remaining coming from pre- and post-production activities--but only around 4 percent of global GDP. About 31 percent of the on-farm emissions are attributed to the conversion of land for agricultural purposes.

Even though the historical contribution of land expansion to increased food production may appear to be relatively small, it has an enormous environmental impact. Over the past 60 years, the area of agricultural land has increased by only 7 percent, with land under crops growing by 15 percent and pasture by only 2 percent. It has nevertheless pulled a substantial 309 million hectares into agriculture (205 million hectares into crop production, and 104 million hectares into pastures for livestock production). This conversion has come at the expense of natural habitats, particularly forests, which are dense stores of carbon. As a result, the conversion of forests for agricultural use has historically been a major source of GHG emissions, accounting for about 11 percent of global emissions over the years 2007–2016 (IPCC 2020). The remaining 12 percent of global emissions comes from crop and livestock production. More recent estimates by Tubiello et al. (2021) suggest that in 2018, of the 22 percent of global emissions accounted for by agriculture, about 15 percent were from on-farm production processes, and 7 percent from land-use change.

Current agricultural practices and the conversion of land from natural habitats have other large negative externalities. Agriculture is the biggest driver of biodiversity loss, and it generates enormous economic costs due to lost ecosystem services (Johnson et al. 2021). Beyond the effect on the environment, current production patterns encourage unhealthy diets with large human capital and health costs. Furthermore, current practices are undermining both current and future economic growth as key resources — land, labor, water, and energy — are either misallocated or degraded. This constrains the pace of structural transformation--which entails increases in productivity within agriculture, and a shifting of labor out of agriculture and into other sectors—as well as progress on poverty reduction.[2]

Incentives are key to viable solutions to the enormous challenge of making agriculture more productive, sustainable, and nutrition-sensitive. A key question to consider is whether current agricultural policies are creating incentives that will help producers make appropriate decisions for achieving the desired goals. The amount of support currently provided to agriculture by governments around the world is substantial—the 79 countries for which data are available provided net transfers of $638 billion annually between 2016 and 2018, through a combination of explicit transfers funded by public expenditures and implicit transfers through policies that alter the prices producers receive for their products.[3]

This support is beneficial to farmers, at least in the short run, but the societal outcomes of this support are disappointing. These include the outcomes for environmental sustainability, the resilience of agri-food systems, poverty reduction, and food security and nutrition. In many countries, the bulk of the support for agriculture is delivered in a manner that is both regressive and highly distortionary, creating incentives that frequently drive producer decisions in favor of targeted commodities and encouraging resource-intensive and polluting practices. At the same time, the large draw on public resources constrains the provision of core public goods such as agricultural research, and advisory and extension services. The resulting market distortions also often disincentivize private investment in research and innovation as well as in value chain development for less-favored commodities, which are often healthier foods.

Could the current level of support be repurposed to deliver better economic, environmental, social, nutritional, and climate outcomes? Given the current level of global support provided to agricultural producers, an outstanding question concerns the scope for repurposing these funds in a form that promotes more desirable outcomes for productivity,

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[2] Several recent global reports provide evidence of the complex and multifaceted problems that were facing the agriculture and food system even before COVID-19. With the majority of the remaining poor in rural areas, the slowing progress on poverty reduction—with a rising total number of poor in Sub-Saharan Africa—is a stark reminder of the need for continued attention to rural incomes (World Bank 2018). Progress on SDG target 2.1 (Eradicating Hunger and Malnutrition) was already off-track, with the number of undernourished rising from 615 million in 2014 to as many as 811 million in 2020—a reversal of a decades-long declining trend (FAO et al. 2021). Beyond undernourishment, the world was also off-track for meeting the targets for malnutrition (stunting and low birthweight), while at the same time child and adult obesity were rising. Furthermore, 2 billion people were food insecure in 2019, meaning that they lacked regular access to safe, nutritious, and sufficient food. The FOLU Global Report (2019) provides estimates of the huge environmental, health, and socioeconomic costs associated with the current food system.

[3] Among these 79 countries, 11 countries implicitly taxed their farmers by about $74 billion (in the form of negative market price support), implying total positive transfers of more than $714 billion.

sustainability, and nutrition. This study was conceived to fill this knowledge gap by assessing potential options for repurposing current agricultural policies and support. Such reforms are expected to have wide-ranging impacts on various outcomes of interest. Accordingly, this analysis considers the potential of a range of options for achieving better economic, environmental, social, nutritional, and climate outcomes.

It is important to also note that the focus of this study on repurposing support does not consider *all* of the potential strategies that could be used to transform the food system. These include the large array of potential measures that might influence consumer demand, such as consumption taxes on particular foods or measures to facilitate agricultural development, such as investments in infrastructure, value chain efficiencies, nutrition supplements, or biofortification of foods. This report also does *not* constitute an impact assessment of the strategies discussed as such; the modelling scope does not include all of the measures (for example, food waste reduction targets, dietary shifts, and organic action plans) that could alter the impacts reported. In other words, not all policies that would affect the transition are captured by this model. Other analytical approaches and tools will be necessary to arrive at a more complete picture of the potential impacts of this transition.

This study is timely in view of the rising global attention to repurposing public support to agriculture to transform the agriculture and food systems in the interest of realizing better health for people, economies, and the planet. Since the launch of the Just Rural Transition[4] at the UN Climate Action Summit (UNCAS) in 2019, growing global momentum has led to recognition of the potential of repurposing public support to agriculture as a potential "game-changing" solution cluster under the action track for boosting nature-positive production that was discussed at the UN Food Systems Summit (UNFSS) in 2021.[5] Repurposing public support and incentives is also identified as one of five core "imperatives" in the new Food Finance Architecture proposed by the Summit's Finance Lever of Change.[6] The study is also timely in light of the UN Climate Change Conference (COP26), held in November 2021, and the Nutrition for Growth Summit in December 2021: these were two additional venues for promoting reforms with a view to achieving the Sustainable Development Goals by 2030.

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[4] Just Rural Transition, https://justruraltransition.org/

[5] "A Just Transition to Sustainable Agriculture through Policy Reform and Public Support: Meeting the Triple Challenge of Food and Nutrition Security, Climate and Biodiversity," https://foodsystems.community/repurposing-public-support-to-food-and-agriculture-2/

[6] https://www.worldbank.org/en/events/2021/07/02/un-food-systems-summit-public-finance-forum

2

BACKGROUND AND CONTEXT

When considering reforms of agricultural support policies, it is vitally important to understand the complex and multifaceted links between the support provided and the outcomes achieved. This requires identifying measurable outcomes and then exploring the relationships between the support instruments and the policy goals. Reducing emissions of GHGs in agriculture is critical to environmental sustainability.[7] This is because agriculture is both an important contributor to global warming and is strongly affected by the impacts of climate change and variability. But policies cannot focus solely on the impacts of reforms on GHG emissions—policymakers are also deeply concerned about impacts on poverty, nutrition, and the natural environment. Thus, the question becomes whether it is possible to identify policy reforms that help—or at least do not hinder—achievement of those goals, while also achieving reductions in GHG emissions.

The analysis for this study was conducted in two phases. Findings from the first phase were presented in Laborde et al. (2020). That phase used the existing Organisation for Economic Co-operation and Development (OECD) database for agricultural support in 51 countries (OECD 2020), adjusting the agricultural support for border measures and domestic support that influence output and input decisions (coupled subsidies). It then augmented the modeling framework to estimate the changes in GHG emissions associated with shifts in output and inputs resulting from the modeled policy shifts. The Laborde et al. study examined the impacts of removing agricultural support for agricultural production but did not consider the impacts of agricultural land-use change. Therefore, the second phase of this study, the results of which are reported here, expanded the agricultural support database to include an additional 28 developing countries, as discussed in Section 3. Importantly, it also includes the impacts of policy shifts on land-use change and the associated changes in emissions.

The first phase of the analysis provided important insights into the degree and channels of influence of agricultural support on production and GHG emissions. A key insight from Laborde et al. (2020, 2021) is that these impacts differ depending on whether producer support is provided

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[7] Agriculture is also the lead contributor to biodiversity loss, through the conversion of natural habitats to agricultural land, and degradation of the natural resource base, including land and water. The analysis in this study, however, is focused on GHG emissions because incorporating all the other dimensions explicitly is enormously complex: this remains a task for future research. Nevertheless, some of these externalities are implicitly subsumed in the estimation of GHG emissions (for example, GHG emissions associated with land-use change, and emissions directly from soils, crop burning, fertilizer and other chemical uses) even though the longer-term and "hidden" costs associated with these externalities, such as loss of ecosystem services and their potential impacts on future productive potential, are not adequately accounted for. As such, the estimates of the economic impacts in this study may be considered as lower-bound estimates of the true cost associated with policies that influence the decisions of agricultural producers.

through domestic support, or market price support. Transfers that are tied to the production of specific outputs or the use of certain inputs and provided through public expenditures are referred to as *direct domestic support*. Support provided through market prices typically arises from trade measures that seek to alter the price producers receive for their outputs. Indirect transfers are effectively transfers from consumers to producers that are generated through higher prices and are not financed through public expenditures.

This study also builds on a more recent FAO-UNDP-UNEP study. The FAO-UNDP-UNEP (2021) study uses the expanded database and the augmented modeling framework described above to also look at the impacts of removal of agricultural support. It provides a qualitative discussion of the outcomes that can be expected from repurposing current support, and lays out a six-step process for developing a potential repurposing strategy.

The main insight from these studies, confirmed by the analysis presented in this report, is that the removal of support involves important trade-offs. The current pattern of direct support provided to producers through various forms of transfers induces higher levels of global agricultural production and GHG emissions than is seen in the absence of such support. In contrast, with market price support created by border measures, the stimulus to global output (and emissions) provided by higher prices in the protected markets is offset by a contraction in global demand resulting from higher consumer prices in those markets.

The present study expands the analysis in an important way. It explores specific approaches to repurposing support for better environmental, economic, and social outcomes. And it looks at the specific implications of alternative approaches to repurposing current agricultural support — such as the use of conditionality to require the use of emission-reducing technologies, and investing in innovations that reduce emissions and raise productivity.

The inclusion of emissions from land-use change and the design of potential repurposing measures are hugely important. This is partly because, globally, gross GHG emissions associated with land-use change[8] are of the same order of magnitude as those from agricultural production. It is also important to account for other potential negative externalities associated with land-use change, such as biodiversity loss (Johnson et al. 2021). Accounting for land-use change is likely to affect the results of the assessment from the first phase of this study (Laborde et al. 2021). This matters for approaches that reduce emissions through conditionality, which may reduce productivity and require the conversion of forests for cropland. It also matters when funds can be repurposed from providing direct support into supporting R&D, which can both reduce emissions and increase productivity. In the earlier analysis (Laborde et al. 2021), some of the benefits of such R&D were found to be offset by a rebound effect, with higher productivity lowering prices, increasing demand and output, and thus offsetting much of the initial reduction in emissions. *The current, more complete analysis, with land-use change incorporated, finds that this rebound effect is outweighed by the benefits of reductions in land use, and hence in emissions from land-use change.*

The empirical analysis for this study was undertaken in three steps. The first step was to enhance the global modeling framework in order to include the expanded database of agricultural support measures; update the baseline estimates of emissions from both agricultural production and land-use change; and include model specifications for the links between support measures, agricultural production, land-use change, and GHG emissions. The second step was to perform experiments to study the impacts of existing support by creating counterfactuals for production, emissions, incomes, prices, and so on, in the absence of various kinds of support. The third step was to conduct experiments that would examine changes in the use of support, including the refocusing of domestic support away from products with high emission intensities; conditionality designed to reduce the emission intensity of production; and greater investments in R&D both to lower emissions and increase productivity, along with incentives to foster the adoption of such "green innovations."

This report is organized as follows. Section 3 describes the analytical tools needed for this study, particularly the modeling framework, the emissions database, the measures of agricultural distortions, and the household models used to assess impacts on poverty. **Section 4** examines the results from a range of simulations. **Section 5** discusses the challenges of implementing a repurposing agenda, and **Section 6** presents a short summary and conclusions.

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[8] "Gross" in this context refers to emissions from land-use change, not accounting for change in GHG sequestration by soils and forests.

3

PATTERNS OF AGRICULTURAL SUPPORT AND EMISSIONS

This section briefly describes the databases developed for this study. The main building blocks are an expanded database on agricultural support; and an enhanced database on emissions from agriculture and land-use change.

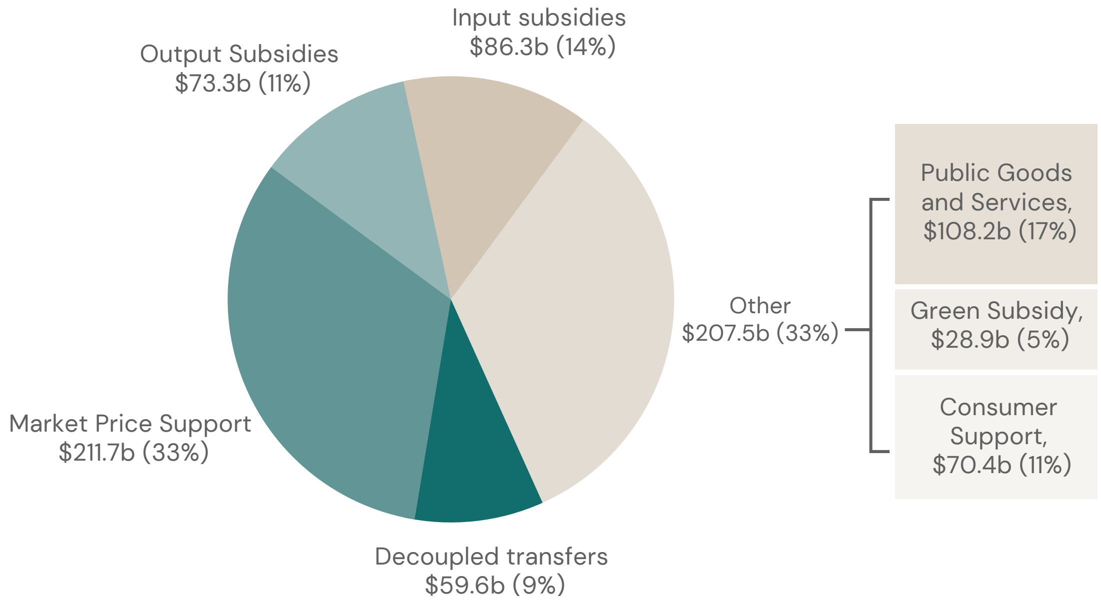
3.1 THE SCALE AND NATURE OF AGRICULTURAL PRODUCER SUPPORT

Total support to agricultural producers flows through multiple channels. These include market price support, which is provided using many different instruments, including measures such as tariffs, licenses, tariff-rate quotas, quotas, and trade bans. While in most countries this support is positive, some countries effectively (either implicitly or explicitly) tax producers using measures such as export taxes or restrictions on export volumes (including quotas or outright bans). The combined impacts of these measures are calculated using comparisons between domestic and world prices for the same product. OECD (2021) computes these measures for 54 countries (including all 38 OECD members, 5 non-OECD European Union (EU) member states, and 11 emerging and developing economies). These measures are complemented by data from the Inter-American Development Bank's Agrimonitor program and the FAO's Monitoring and Analyzing Food and Agriculture Policies (MAFAP) program, and curated by the International Food Policy Research Institute (IFPRI) in the Ag-Incentives database for the International Organizations (IO) Consortium (www.ag-incentives.org). This database allows the tariff equivalent, or nominal rate of protection (NRP), to be calculated as a summary measure capturing the effects of all prevailing border measures. The coverage of countries in the resulting database varies since some countries do not have data for all years since 2005. At its peak in 2012 the database included 88 countries, accounting for 88 percent of global agricultural production. The coverage declined to 73 countries with the data for 2017, but it still accounts for 83 percent of the value of world production, and the pattern of protection remains consistent.

The nominal rate of assistance (NRA) is a comprehensive measure of support provided to agricultural producers. This includes both market price support and support provided through budgetary transfers from governments to agricultural producers. For modeling purposes, this type of support may be broadly categorized into tied transfers (or subsidies) to produce certain outputs, inputs, or factors of production, such as land, labor, or machinery. For this study, the database combines all of the available measures of distortions in a way that allows the impacts of changes in these measures on output and production to be modeled.

The scale of total support provided to agriculture is quite large. Looking at only the 79 countries for which data are available for 2016–18, the average annual positive support (as transfers from the government or between consumers and producers through market price support) is estimated to be $713 billion. This was offset by implicit taxation of producers through negative market price support, which on average between 2016 and 2018 amounted to about $74.3 billion across 11 countries, leaving $638.3 billion in net support,[9] as shown in Figure 3.1. Of the total, about 11 percent was provided through measures to support poor consumers: for example, public food coupons or food distribution programs.

FIGURE 3.1: Total Annual Support to Agriculture Provided by 79 Countries, 2016–18 (in billions of current dollars and percentage share)



Source: Authors, using data from AgIncentives International Organizations Consortium. b=billion

Public goods and services account for only 17 percent of the total support. Of this, about 31 percent is for R&D; 42 percent for infrastructure (most prominently irrigation development); and the remaining 27 percent for other public services. In other words, only about 5.3 percent of the total support provided for agriculture is devoted to R&D spending, even though it is identified as a core driver of productivity, and a key instrument for addressing the challenge of resilience in the face of climate change.

About 5 percent, or nearly $29 billion, is provided as "green" subsidies, or subsidies to support environmental outcomes. This support is channeled through various instruments across countries—as input subsidies to promote less-polluting inputs, or to encourage the production of outputs with fewer negative externalities, or as payments for resource conservation or land set-asides. Support through green subsidies has increased in recent years but it remains limited both in volume and in the number of countries providing such support.

In contrast, the bulk of transfers to producers was provided through measures that the OECD refers to as "potentially most distorting." These include subsidies linked to outputs, inputs, or factors of production such as land area (referred to as ***domestic support*** in this study), as well as market price support provided through trade restrictions such as import tariffs and other border measures (referred to as ***trade barriers*** in this study) (OECD 2020). These measures account for 82 percent of the $456 billion provided annually between 2016-18 as producer support (that is, total support less expenditures on public goods and services and for consumer support). Of the remaining 19 percent of producer support, 13 percent is in the form of relatively less-distorting decoupled income transfers, and 6 percent in the form of "green" subsidies.

Behind these aggregate global numbers, the level and nature of support varies significantly across countries. Importantly, market price support remains the dominant form of distortionary support for most countries (Figure 3.2). Several emerging and developing countries continue to implicitly tax their producers by keeping domestic prices for key commodities below the world market (or reference) prices. In most OECD countries, positive market price support through trade measures remain the most popular form of support that governments provide to producers. As a group, the emerging and developing countries provide the largest share of their direct public support for agricultural public goods and services. Green subsidies are emerging, but the evidence shows that except in China, these are largely offered in the developed countries.

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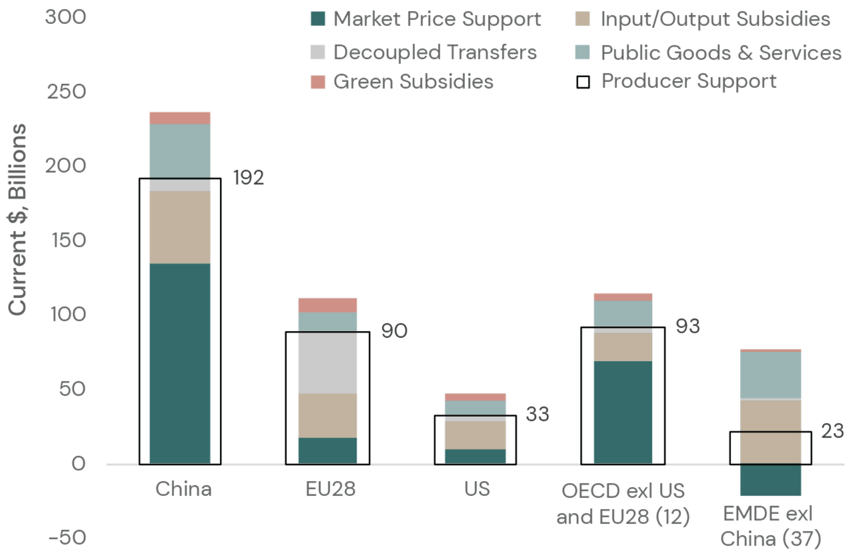
[9] More recent data (the average of the years 2018–20) are available for the 54 countries monitored by OECD (OECD 2021). These data show that these 54 countries provided $720 billion per year as positive transfers to producers, which were counteracted by $104 billion in implicit taxation of farmers through negative market price support in some countries, resulting in a net global transfer to producers of about $616 billion.

FIGURE 3.2: Agricultural Support Across Main Countries and Country Groupings, 2016–18

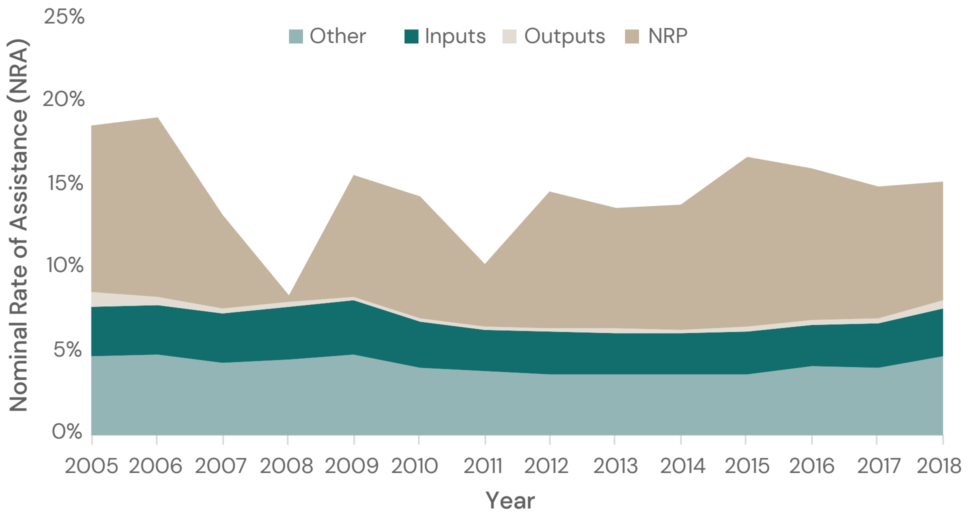


Source: Authors, using data from AgIncentives IO Consortium (IFPRI, OECD, FAO, IDB, and the World Bank).
Note: EMDE = emerging market and developing economies.

Focusing on the elements of support that have the potential to alter the incentives that influence producer decisions, it is useful to assess their size relative to the value of agricultural production. Two key measures that capture the major forms of support are the NRP and the NRA. The NRP reflects market price support, or support provided by border measures, as a proportion of gross farm receipts (GFR) valued at world market prices. Adding to market price support, the direct transfers provided as output and input subsidies and other forms of support, including support decoupled from production, yields the NRA, which is the total support relative to the GFR. The trends in global agricultural producer support, using data for countries for which consistent time series are available are presented in Figure 3.3.

The NRA averaged 15.4 percent of gross farm receipts for the three years 2016–18. Figure 3.3 indicates the predominance of the support provided by protection relative to support provided in the form of public expenditures—through transfers to outputs or inputs, or support that is conditional on other variables. As noted above, support varies significantly across countries. To capture this, a breakdown of NRAs by groups of countries classified by income levels is provided in Appendix A (Figure A1.1). It shows the minimal average support provided by low-income countries, with some countries implicitly increasing taxes for farmers as a way of keeping consumer prices in check. The level of publicly funded support also tends to be low (about 5 percent on average) across middle-income countries, but is close to 15 percent in high- income countries.

FIGURE 3.3: Nominal Rate of Assistance, by Major Component (%)



Source: Authors' database of agricultural support.

Border protection measures accounted, on average, for roughly half of the total assistance provided (8.1 percent of GFR on average for 2016–18). Of the tied transfers or domestic support provided directly by governments, most are not based on production inputs or outputs, but on factor use, such as amount of area planted or numbers of animals (4.3 percent of GFR). While roughly 45 percent of this support is not linked to current production decisions (OECD 2020, 102), most of it nevertheless indirectly influences production through conditions such as the restrictions on payments to active farmers (Abbott 2020; EU 2015), or through perceptions that payment bases are likely to be updated (Bhaskar and Beghin 2010). In order of magnitude, support based on factor use is followed by support coupled to input use (such as water, power, and fertilizer), at about 2.7 percent of GFR. Direct transfers coupled to output are the smallest, averaging 0.4 percent of GFR.

Market price support has been rather volatile, particularly in periods of sharply rising commodity prices, such as in 2008 and 2011, when many governments reduced protection of or increased taxation on farmers (for example, through export restrictions), as they sought to reduce the impacts of increases in world prices on consumers. Unfortunately, this led to a serious collective action problem, since containing domestic prices increased the demand for food and thus exacerbated the increases in world prices (Anderson, Ivanic, and Martin 2014). During periods of stability in world market prices, such as 2016–18, market price support has been relatively stable.

The incidence of market price support varies widely across countries. The database used in this analysis provides estimates of the amount of support provided, not only for major producer countries but also for many countries where agriculture accounts for a substantial share of the national economy. Table 3.1 provides 2016–2018 data on positive market price support in a range of economies and key regions for products that were important both for the economy and for GHG emissions. Almost all of the support shown in this table was provided by import protection, with just a few cases where protection was provided to export-oriented industries through implicit export subsidies.

For countries with positive market price support, the differences between developed and developing countries are relatively small. Table 3.1 highlights the relatively small differences in rates of protection between developed and developing countries, with two notable exceptions. For rice, the protection rate is nearly three times higher in developed countries. For wheat, many developed countries that export the crop keep protection rates relatively low (0.7 percent), while developing countries maintain higher levels of protection (24.4 percent on average). Overall, while many developing countries have minimal protection for many commodities, they tend to apply relatively high rates to those they do protect. The highest rate of protection in the table, for instance, is for milk production in the Dominican Republic (at 231 percent).

TABLE 3.1: Positive Protection Rates for Key Commodities by Region and Country, 2016–18 (%)

REGION/COUNTRY	BEEF	MILK	PORK/ POULTRY	RICE	SUGAR	WHEAT
World	11.5	17.5	14.1	46.1	28.5	12.6
Developed	10.7	15.8	11.8	123.8	25.8	0.7
Developing	12.5	22.6	15.4	34.4	29.1	24.4
Africa	0.7	0.9	0.5	38.8	59.1	12.3
Asia	25.0	56.2	20.8	48.3	44.4	27.3
Latin America & Caribbean	0.9	6.6	3.6	38.9	9.7	2.0
Argentina	0.0	0.0	2.9			0.0
Australia	0.0	0.0	0.0	0.0	0.0	0.0
Benin				61.1		
Brazil	0.8	4.4	0.0	21.5	0.0	6.3
Burkina Faso				60.0		
Burundi				48.0		
Canada	0.0	66.9	0.9			0.0
Chile	0.0	0.0	0.0		3.5	0.0
China	15.5	72.0	16.9	31.3	103.1	55.0
Colombia	3.5	40.5	8.3	113.9	13.0	
Costa Rica	0.0	0.6	43.8	130.0	29.1	
Dominican Republic	29.4	230.8	45.1	58.9		
Ecuador	0.0	19.0	36.1	64.2		
El Salvador	14.4	22.4	148.2	22.4	40.8	
Ethiopia						15.7
European Union	27.0	0.1	9.0	23.9	3.1	0.8
Guatemala			67.9	6.2	81.5	
Honduras	26.1	22.1	28.9	7.2	27.5	
Iceland	37.2	92.7	210.2			
India			25.2		25.8	0.4
Israel	4.5	50.4	43.1			16.9
Japan	38.5	134.8	94.0	228.3	34.3	0.0
Kazakhstan	3.5	0.0	0.0			4.2
Kenya				30.6	80.8	18.3
Korea, Republic of	43.4	133.8	136.5	102.3		
Mali	13.9			34.7		
Mexico	0.0	0.2	0.3	0.0	42.5	0.0
Mozambique			9.8	4.3		
New Zealand	0.0	0.0	7.5			0.0
Nicaragua	0.0	0.0	83.3	75.2	0.0	
Norway	84.0	102.2	111.6			89.1
Paraguay	0.0	0.0	0.0	0.0		0.0
Philippines	10.0		37.3	136.6	59.7	
Russian Federation	22.1	38.8	11.5		46.3	0.2
Rwanda				80.7		104.6
Senegal				20.0		
South Africa	0.0	0.9	0.5		56.1	0.4
Switzerland	71.4	29.0	138.9		2.1	32.5
Turkey	120.3	0.5	39.4		2.8	0.0
Uganda				74.9	48.3	
Ukraine	0.0		4.5		2.7	0.0
United States	0.0	27.6	0.0	0.0	81.6	0.0
Uruguay	0.0	0.0	43.0	0.0		0.0
Vietnam	21.2		0.0	9.2	98.6	

Source: Authors' calculations for countries/commodities with positive protection.

China currently provides substantial positive support for key agricultural products. The current situation is a complete reversal from China's overwhelming taxation of the sector in the 1980s and 1990s (Huang et al. 2009). The European Union (EU), by contrast, provides relatively modest market price support for the key commodities in Table 3.1, while high rates of market price support in the United States are applied only on milk and sugar. Japan continues to have relatively high protection on rice and milk. A set of relatively land-scarce high-income countries including Iceland, the Republic of Korea, Norway, and Switzerland also have high rates of protection. But high rates of protection are also seen in many developing countries, with rates above 100 percent on rice in Colombia, Costa Rica, and the Philippines.

A very different pattern is evident across countries with negative protection. Negative protection is generally the result of the explicit or implicit taxation of exports, and occasionally of import subsidies that are used to keep domestic prices below world prices. Such negative support is almost nonexistent in the developed countries and is much less widely used than positive import protection in developing countries (Table 3.2). Developing countries that do apply export taxes or import subsidies, however, tend to do so at quite high rates, ranging up to 26 percent for beef, 57 percent for milk, and 39 percent for poultry. One important case is India, where domestic prices for bovine meat and milk are substantially below world prices, with important implications for global production and consumption levels.[10] Argentina is another important outlier, particularly at its income level, with domestic prices of beef, milk, and pork all substantially below world prices.

From earlier analysis, it is known that domestic support increases GHG emissions more than market price support does. As Laborde et al. (2020, 2021) point out, this is partly because domestic support increases output without the offsetting impact on global demand associated with market price support, and partly because this support is often in the form of direct support, or subsidies tied to the use of inputs such as chemical fertilizer or pesticides that directly affect emissions.

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[10] Bovine meat exports from India are composed entirely of carabeef, or the meat of water buffalo. Trading of the meat of cows, oxen, and calves is prohibited in India.

TABLE 3.2: Negative Protection Rate for Key Commodities by Region and Country, 2016–18 (%)

REGION/COUNTRY	BEEF	MILK	PORK/ POULTRY	RICE	SUGAR	WHEAT
World	-2.0	-12.1	-0.9	-8.4	-1.1	-1.0
Developed	0.0	0.0	0.0	0.0	0.0	-1.8
Developing	-6.0	-18.7	-3.1	-8.8	-1.3	-0.3
Africa	-2.6	-56.7		-42.4	-20.3	
Asia	-26.2	-20.7	-34.3	-7.4		-12.6
Latin America & Caribbean	-18.7	-31.8	-35.6		-3.0	-0.3
Argentina	-18.3	-33.5	-39.2			-0.3
Burundi				-0.1		
Dominican Republic	-12.4				-3.0	
Ghana				-63.1		
Guatemala	-22.2	-9.2				
Honduras			-2.2			
India	-26.2	-20.7		-6.2		
Kazakhstan				-52.4		-12.6
Kenya				-49.2		
Malawi					-20.3	
Mali	-2.6					
Mozambique				-25.8		
Russian Federation						-6.5
Rwanda		-56.7				
Tanzania				-37.4		
Uganda				-45.9		
Ukraine		-21.1				
Vietnam			-34.3	-12.9		

Source: Authors' calculations for commodities/commodities with negative protection.

One key question is whether support is being provided at high rates or in large volumes to the products that are responsible for the largest contribution to agricultural emissions. As will become clear in Section 4, by far the most agricultural emissions arise from beef and dairy production, and from rice. But these products receive only around a quarter of total support, as shown in Table 3.3. This table also shows that most current support, about 72 percent of total domestic support, accrues to crops, and only 28 percent to livestock products. Table 3.4 shows that the rates of domestic support on those products are about or below the average for all products.

TABLE 3.3: Distribution of Domestic Support by Product, Instrument, and Country Grouping, 2016–2018 (percentage shares)

	HIGH-INCOME COUNTRIES				LOW- AND MIDDLE-INCOME COUNTRIES				
SECTOR	Output subsidies	Input subsidies	Factor subsidies	Subtotal	Output subsidies	Input subsidies	Factor subsidies	Subtotal	World total
Cattle	0.1	1.3	4.1	*5.5*	0.1	1.2	1.1	*2.4*	**7.9**
Dairy	0.4	1.2	4.4	*6*	0.2	1.3	0.5	*2*	**8**
Poultry & Pigs	0.3	1.8	5.1	*7.2*	0.2	2	2.3	*4.5*	**11.7**
Livestock subtotal	**0.8**	**4.3**	**13.6**	**18.7**	**0.5**	**4.5**	**3.9**	**8.9**	**27.6**
Fibers	0.1	0.1	0.6	*0.8*	6.1	0.9	1.2	*8.2*	**9**
Maize	0.4	0.9	2.8	*4.1*	0.1	2.1	7.2	*9.4*	**13.5**
Oilseeds	2.4	0.7	1.8	*4.9*	0.1	1.8	3.6	*5.5*	**10.4**
Other crops	0	0.9	3.5	*4.4*	0.3	3.3	1.1	*4.7*	**9.1**
Rice	0.1	0.1	0.8	*1*	0.1	3.7	2.1	*5.9*	**6.9**
Sugar crops	0.3	0.2	0.5	*1*	0.1	0.8	0.2	*1.1*	**2.1**
Vegetables & Fruits	0	2.1	5.5	*7.6*	0.5	4.8	2.5	*7.8*	**15.4**
Wheat	0.8	0.4	1.9	*3.1*	0.2	1.6	1.1	*2.9*	**6**
Crops subtotal	**4.1**	**5.4**	**17.4**	**26.9**	**7.5**	**19**	**19**	**45.5**	**72.4**
***All* products**	**4.9**	**9.7**	**31**	45.6	**8**	**23.5**	**22.9**	54.4	**100**

Source: Authors' calculations.

TABLE 3.4: Rate of Domestic Support by Instrument, Sector, and Country Grouping, 2016–18 (%)

	HIGH-INCOME COUNTRIES				LOW- AND MIDDLE-INCOME COUNTRIES			
SECTOR	Output subsidies	Input subsidies	Factor subsidies	Total	Output subsidies	Input subsidies	Factor subsidies	Total
Cattle	0.3	1.8	4.5	**6.6**	0.4	1.2	1.7	**3.3**
Dairy	0.7	2.2	5.7	**8.6**	0.7	1.5	1	**3.2**
Poultry & Pigs	0.3	1.7	4.2	**6.2**	0.7	1.2	1.9	**3.8**
Fibers	2.1	2.5	8	**12.6**	34.6	3.2	3.3	**41.1**
Maize	0.8	2.6	4.2	**7.6**	0.5	1.8	5.1	**7.4**
Oilseeds	7.7	2.4	4.7	**14.8**	0.4	1.7	3	**5.1**
Other crops	0	2.7	12.4	**15.1**	1.5	3.1	1.5	**6.1**
Rice	0.1	1.3	9.3	**10.7**	0.7	3.2	2.4	**6.3**
Sugar crops	6	1.8	4.3	**12.1**	0.4	2.5	0.9	**3.8**
Vegetables & Fruits	0	2	5.4	**7.4**	1	2	1.5	**4.5**
Wheat	5	2.3	6	**13.3**	0.9	3.2	2.6	**6.7**

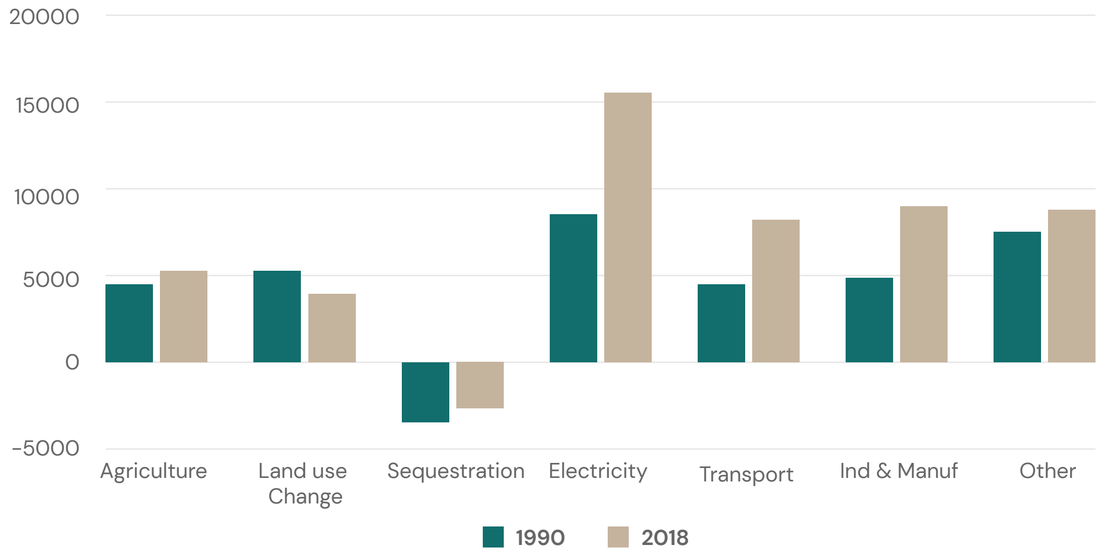
Source: Authors' calculations.

3.2 THE DATABASE FOR EMISSIONS

GHG emissions from agricultural production and land-use change remain important components of total emissions. Figure 3.4 shows key components of global GHG emissions in megatons of CO_2eq for 1990 and 2018. Emissions from agricultural production increased 17 percent during that period. In contrast, gross emissions from land-use change declined by 25 percent because of a reduction in the rate of deforestation and in emissions from organic soils. However, the annual quantity of CO_2eq sequestered by forests also declined by 24 percent, partly because of declines in overall forest cover and forest health. But the increases in emissions associated with agriculture were small relative to the increases observed for other sectors, especially energy/electricity (81 percent), transport (79 percent), and industry (82 percent).

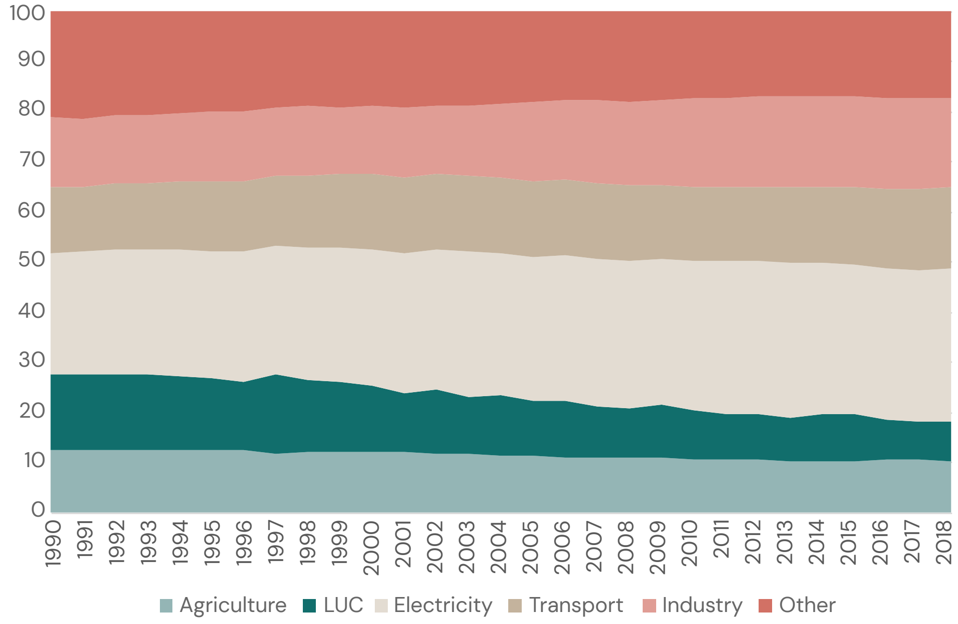
Longer-term trends show a decline in agricultural and land-use emissions, but agriculture remains a significant contributor to total emissions. Figure 3.5 shows that the share of agriculture and land-use change in gross emissions (excluding sequestration), which averaged 23 percent over the period, fell from 28 percent in 1990 to 18 percent in 2018. This leaves the share of agriculture and land-use change roughly on par with the shares for transport, industry, and "other," which includes fugitive emissions from energy production and waste. Despite the decline in agriculture's share, achieving global climate goals will likely not be possible without major efforts to reduce emissions from agricultural production and related land-use change.

FIGURE 3.4: Changes in Levels of GHG Emissions by Main Economic Sector (megatons of CO_2eq)



Source: FAOSTAT for agricultural and land-use change emissions (faostat.org, extracted April 17, 2021). Other categories of emissions from Climate Watch data (www.climatewatchdata.org, extracted April 17, 2021).

FIGURE 3.5: Shares in Global Gross GHG Emissions by Main Economic Sector (%)



Source: FAOSTAT for agricultural and land-use change emissions (faostat.org extracted April 17, 2021). Other categories of emissions from Climate Watch data (www.climatewatchdata.org, extracted April 17, 2021). LUC = land-use change.

For this study, detailed databases of emissions from agricultural production and from land-use change were created. FAOSTAT presents data on emissions by type and by commodity for each country, but a full matrix of emissions by type, commodity, and source is needed in order to consider changes in emissions by type in the production of each commodity, such as reductions in emissions from enteric fermentation in beef production. The approach this study uses to develop this database is described in detail in Appendix B, along with the modeling approaches used to capture the impacts of policy changes.

Emissions by commodity and source show the predominance of livestock products in total emissions from agricultural production. Table 3.5 highlights the extraordinary importance of emissions from milk and ruminant meat in overall emissions. Enteric fermentation associated with the production of these commodities accounts for almost half of total emissions, while manure accounts for another 22.6 percent. The main source of emissions from crop production is rice, accounting for 12.5 percent of total agricultural emissions, while crop residues account for 5.2 percent, and chemical fertilizers 4.5 percent.

TABLE 3.5: Shares of Emissions from Agricultural Production by Commodity and Source, 2017 (%)

	RICE	OTHER CEREALS	MILK	RUMINANT MEAT	PIG, POULTRY MEAT, AND EGGS	TOTAL
Burning of crop residues	0.2	0.5	0.0	0.0	0.0	**0.7**
Crop residues	1.3	3.2	0.0	0.0	0.0	**4.5**
Enteric fermentation	0.0	0.0	28.0	21.2	0.5	**49.7**
Manure management	0.0	0.0	2.2	1.9	3.4	**7.5**
Manure left on pasture	0.0	0.0	6.4	10.0	1.2	**17.7**
Manure applied to soils	0.0	0.0	1.1	1.0	2.0	**4.1**
Pesticides	0.0	0.3	0.0	0.3	0.0	**0.6**
Rice cultivation	10.7	0.0	0.0	0.0	0.0	**10.7**
Synthetic fertilizers	0.3	1.9	0.0	2.2	0.0	**4.5**
TOTAL	**12.5**	**5.9**	**37.6**	**36.8**	**7.1**	**100.0**

Source: FAOSTAT.

Another potentially important distinction is between emission intensities across products and countries. At the world level, the emission intensity of ruminant meat is roughly 40 times that of chicken and 17 times that of pork. The emission intensity of rice is more than four times that of other cereals. There are also large differences between countries and regions, with the emission intensity for beef much lower in the United States than in countries like Australia that primarily use grass-fed production methods, while emission intensities are particularly high in India (Table 3.6). For both milk and ruminant meat, the emission intensities in the industrial countries are much lower than in developing countries.

TABLE 3.6: Emission Intensities for Key Products and Regions, 2017 (kg CO$_2$eq/kg of product)

COUNTRY/ REGION	CEREALS EXCL. RICE	EGGS	BOVINE MEAT	CHICKEN	PIG MEAT	MILK	RICE
Australia	0.2	0.4	24.5	0.2	2.5	0.6	0.7
Brazil	0.2	0.8	34.6	0.3	2.4	1.1	0.5
European Union	0.2	0.7	15.5	0.3	1.5	0.5	3.1
India	0.3	0.5	108.3	0.4	5.0	1.0	0.7
United States	0.2	0.5	11.9	0.3	2.0	0.4	1.1
Developed	0.2	0.6	15.0	0.3	1.7	0.5	1.1
Developing	0.2	0.7	31.8	0.7	1.4	1.3	0.9
World	**0.2**	**0.6**	**25.5**	**0.6**	**1.5**	**0.9**	**0.9**

Source: FAOSTAT.

Emissions from land use and land-use change were estimated by a detailed tracking of the carbon stock adjustments. Beginning with an inventory of land in each region mapped to the category "Cropland, Pasture, Forest, and Other," the stocks of carbon associated with land use and land-use change were then tracked using procedures consistent with FAOSTAT and IPCC (2003). Carbon stock accumulation in croplands and grasslands and sequestration in forests was tracked, as well as conversion between cropland and forests.

4

SIMULATING POLICY OPTIONS

This section considers the modeling framework used to assess the impacts of changes in support policies to global GHG emissions. The global modeling framework used for this study is briefly introduced first. The scenarios used for the analysis are then presented, followed by their key results.

4.1 THE MODELING FRAMEWORK FOR ASSESSING POLICY TRADE-OFFS

This study uses a global dynamic general equilibrium model to simulate the outcomes to 2040 based on a series of policy shifts. IFPRI's global computable general equilibrium (CGE) model, MIRAGRODEP, provides the core of the modeling framework. This is an extension of the widely used MIRAGE multisector, recursive dynamic CGE model of the global economy (Decreux and Valin 2007; Laborde, Robichaud, and Tokgoz 2013), which allows for a detailed and consistent representation of the economic and trade relations between countries. Appendix C provides a detailed description of the model, including an explanation of how the global model framework is linked to the large set of household data and models needed to assess the impacts of agricultural policy reforms on poverty.

As with any ex-ante modeling analysis, the findings discussed in this study are intended to provide strategic guidance on trade-offs and potential outcomes. The simulations are *not* intended to provide precise predictions or quantitative assessments of impacts, but rather insights into the outcomes associated with policy options of the broad type considered. The magnitudes of the shocks applied were chosen to be relevant to recent policy proposals and/or assessments of the impacts of potential reforms, and to provide a basis for understanding the qualitative effects of reforms that might involve larger or smaller shocks than those implemented. If, for instance, a reform involves a reduction in emissions per unit of land but lower yields, does the reduction in emissions from production outweigh the increase in emissions from land-use change as additional land is brought into agricultural use?

The results from the baseline simulation are presented first. This "zero" scenario simulates the business-as-usual, or "no policy change" option; that is, it assumes that current policies and patterns of producer support will continue unchanged, and projects global economy-wide outcomes in such a case, from 2020 to 2040. It provides the benchmark against which agricultural policy changes can be examined. This approach allows the analysis to reflect the anticipated changes in the structure of the world economy, and particularly the changes in the share of developing economies over this period. Simulating relative to this dynamic benchmark also allows the effects of changes in policies to cumulate over time. In the baseline scenario, the rates of protection and assistance provided by import and export barriers and subsidies were held constant. All of the scenarios yield simulated projections of impacts for the period 2020–2040.

The first reform scenario considers removing current producer support. Two complementary simulations (1a and 1b) examine removal of the two distinct forms of producer support–domestic support provided to producers, and both domestic support and trade barriers, or market price support. These simulations help to shed light on the potential trade-offs associated with a blanket removal of current support and establish the "value for money" for the substantial public resources spent on domestic support.

The next three sets of scenarios simulate the outcomes associated with various options for redirecting or repurposing current domestic support to producers. These scenarios correspond to three broad categories of options. **Scenarios 2a and 2b** consider ***restructuring*** the current pattern of domestic support, relying on currently available technologies and practices, either to make support uniform or to focus it only on low-emission products. **Scenario 3** makes domestic support ***conditional*** on environmental outcomes, using currently available technologies and practices. **Scenario 4** simulates ***repurposing*** a part of the current domestic support to target investments in green innovations; that is, technologies that reduce emissions while also enhancing productivity. More details on the simulations analyzed are provided below, with detailed results presented in Appendix D.

4.2 CONTINUING WITH BUSINESS AS USUAL

The potential impacts of policy changes are estimated as deviations from the baseline projection of outcomes with unchanged policies. It is therefore important to have a good understanding of the baseline trends and their underlying assumptions. The key assumptions are summarized in Box 4.1. To focus on the core issues at hand—the impacts of policy reforms—and to avoid what are likely, in retrospect, to be extraordinary and uncertain adjustments to the baseline due to COVID-19 shocks, the last pre-pandemic set of economic forecasts from the World Economic Outlook were used—that is, those from October 2019 (IMF 2019). These provide historical data up to 2018, and then forecasts to 2024. The GDP forecasts to 2024 were used to capture adjustment dynamics during that period. The growth rates for 2024 were then used to provide a benchmark growth rate for subsequent years. In line with the trends of recent decades and most long-term projections for the world economy, the average rate of income growth in developing countries is assumed to be higher than in developed countries from 2021–2040, as are the rates of growth for population, agricultural total factor productivity (TFP), and agricultural emissions (Figure 4.1).

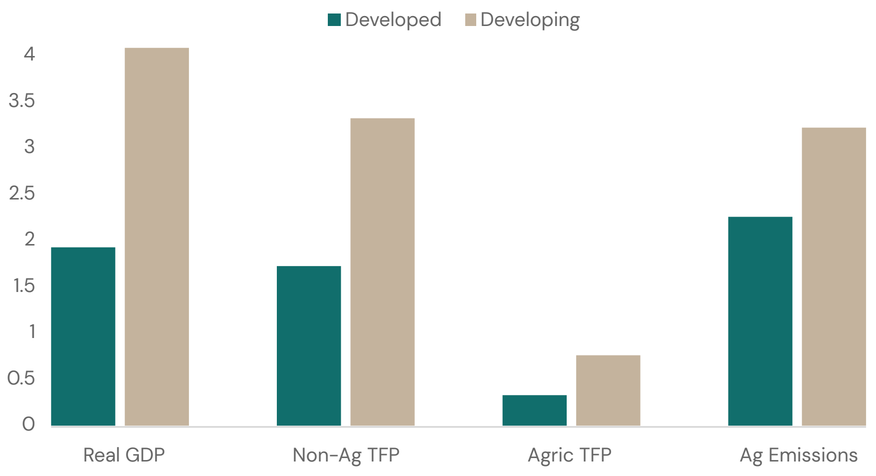
BOX 4.1: BASELINE SIMULATIONS

The basic ingredients for the baseline simulations are a set of economic projections that provide output targets and a set of demographic projections for the evolution of the labor force. These are treated as exogenous parameters, with the economy-wide rate of productivity growth that would be consistent with these outcomes determined within the model. With this information, the model solves for spending and saving levels in each year and calculates the opening stock of capital for the next year. It then solves repeatedly to create a projection to 2040. Because of the particular importance of agricultural productivity growth in this study, it was specified separately from nonagricultural productivity growth, with a slower rate reflecting the depressing effect of climate change on agricultural productivity. For subsequent policy simulations, the roles of GDP and productivity growth are reversed, making productivity growth exogenous, and allowing the model to determine the level of GDP in the policy simulations. This allows the model to assess the impacts of changes in policies on the full range of variables determined within the model.

4.2.1 Scenario 0: Baseline Trends

The "business-as-usual" (or zero) scenario provides projections of probable outcomes with unchanged policies. The projections for key economic indicators show important differences in the outlook for developed and developing countries. Figure 4.1 shows substantial differences in GDP growth rates between developed and developing countries. In addition, much higher TFP growth rates are projected in developing countries for both agricultural and nonagricultural products, a projection that is consistent with continuing income convergence (Martin 2019; Startz 2020). Agricultural TFP was adjusted relative to nonagricultural TFP, taking into account information on rates of yield growth, the desirability of avoiding excessive changes in real agricultural prices during the projection baseline, and the adverse impacts of climate change on yield growth going forward (Schlenker 2021; Ortiz-Bobea et al. 2021).

FIGURE 4.1: Baseline Projections of Key Economic and Environmental Outcomes, 2017–2040 (average annual growth rates in percent)

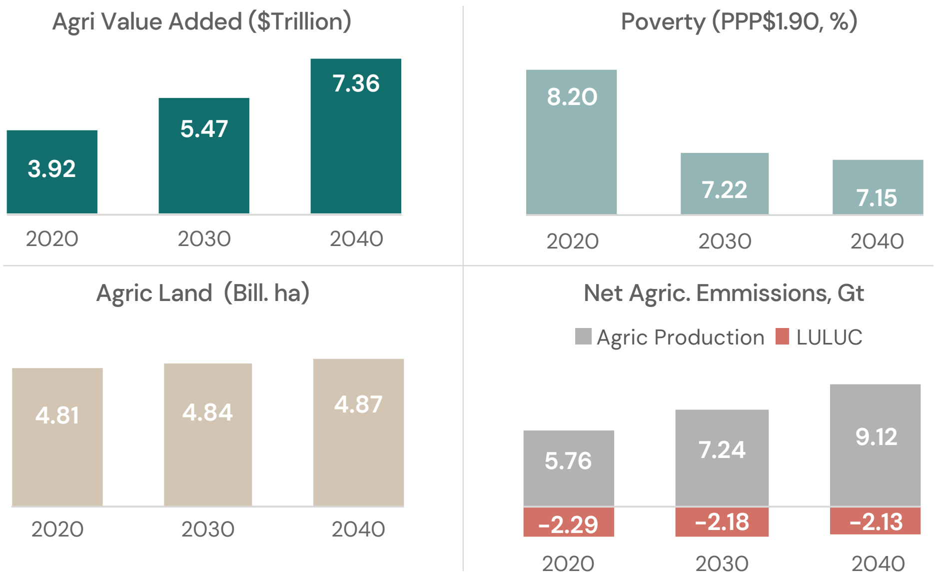


Source: Authors' baseline scenario.

Key projected outcomes relevant to the agriculture sector are shown in Figure 4.2. Real agricultural value added in 2017 in US dollars rises by 88 percent, from $3.92 trillion to $7.36 trillion. This growth includes an increase of 87 percent in crop production and 48 percent in livestock production between 2020 and 2040. Global poverty headcount rates fall from 8.2 percent to 7.2 percent. The slow rate of decline in poverty is strongly influenced by the relatively low rate of growth in agricultural productivity (Ivanic and Martin 2018). Agricultural land use rises by 23 million hectares between 2020 and 2030—an increase similar to the 28 million hectare expansion projected by the World Bank (Johnson et al. 2021, 27)—and then is projected to increase further by 33 million hectares by 2040, implying an expansion in agricultural land use of 56 million hectares (an increase of 1.2 percent) over the entire period 2020–2040.

The baseline scenario projects a substantial increase in the level of agricultural emissions in coming decades. Continuing with business-as-usual, GHG emissions from production would increase from 5.8 gigatons CO$_2$ equivalent (Gt CO$_2$eq) to 9.12 Gt CO$_2$eq between 2020 and 2040, an increase of 58 percent (Figure 4.2). Net annualized emissions from land use and agricultural land-use change are negative, because emissions from land-use change are offset by sequestration. However, the size of these net benefits declines by 7 percent because of the dual effect of higher emissions from forest conversion and reduced capacity for sequestration.

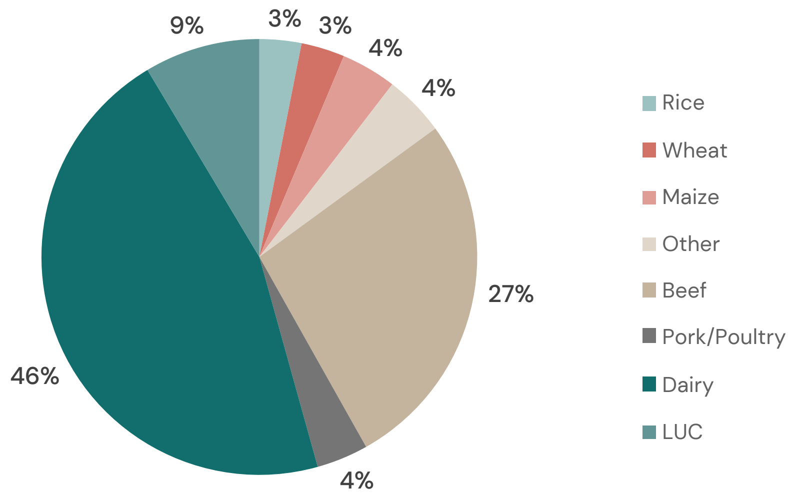
FIGURE 4.2: Key Features of Baseline Projections



Source: Authors' baseline scenario projections.

The largest increase in emissions is expected from livestock production. Figure 4.3 shows the increase in agricultural emissions by source. Dairy alone accounts for 46 percent of the incremental emissions to 2040, and dairy, beef, and pork production together account for 77 percent. Fourteen percent of the total growth in emissions will be from crop production, part of which reflects increased demand for livestock feed. However, the primary contributor to these increased emissions will be synthetic fertilizers (55 percent of crop emissions and 9 percent of all total production emissions).

FIGURE 4.3: Contributions to Growth in Emissions from Agriculture and Agricultural Land-Use Change, 2020-2040 (%)



Source: Authors' baseline scenario projections.

4.3 REMOVAL OF CURRENT SUPPORT MEASURES

Before turning to options for repurposing existing support, it is important to understand the impacts of the current support measures. This can be assessed by looking at what would happen if the current support provided to agriculture were removed. Answering this question provides insight into the likely trade-offs, if any, that a change in current policies might entail. One issue of particular interest to policymakers is the likely impact on production, which is often equated to food security. It is equally important to assess the "value for money" for the hundreds of billions of dollars that are currently spent globally on agricultural support. Domestic support measures are of particular interest, as these rest on re-allocable fiscal resources within limited budgets; earlier work has found that this type of support tends to have a greater impact on global GHG emissions than do market access barriers (Laborde et al. 2021).

A key question is how current support measures are affecting development outcomes. These outcomes include food production, national income, poverty, the cost of healthy diets, the level of GHG emissions from agriculture and land use, and the demand for agricultural land (along with its corollary impact on forest habitat). To delineate the potentially distinct impacts of domestic support from those of trade barriers, the analysis first simulates the impact of removing only domestic support measures, and then considers the removal of both domestic support and trade barriers simultaneously. All of the policy reforms considered are implemented progressively between 2020 and 2025, with the 2025 policy position held constant during the projections to 2040 to allow the longer-term impacts of the policy changes to be identified. Most of the impacts are reported as deviations from the benchmark (or baseline) outcomes in 2040; that is, the outcomes projected assuming there were no change in policies from the "business-as-usual" scenario.

4.3.1 Scenario 1a: Remove All Domestic Support

The first policy experiment (Scenario 1a) simulates the effect of *all* countries eliminating *all* domestic support *simultaneously*. While achieving such a global consensus would be challenging in practice, this set of simulations helps to quantify the influence of current forms of support on global outcomes of interest, including climate outcomes: a truly global public good. It should be noted that collective action is vitally important in achieving progress on climate outcomes. While reducing GHG emissions requires actions at the country level, the gains at the individual country level may be offset by increases in production in other countries as the country reducing emissions increases its imports or reduces its exports, leading to carbon "leakage." The key results from the first experiment, which assumes that all domestic support provided through transfers to producers would be eliminated, are shown in Figure 4.4. Given the major differences in the nature and form of support provided by developed and developing countries, this figure shows impacts both for the world as a whole and for developed and developing countries.[11]

One important message emerging from these simulations is that a blanket removal of all domestic support would entail important trade-offs. Tracking the impact of such reforms through to outcomes related to income, GHG emissions, land-use change, poverty, and nutrition reveals the complexity of these effects.

Removal of domestic support would have favorable, but small, impacts on the climate and nature. Abolishing domestic support would reduce agricultural GHG emissions by about 103 megatons of CO_2eq. These reductions would be induced by a decline in the use of agricultural inputs and the factors of production that are currently supported; the larger fall in crops than in livestock reflects the relatively higher current support for crops. The environmental gains would also vary across countries, reflecting the level of support provided by individual countries—hence the reduction in GHG emissions would be larger for developed than for developing countries. The removal of support would also reduce the territorial footprint of agriculture, reducing the amount of land under agriculture by a substantial 27 million hectares by 2040—and preventing nearly 49 percent of the *potential* conversion of land to agriculture that is projected over the next 20 years under the current policy and support regime. This land savings would directly contribute to an increase in forest habitat, with important positive contributions to reducing GHG emissions through sequestration and protecting biodiversity. The patterns observed are consistent with the nature and structure of domestic support across countries.

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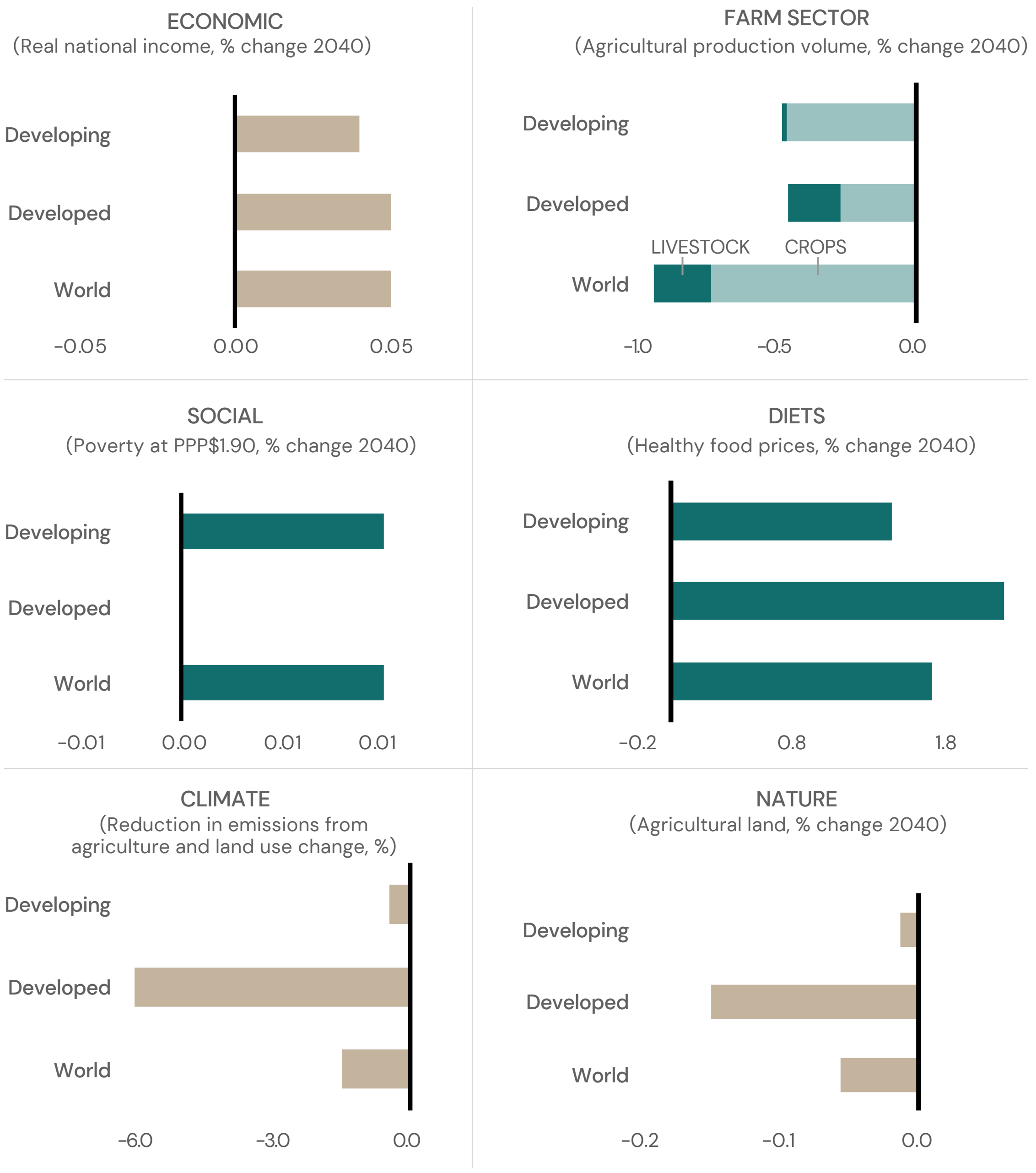
[11] Additional experiments were also carried out to assess the impact of eliminating various components of the coupled support differentiated by form of payment, and whether to crops or livestock, or for developed countries only. Detailed results from these experiments are presented in Table D.1.

FIGURE 4.4: Global Implications of Removing All Current Domestic Support
(Percentage of Change Relative to Baseline Projections for 2040)



Source: Authors, using model simulation results.
Note: *Brown bars* indicate movement toward, and *teal bars* indicate movement away from achieving the related SDG(s).

However, these environmental gains would come with mixed economic outcomes. On the one hand, the removal of economic distortions created by distortionary domestic support would generate efficiency gains, raising real world income in 2040 by about $74 billion per year relative to the baseline.[12] On the other hand, such reform would face a major political economy challenge because it would lead to a decrease in farm output, reinforcing some policymakers' concerns about food security. Crop production would fall by 2.6 percent in developed countries and 1 percent in developing countries, and livestock production would fall by 1 percent in the developed countries and close to zero in developing. These reductions in output would drive up global prices, but despite the price increases, real farm incomes per worker would decline by about 4.5 percent globally, with more dramatic declines in developed countries (11.4 percent) than in developing countries (2.7 percent).

Impacts on poverty and nutrition would also be adverse. Another problem is associated with impacts on the poorest, and on diets at the national level. While current farm support regimes do not appear to have been designed to reduce poverty or to improve diets, their abolition would likely both increase poverty (albeit marginally) and make healthy diets more costly. The rise in prices would make food more expensive for the poor, constraining progress on poverty reduction. Rising prices would also raise the prices of nutrient-dense foods such as dairy products, vegetables, and fruit, thus reducing their consumption; at the same time, sugar consumption would also fall.

One important insight from this analysis is that the type of support matters. Different types of support have heterogenous impacts, making it difficult to generalize across different interventions (Figure 4.5). Different support measures and policy instruments show broadly similar effects on *some* outcomes but notably different effects on others (see Table D.1). This points to the need for a carefully considered and nuanced strategy for reforming current agricultural support. For example, among transfers, direct input subsidies have the largest impact on production emissions. This is not surprising, since most input subsidies are targeted at crop inputs, specifically fertilizers; but they account for less than half the reduction in emissions when all domestic support to crop production is removed. Eliminating all support to crops would reduce emissions the most—equivalent to a substantial 136 megatons of CO_2eq, or a 24 percent reduction in the estimated incremental emissions from crops between 2020 and 2040 when compared to the baseline scenario. This is a sizable impact considering that production would fall by only 1.3 percent. While most crops have low direct emission intensities, this result also partly reflects the fact that crop output is also a major input (as feed) into the livestock sector.

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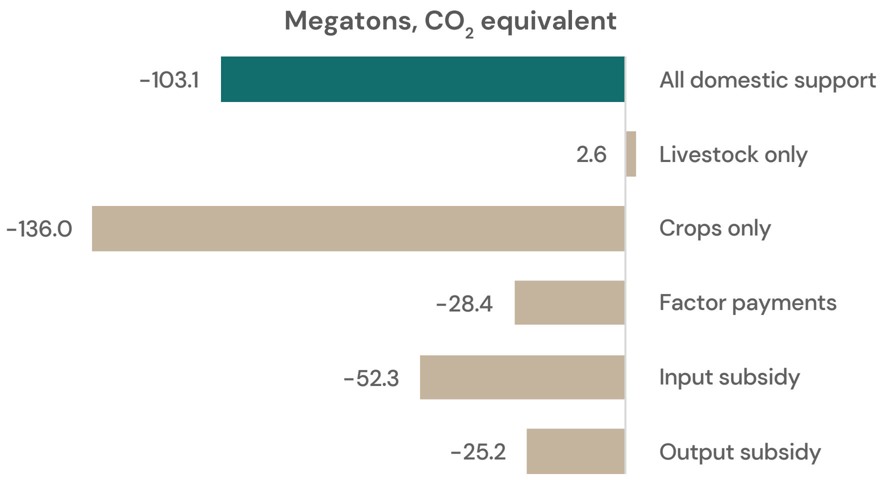
[12] Economic efficiency gains were calculated using the projected estimate of global real GDP of $149.8 trillion in 2040 (an increase of 82.1 percent from the 2017 real GDP of $81.7 trillion).

FIGURE 4.5: Impact on GHG Emissions of Removing Different Types of Support



Source: Authors, using model simulation results.

Removing subsidies to the livestock sector, on the other hand, gives surprisingly different results. Given the overwhelming importance of livestock—and particularly ruminants—in overall emissions from agricultural production, the abolition of subsidies to livestock production might be expected to substantially reduce global GHG emissions. But this does not appear to be the case. One reason for this result is that only about a quarter of domestic support is targeted at livestock production (as shown in Table 3.3), and livestock production benefits from the substantial support to crops such as maize that are used for livestock feed, and which were not removed in this scenario. In addition, much of the emissions from livestock are generated in countries with low levels of farm support: either advanced economies like Australia and New Zealand, or developing countries with large, low-productivity, and relatively high-emission intensity herds (for example, Ethiopia and India). While emissions from production would decline with the removal of livestock subsidies, emissions from land-use change would increase slightly as cropland expanded, creating a marginal increase in emissions. Also, in this scenario per capita dairy consumption worldwide would fall by 0.7 percent, including in developing countries, where the average level of dairy consumption is already considered to be below the requirements for nutrition-adequate diets.

Finally, the global aggregates mask shifts in production across countries*.* A case in point is the modest reduction in global output, which reflects shifts in production across countries to meet global demand and that is expected to continue to grow. Looking at the impacts of removing global domestic support for some key agricultural economies, the analysis shows that the gains in economic welfare would be distributed unevenly across countries. (See Table D.2, which shows outcomes for developed and developing countries as groups, and for some selected large agricultural countries, including Brazil, China, the EU, India, and the US). The reduction in farm output would vary significantly across countries, with larger declines in both crop and livestock output for developed than for developing countries. Among the countries included in Table D.2, crop production would fall significantly in the US (-5 percent) and the EU (-4 percent), but also in India (-3 percent) and China (-2 percent). It would rise in Brazil. Livestock production would shift from the EU and India to Brazil, China, and the US. In general, countries that are light subsidizers and major exporters, such as Brazil, would gain from such a global reform. Emissions would fall in most countries, but with significant variation across countries. The US would experience a 32 percent decline driven by emissions from land use and land-use change. On the other hand, emissions in China would rise, as they would in Brazil and the EU, driven by an increase in land-use change relative to the baseline in China and the EU, and by increased production in Brazil.

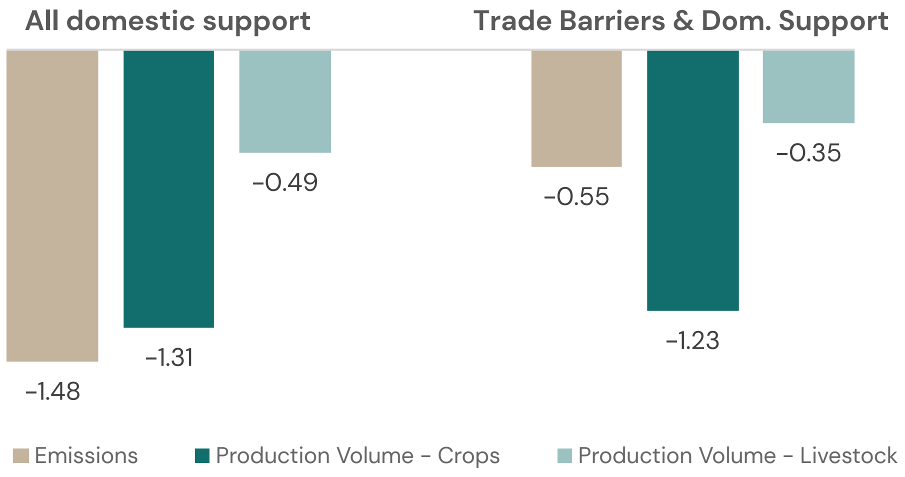
The second key message from this first set of simulations is that simple reductions in, or even removal of, all domestic support would not be sufficient to "bend the arc" on climate change. The results show that while the overall reduction in global GHG emissions would be substantial as a proportion of the baseline global level of GHG emissions in 2040 (1.5 percent), or as a proportion of growth in emissions from agriculture and land-use change over the period 2020 to 2040 (3 percent), this reduction in emissions is an order of magnitude short of what is needed to stabilize the climate. This striking result follows from the limited apparent impact of domestic support on global output and emissions under current production technology and practices.

The third message is that the large amounts of public spending on domestic support appear to have low "value for money." One notable conclusion is that the gains from these subsidies in terms of incremental global farm output and farm returns appear to be quite small. Globally, the equivalent of 14.4 percent of real farm value added was provided on average between 2016 and 2018 as annual domestic support to producers. Under the baseline scenario, this level of support would be maintained for the entire simulation period (to 2040). The model results show that when domestic support is removed, farm value added would fall by about 5 percent. In other words, domestic support equivalent to 14.4 percent of farm value added—a substantial cost in terms of public expenditures—would "buy" a return of only 5 percent in value added, implying very low value for money as a means of transferring income to farmers (OECD 2003). If farm support is thought of solely as a means to provide transfers to farmers, its implied transfer efficiency would be only about 35 percent. The primary causes of this outcome are the declines in prices resulting from the increase in supply and the increases in production costs resulting from the distortions. While the lower prices would be a benefit to consumers, particularly poor consumers, the distortions to production would be a loss to the world. A policy of transferring income directly to producers could, in principle, provide almost three times the benefit to farmers while avoiding the incentive distortions that current forms of support create, an insight of the type that guided the McSharry reforms of the EU's Common Agricultural Policy (OECD 2011).

4.3.2 Scenario 1b: Remove Both Domestic Support and Trade Barriers

The second experiment (Scenario 1b) removes trade barriers such as tariffs and quotas in addition to all domestic support. The main results are shown in Figure 4.6, and more detailed results are presented in the last column of Table D.1. It might be expected that because trade measures are such a large share of total support, their elimination would significantly reduce both global agricultural output and GHG emissions. But, as noted by Mamun, Martin, and Tokgoz (2021), this ignores an important distinction between domestic support and trade measures: trade protection raises domestic prices, which depresses domestic demand for agricultural products. So, while the protection is typically intended to raise the incomes of farmers, its transfer efficiency at the global level is zero. Any benefit to farmers in protected regions is offset by the decline in global demand that reduces world prices, by the losses to farmers in other countries, and by the inefficiencies created in both production and consumption.

FIGURE 4.6: Impact on GHG Emissions and Production of Removing All Support (% change from baseline in 2040)



Source: Authors, using model simulation results.

The key message emerging from these findings is that removing trade barriers involves stark trade-offs between economic efficiency and emissions. The combined effects of removing trade barriers (a rise in demand) and of eliminating domestic support (a decline in output) results in a smaller decline in output, and a larger increase in world prices for agricultural products than occurs when abolishing only domestic support. The removal of trade barriers offsets some of the decline in global production volumes for crops and livestock observed in the first scenario, where domestic support is eliminated. The net result is that, with greater integration of domestic prices with world market prices, the change in farm incomes per worker (-3.5 percent) is smaller in this scenario than in the first (-4.5 percent).[13] Economic efficiency gains would also be larger (about $135 billion), and poverty would decline slightly more in this scenario than in the first one. But this more comprehensive reform would also reduce the impact on global GHG emissions when compared with the scenario in which only direct support is removed. This finding is consistent with the smaller decline in global agricultural output. A corollary to this outcome is that the removal of trade barriers alone would deliver positive economic efficiency gains, but also higher emissions. This is because as protected markets are liberalized with the removal of trade barriers, consumers would demand more of these products, contributing to higher output and emissions than would be the case under protected markets.

To summarize, the results in this section provide important insights into the complexities associated with simply removing all domestic support and trade barriers. The analysis of the implications of removing farm support is purely a thought experiment, designed to assess the implications of changes in farm support. A clear result of the analyses for domestic support only, and for all support, is that their effects on key policy goals would be mixed. While the increase in national income and the reduction in emissions associated with removing support would be favorable, the associated reductions in farm output would make such a reform extremely challenging from a political economy perspective. A somewhat surprising finding is that the reduction in global emissions and in average net farm output would be similar (in fact, a bit lower) if both trade measures and domestic support were abolished than if only domestic support were abolished. As discussed above, this reflects complex dynamics on both the demand and supply sides for agricultural products. More concretely, it rests on three factors: the tax on consumers imposed

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[13] The dynamics at the farmgate are much more complex and context-specific, depending on the mix of policies in effect at the time. They require more detailed analysis at the individual country level, which is beyond the scope of this global study.

by market price support; the presence of substantial negative market price support in a few major producing and consuming countries; and the fact that removing trade protection raises world prices, and hence the prices received by producers.

The impacts on the costs of healthy foods shown in Figure 4.4 point to trade-offs between economic, environmental, and nutritional outcomes. These results reflect a mix of nutritional outcomes. If trade barriers were eliminated, increases in the consumption of dairy products in developing countries would likely contribute to better nutritional outcomes. Likewise, in all but one of the simulations involving the removal of domestic support, the sugar consumption per person would decline, which would also contribute to better diets. By contrast, in the simulation that includes the removal of trade barriers, sugar prices would fall, and demand would increase, which would worsen the quality of diets. Nevertheless, in all scenarios the average cost of the "healthy diet" food basket would increase. As a result, the share of the global population unable to afford healthy diets would also increase in all cases.

Overall, the baseline and support removal scenarios yield sobering results. With sustained growth in demand as population and incomes continue to grow, *simply removing all agricultural support, even if a global consensus were achieved to do so, would be insufficient to achieve large enough reductions in global GHG emissions to appreciably reduce agriculture's impact on the climate, and nature*. This is because, despite shifts in production across countries and gains in economic efficiency associated with the removal of incentive distortions, there would be only modest changes in global output as world prices adjusted to the removal of support. These results, as well as the adverse impacts on farmer incomes, poverty, and nutrition, suggest that "simple" policy options like removing all domestic support and border distortions are naïve. The real trade-offs they entail make such actions extremely challenging politically, and likely infeasible. Together with the key finding on the low value for money of the current large volume of domestic support provided to agricultural producers, the results point to the imperative of exploring other options for repurposing current policies and support, to identify much-needed "win-win" outcomes.

4.4 REALIGN AGRICULTURAL POLICIES AND SUPPORT FOR BETTER OUTCOMES

Given the trade-offs and the associated political economy dilemmas involved in reducing or removing support—despite its low value for money—this section explores potential options for *repurposing* current support. The analysis here is again at the global level, recognizing that while policy action needs to be taken at the individual country level, these actions impact global outcomes such as climate change through important transboundary effects—both directly, and indirectly through trade. Achieving a shared global goal thus will require an internationally concerted and broadly accepted agenda of policy shifts to make meaningful progress. Repurposing agricultural policies and support also involves significant political economy challenges that must be considered as part of a broader strategy for making agriculture more sustainable, as discussed in Appendix E.

Three broad categories of reform options are examined: they all aim to maintain the current level of support for agriculture, but to redirect and deliver it in more beneficial ways. The analytical framework used in this study allows for analysis of the impact of a broad range of policy options on the triple goals of reducing GHG emissions; making gains in farm efficiency and income, and hence poverty; and achieving improved nutritional outcomes. The three categories of options considered in this study are representative of a range of specific policy options that are conceptually similar, but that need to be tailored to individual country contexts.

> **Scenario 2***: **Restructuring*** domestic support within the current subsidy budget includes two different experiments. In the first, Scenario 2a, the budget is redistributed uniformly across *all products*. Under Scenario 2b all support is transferred to *low carbon-intensity products*.
>
> **Scenario 3**: ***Conditionality*** makes the availability of domestic support conditional on producers switching to products or production processes that are less environmentally harmful (for example, less GHG-intensive), using *currently available technologies*.
>
> **Scenario 4: *Repurposing for green innovation*** redirects a portion of the public expenditures currently being spent on domestic support to invest in the development, dissemination, and adoption of *new green technologies that both reduce emissions and increase productivity*. The balance of the domestic support goes back to the taxpayers and is potentially available to deliver as nondistorting transfers to producers and other stakeholders to compensate them for potential losses due to the reform, and for spending on extension services, rural infrastructure, and other essential public goods and services that are fostering agricultural and rural development.

The restructuring simulations consider moving from the current, highly differentiated set of subsidy rates across outputs, inputs, and factors in two less distortionary directions. Scenario 2a moves to a uniform rate across all agricultural products, while Scenario 2b moves to a uniform subsidy rate on non-emission-intensive products. Both simulations are based on uniform domestic support rates, but they keep the average rate of support unchanged from the level of support in 2020. By reducing the currently very uneven spread of support across commodities, these simulations also move in the direction of decoupled transfers: that is, direct income transfers that are not tied to specific commodities or inputs.

In the "conditionality" simulation (Scenario 3), support is conditioned on farmers' willingness to provide environmental services. There is strong evidence that in countries where there is substantial support to farmers, cross-compliance conditions can increase the adoption of sustainable agricultural practices (Piñeiro et al. 2020). These policies frequently involve reductions in the use of chemical inputs such as fertilizers and pesticides, and sometimes more comprehensive moves to organic agriculture that reduces emissions. If farmers are minimizing costs, as is assumed in the modeling performed for this study, then requiring them to produce using approaches they have previously rejected can be expected to result in higher costs and lower productivity. Consequently, policies of this type are also likely to involve compliance-monitoring challenges akin to those seen with organic food certification (Parker 2021).

An example of this broad approach in industrial countries is the use of enhanced conditionality in the European Union's future Common Agricultural Policy (CAP) proposal (European Commission 2020a). This seeks to achieve reductions in the emissions associated with specific inputs, while compensating farmers for providing environmental services by adopting technologies that they otherwise might not adopt, or that might be less productive than the technologies they currently apply. The EU's Farm-to-Fork proposal (European Commission 2020b) includes the condition that in exchange for direct payments farmers should strive to reduce pesticide use by 50 percent, chemical fertilizer use by 20 percent, and antimicrobials by 50 percent, while increasing the share of organically farmed output to 25 percent. The reduced use of chemical inputs is pursued both because of local externalities (risks to land and water quality, and public health), as well as because of global externalities from GHG emissions. The move to organic agriculture is driven by similar motivations, including to improve soil quality and reduce GHG emissions.

Any conditionality scenario of this type can be expected to have two potentially offsetting impacts on GHG emissions. The first is direct reductions in emissions per unit of output as the use of polluting inputs declines. The second is the likely increase in emissions from land-use change with a move away from the current technologies chosen by farmers to lower-yielding technologies requiring an increase in agricultural land use to meet global food demand. The direct impacts of reducing polluting inputs can be seen relatively easily since they are tracked in the emissions modeling framework used in this study. The impacts of reductions in productivity are much more wide-ranging, involving changes in the allocation of land and in the product mix, and require a global general equilibrium approach of the type used here if their full impacts are to be accounted for. The available literature points to indicative values for the productivity impacts of moving to organic agriculture. Ponisio et al. (2014) found a smaller reduction in yields from moving to organic agriculture than earlier studies, but still estimated a decline of 19.2 percent, while the survey by Seurfert, Ramankutty, and Foley (2014) put the associated yield reductions between 13 and 34 percent. If, for illustrative purposes, the productivity of organic agriculture is around 20 percent less than that of nonorganic, then the EU's proposed requirement for 25 percent organic production would translate into an average productivity reduction of 5 percent.

The specific conditionality scenario used in this study assumes a reduction in both productivity and emission intensities of 10 percent. While any such scenario is inherently arbitrary, this scale of shock to productivity seems broadly consistent with the impacts of the EU's Farm to Fork proposals (European Commission 2020b). The goal of this scenario is to provide insight into the impact of a potentially plausible policy reform—one that could be scaled for greater impacts on productivity or emission intensities.

Impacts on emissions and on productivity are uncertain. Any such policy must carefully assess whether that technology really has higher private productivity than the ones that producers would otherwise have chosen. If the technology on which support is conditioned has lower productivity, and hence would require expansion of global agricultural land use, a key question is whether the emissions associated with the resulting land-use change will outweigh the lowered emissions. This question has been addressed for individual countries (see, for example, Smith et al. 2019), but not, to the best of the authors' knowledge, on a global scale.

The repurposing for green innovation simulation (Scenario 4) redirects a part of current domestic support to investment in new technologies that overcome the limitations or trade-offs associated with current technologies. This option focuses on green innovations, that is technologies and practices that reduce emissions while increasing productivity. Climate-smart agriculture (CSA) is one approach to this goal. This approach, promoted in many developing countries (Bell et al. 2018), seeks to achieve three objectives: (1) increasing productivity; (2) increasing resilience; and

(3) mitigating climate change by reducing emissions. De Pinto et al. (2020) use crop modeling techniques to argue that widespread adoption of CSA techniques could sharply increase agricultural productivity. Where it is feasible, approaches that can do this are highly desirable because they can help raise productivity while also lowering GHG emissions.

A key challenge, which is addressed in the paper by Bell et al. (2018), is to identify approaches that will better support the objectives of CSA, or other agroecologically sound approaches, rather than the technologies and practices currently in use. If the current lack of adoption of these technologies is due to a lack of information, high capital costs, or a need for adaptive research to meet particular production conditions, then approaches that will alleviate the associated market failures are better than blunt instruments that induce compliance by, for example, conditioning support on the adoption of new technologies, or simply by regulatory fiat.

The main challenge is creating green innovations that will achieve these outcomes. Some such innovations already exist or are emerging and have been proven effective in some contexts. Based on an examination of the evidence provided by recent literature, the specific simulations used in this report assume a 30 percent reduction in emissions per unit of output, and a 30 percent increase in productivity. These assumptions are within the range observed with key new technologies. (See, for example FAO 2016). A 30 percent reduction in emissions is broadly consistent with the potential that was identified by Mernit (2018) for ruminant feed supplements and analyzed by Laborde et al. (2020). Runkle et al. (2019) found reductions of 65 percent in methane emissions from rice production, with substantial water savings and no yield loss, using alternate wetting and drying practices. More recent evidence suggests that the reductions in emissions and in the costs associated with livestock feed additives may be substantially higher than the 30 percent considered here. For example, Kinley et al. (2020) found emission reductions of 40 to 98 percent, and weight gain improvements between 42 and 53 percent in cattle. And Chang et al. (2021) have highlighted substantial reductions in emission intensities associated with livestock production in the past two decades; they conclude that improvements in livestock production efficiency for achieving emission reductions show much more promise than efforts to change consumer demand patterns.

Reducing methane emissions is a high priority if global warming of over 1.5°C is to be avoided. The Energy Transitions Commission (2021) and Wolf (2021) both highlight the need for much greater emphasis on reducing methane emissions than is provided under the current nationally determined contributions (NDCs). Since emissions from enteric fermentation account for over a third of anthropomorphic methane emissions (Terazono and Hodgson 2021), together with emissions from rice, which account for an additional 9 percent, they present an extremely important opportunity for mitigating emissions of this potent GHG. Ocko et al. (2021) see the potential to lower methane emissions from livestock by 30 percent and rice by 49 percent using currently available methods. They see this as part of a package of methane emission reductions that—alone—could slow the global mean rate of warming by 30 percent by midcentury. The reduction in emissions from agriculture is also consistent with the Global Methane Pledge for rapid reductions in methane emissions that was supported by more than 30 countries in the lead-up to COP26 in Glasgow (US Department of State 2021).

To turn these aspirations to outcomes will require investment in research and development (R&D). The urgency of such action takes on added importance in light of two key findings from a new study from the Commission on Sustainable Agriculture Intensification (CoSAI) (Dalberg Asia 2021). First, while funding for agricultural innovation across the Global South[14] has been increasing, it remains low. It is highly concentrated (China, Brazil, and India account for 60 percent of public funding for R&D); and its rate of growth is decelerating. The second finding is that currently only a small fraction (7 percent) of the current $60 billion spent on innovation is targeted at sustainable intensification.[15]

Public support for future R&D requires careful design. The final simulation (Scenario 4) increases investment in research and innovation to develop technologies that target reducing emission intensities and raising productivity. A key feature of this scenario is that it demonstrates the critical role of innovation in achieving the desired “triple wins.” To highlight this, a subsidiary simulation (Scenario 4a), where green innovations are assumed as “manna from heaven” (that is, costless to taxpayers), demonstrates the importance of innovation in driving appreciable gains on the “triple wins.” In addition to investing in the development of green innovations even where technologies have a strong demonstrated capability to raise productivity and reduce emissions in specific contexts—as, for example, in the Kinley et al. (2020) experiment with cattle in Townsville, Australia—considerable investment in adaptive research and dissemination may be needed before they can be adopted more widely. Based on available studies, a rough indication of the cost needed to achieve such productivity gains might be given by the benefit-cost ratio investments for rural R&D of 10 found by Alston, Pardey, and Rao (2020). If the benefits of this type of R&D follow the 50-year distributed-lag they identified,

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[14] CoSAI uses the World Bank’s definition of the Global South, which includes Asia (excluding Japan, Singapore, and South Korea), Central America, South America, Mexico, Africa, and the Middle East (excluding Israel).

[15] Total of current funding by the domestic and development partners, and the private sector.

a sustained increase in output of just over 30 percent[16] would require an investment equal to one percent of agricultural output. To finance the needed investments, this scenario considers repurposing part of current domestic support to agriculture that, based on past investment returns, would be enough to generate the 30 percent increase in output. Alternatively, green innovations could be financed through additional public funding. Another subsidiary simulation (Scenario 4b) shows that this would yield similar but slightly smaller gains on key outcomes. Many countries face fiscal constraints that would complicate the public funding option. This constraint has become even more binding as many economies struggle to recover from the COVID-19 pandemic (Laborde, Martin, and Vos 2020). Another consideration is the current low intensity of public spending on research and innovation, which is further declining in the very countries where it is needed the most (Fuglie et al. 2020).

The following discussion compares results from the restructuring scenarios (Scenarios 2a and 2b) with a conditionality (Scenario 3) and a repurposing scenario (Scenario 4). The key features of these scenarios are set out in the shaded rows in Table 4.1 (Scenarios 2a, 2b, 3, and 4). Results for subsidiary simulations (3a, 3b, 4a, 4b, 4c, and 4d) are similar to those for Scenarios 3 and 4, and are given in Table D.3. Focusing the discussion on the key outcomes of interest: the main results related to the overall economy, farm production, social outcomes, people's diets, emissions, and the effect on nature are summarized in Figure 4.7. This figure also shows results from the previous scenarios that simulate the removal of current support, to put the magnitudes of the projected impacts in perspective.

TABLE 4.1: Scenarios Considered

SCENARIO	LABEL	REGION	CHANGE IN INSTRUMENT	EMISSION COEFFICIENT
2a	Uniform subsidy	World	To weighted average	None
2b	Uniform on non-CO_2 -intensive products	World	To weighted average for non-CO_2 intensive products, 0 otherwise	None
3	Conditionality	World	Agricultural TFP= -10%	-10%
3a	Conditionality	Developed countries only	Agricultural TFP= -10%	-10%
3b	Conditionality	Developing countries only	Agricultural TFP =-10%	-10%
4	Repurposing for GI	World	Agricultural TFP =+30%; repurpose 1% of Ag Output equiv. of domestic support to invest in R&D, with rest available for other ARD PGs	-30%
4a	Green Innovation – as "manna from heaven"	World	Agricultural TFP =+30%	-30%
4b	Green Innovation – publicly funded	World	Agricultural TFP =+30%; additional 1% of Ag Output is spent on R&D	-30%
4c	Green Innovation – publicly funded	Developed countries only	Agricultural TFP =+30%; additional 1% of Ag Output spent on R&D	-30%
4d	Green Innovation – publicly funded	Developing countries only	Agricultural TFP =+30%; additional 1% of Ag Output spent on R&D	-30%

Note: TFP=Total factor productivity; GI=Green Innovation; ARD=Agriculture and Rural Development; PG=Public Goods.

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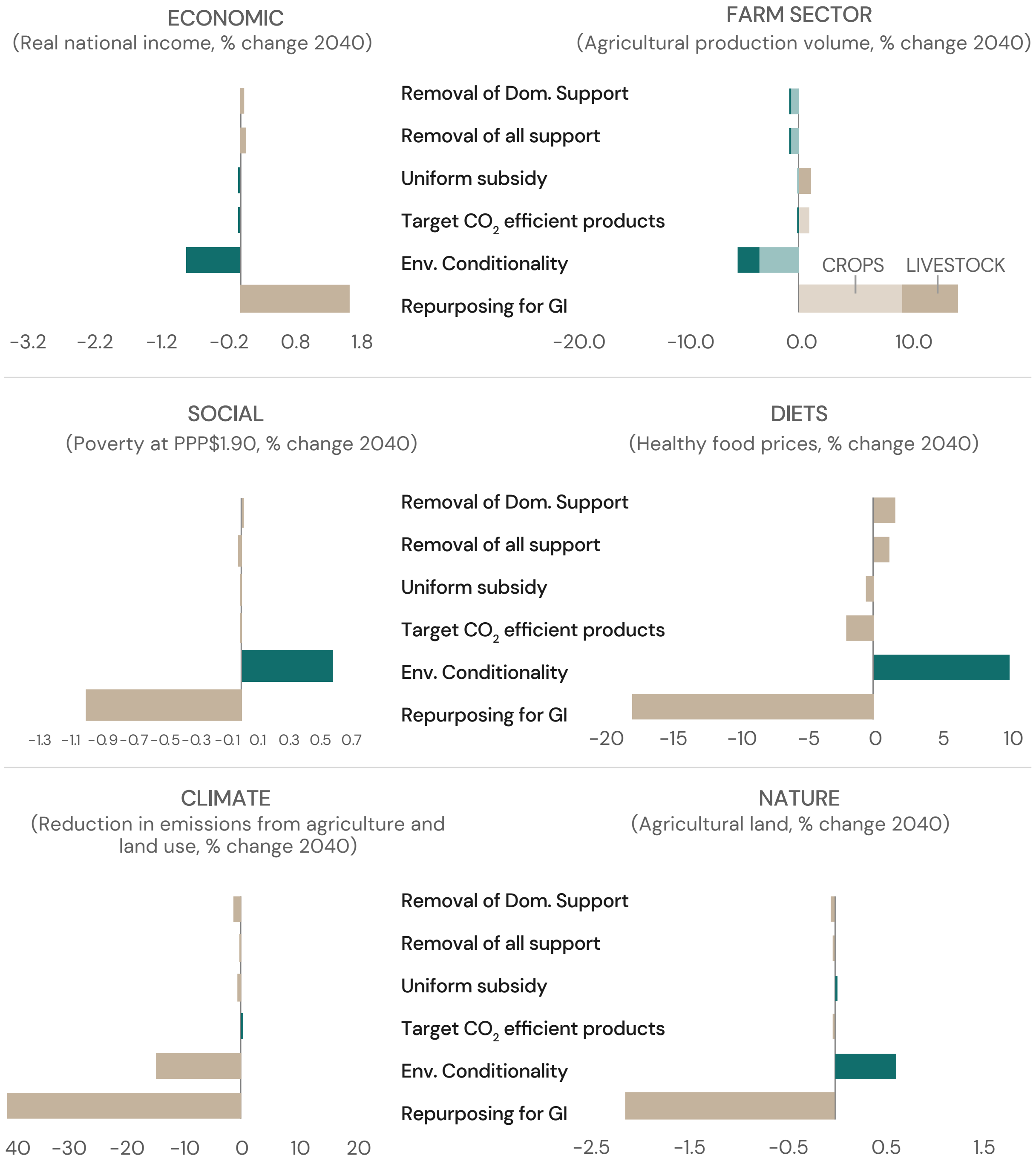
[16] At a discount rate of 5 percent.

FIGURE 4.7: Global Implications of Repurposing Domestic Support (Percentage Change Relative to Baseline Projections for 2040)



Source: Authors, using model simulation results.
Note: ***Brown bars*** indicate movement toward, and ***teal bars*** indicate movement away from achieving the related SDG(s). GI= Green Innovation.

4.4.1 Scenario 2: Shift to Less Distorting Forms of Support and Lower-Emitting Activities

Maintaining the current level of support, but changing the patterns would offer only small economic, social, and environmental gains. The two restructuring experiments address the question of whether it is the *pattern* of current direct supports, or their *level* that most affects their impacts on economic, social, and environmental outcomes**.** In the first experiment, moving from the current patterns of support to a uniform output subsidy with the same budget cost would have only modest impacts. Surprisingly, real national income would fall, albeit very slightly, a second-best result consistent with budget support being transferred away from lightly protected commodities to commodities with greater support from border measures. Overall, agricultural prices would fall, with the net result that farm incomes per worker would also fall slightly. On the plus side, reductions in the prices of dairy products would raise consumption levels, modestly reducing the costs of healthy diets. Emissions from agricultural production would increase slightly by 0.5 percent, but this increase would be more than offset by a decline of 1.1 percent in land-use emissions, with total emissions from agriculture and land use falling by 0.7 percent.

Reallocating support away from the most emission-intensive agricultural commodities to other agricultural commodities might not reduce emissions, since it would encourage increases in agricultural land use. In this experiment, support is shifted away from high-emission livestock production and rice toward other agricultural commodities, mostly crops that have much lower emission intensities. This scenario would also reduce real national income, but again only slightly. Production of the highly traded grains and other non-livestock commodities would expand, while livestock production would fall slightly. With a reduction in overall prices driven by expanding production of non-livestock products, real farm incomes per worker would fall, but less so than in the first scenario. Consumption of dairy products and fats would decline, while vegetable consumption would increase slightly. However, the biggest dietary impact by far would be a 14 percent increase in the consumption of sugar, as increased support for production interacts with relatively low demand elasticities. On the favorable side, the cost of a healthy diet dominated by non-livestock products would fall by almost 2 percent. However, global GHG emissions would increase slightly in this scenario because the decline in emissions caused by lower agricultural production would be outweighed by increased emissions from deforestation, even though pastureland would be retired with the reduction in livestock production. This experiment suggests that, while appealing, ideas like shifting subsidies away from emissions-intensive commodities without changing current technologies and practices may have surprisingly complex results, and might not necessarily help to reduce overall emissions.

4.4.2 Scenario 3: Condition Support on Environmental Services

Making support conditional on reducing emissions would be positive for planetary health. The conditionality scenario delivers greater environmental benefits than the earlier scenarios considered, despite an increase in the amount of land being used for agriculture. Emissions from agricultural production would fall by 19 percent, driven by the decline in emissions per unit of output. This reduction in emissions from production would be only partially offset by an increase of almost 4 percent in emissions from land-use change as the sector drew in more land to offset the adverse impact on productivity. Therefore, there would be a net reduction in emissions of 15 percent.

But conditionality might also entail important and surprising trade-offs for people and for economic prosperity. Shifting to production methods and practices that improve environmental outcomes but reduce the productivity of land does come with economic and social costs. Real gross national income (GNI) would decline by 0.8 percent, or about $1.21 trillion in 2040, compared to the baseline projection in 2040, because this experiment involves a decline in productivity in an important sector. With this decline in productivity, agricultural production would fall by more than 5 percent. The decline in output would raise world food prices by a substantial 12.7 percent, contributing to an increase in the poverty headcount. The decline in productivity, and the consequent 10 percent increase in the simulated cost of a healthy diet food basket would also cause per capita consumption of healthier foods to decline—dairy product consumption would fall by 6.4 percent, and vegetable and fruit consumption by more than 4 percent. The decline in productivity would also draw additional resources into the sector —agricultural land use would increase to offset the decline in productivity, as would farm employment, slowing structural transformation. Finally, increased use of land for agriculture and the related loss of forest habitat would incur further biodiversity losses. Against the backdrop of these developments, the simulated increase in farm income associated with a global reduction in agricultural productivity might seem surprising, but it is a consequence of the relatively low price elasticities of demand for agricultural products; that is, food prices would rise more than proportionately with the decline in output.

It is important to remember that these results relate to a move to a presumed lower productivity technology *by all countries*. Moving to a lower productivity technology in just one individual country would have exactly the opposite effect on farm income, reducing the volume of output for sale without a strong compensating increase in prices. A country or an individual farmer that moves to a lower productivity technology while the rest of the world turns to higher productivity options faces the technology treadmill problem identified by Cochrane (1958). Farm returns go down both because the decline in productivity reduces output and technical progress elsewhere lowers output prices.

The conditionality experiments for developed and developing countries have substantially smaller impacts than conditionality at the global level. Weighting the percentage changes in real farm income for each country group by its income share would suggest a much smaller increase in real farm income than is seen with global implementation. (See Columns 3a and 3b in Table D.3). This difference arises because when conditionality is introduced in both developed and developing countries, its effects on world prices cumulate, increasing key impacts such as the rise in real farm income and the pressure to use more land in agriculture. An important difference is the impact of conditionality on poverty in developing countries. Poverty rises much more when conditionality is used in developing countries than in rich countries because most poor people in developing countries are farmers. These results share many features with recent analyses of the EU's Farm to Fork proposals, which indicate that those proposals would lead to yield reductions and increased agricultural land use (Barreiro-Hurle et al. 2021; Henning and Witzke 2021).

These conditionality scenarios are potentially very interesting thought experiments to foster policy dialogue. The reduction in emissions turns out to be more or less proportional to the reduction in agricultural productivity. This finding highlights the importance of key links that are often overlooked. First, assuming effective enforcement of the conditionality, the productivity loss would lead to lower agricultural production, compounding the reduction in emissions per unit of output. However, the decline in productivity would induce farmers to expand the amount of land used for agriculture, leading to higher emissions from land-use change. Thus, it becomes particularly important to scrutinize proposals for conditionality to assess their potential impacts on productivity. The validity of assumptions that any productivity losses would be small, or that productivity would actually increase, therefore need to be carefully assessed.

4.4.3 Scenario 4: Repurpose Support to Target Emission Reduction and Productivity Enhancement

The repurposing scenarios illustrate the impacts of green innovations that have an assumed 30 percent increase in agricultural productivity along with a 30 percent decline in emission intensity. The final simulation presented in Figure 4.7 (Scenario 4) refers to the case in which domestic support is repurposed to invest in productivity increases, with resources equivalent to 1 percent of agricultural output (about $70 billion of the $244 billion provided as domestic support annually from 2016-18), and redirected to invest in the development of productivity-enhancing and emissions-reducing technologies and practices. The rest of the domestic support would be returned to taxpayers and potentially available to deliver as non-distorting transfers to producers and other stakeholders, to compensate them for any losses they might incur; to finance incentives for the widespread adoption of green innovations, or to spend on other underfunded agricultural public goods and services such as agricultural infrastructure; and to foster broader agricultural and rural development.[17] The importance of innovations in driving the results in this scenario are highlighted in the subsidiary simulations, the first of which assumes productivity "shocks" to come as "manna from heaven": that is, they are assumed to be exogenous and costless to taxpayers (Scenario 4a). Additional subsidiary simulations (Scenarios 4b–4d) consider financing such innovations through additional public resources. These show similar, albeit slightly muted results on some outcomes—for example, a reduction in emissions and agricultural land, and gains in real national income and structural transformation—and are not discussed here. (See Table D.3 for the full set of results).

Repurposing support toward targeted productivity investments has the potential to deliver large gains through improved economic efficiency, reduced environmental impacts, and better health outcomes. The broad impacts of targeted productivity investments are evident from the "productivity" and "repurposing" scenarios shown in Figure 4.7. The discussion here focuses on the repurposing outcomes, since the productivity simulations give very similar results. Aggregate (world) GNI would be higher than the projected baseline scenario GNI for 2040 by around 1.6 percent, implying a substantial payoff—equivalent to $2.4 trillion in 2040.[18]

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[17] On average between 2016 and 2018, agricultural domestic support is estimated to have been about 6.6 percent of global agricultural GDP. The equivalent of 1 percent of agricultural GDP would imply repurposing about 15 percent of current domestic support toward targeted emissions-reducing public productivity enhancements.

[18] Applying the projected growth rate for GNI from the repurposing scenario to the World Bank's World Development Indicators (WDI) estimate of the average annual global GNI for 2011–18 of $81.5 trillion would result in a 2040 global GNI of $149.4 trillion compared to the baseline 2040 projection of $147.1 trillion (World Bank 2021).

This reflects a substantial gain in economy-wide efficiency.[19] However, the large global productivity shock and the low elasticity of demand for agricultural products would drive prices down by 21 percent as the production of crop and livestock products would rise by 16 percent and 11 percent, respectively. Because the increase in national income and the "savings" in public expenditure from the removal of the remaining domestic support would be much larger than the fall in farm income, it would be possible to compensate farmers for any potential loss in income associated with lower farmgate prices as a result of the productivity increases.

Importantly, these green innovations would deliver huge benefits for climate and nature. Overall emissions from agriculture would fall by a substantial 40.5 percent, or nearly 2.8 Gt CO_2eq—avoiding nearly 80 percent of the incremental emissions expected under the baseline (business-as-usual) scenario between 2020 and 2040. Emissions from production would fall by 24 percent, as efficiency gains significantly reduced input use. In addition, about 2.2 percent of agricultural land would move from agricultural use back to its natural uses, resulting in a 16 percent reduction in emissions from land-use change. The decline of about 105 million hectares of land under agriculture would deliver substantial ecological benefits through the restoration of natural habitats and reduced biodiversity loss. This scenario would not only avoid the need to add 56 million hectares of agricultural land use between 2020 and 2040 as in the baseline scenario; it would also allow another 48 million hectares of current agricultural land to be restored to natural habitats.

Productivity-driven growth would also reduce poverty and generate nutritional benefits. Poverty measured against a poverty line of $1.90 purchasing power parity (PPP) declines substantially (about 1 percent) when productivity rises in developing countries. The composition of diets would shift substantially as the cost of healthier food declined and incomes rose; the consumption of dairy products would increase by 16 percent and the consumption of vegetables and fruit by 12 percent. Overall, the cost of a healthy diet would fall by a remarkable 18 percent and would be expected to drive large increases in the consumption of nutrient-dense foods. At the same time, however, the prices of unhealthy foods would also fall, explaining the increase of almost 28 percent in sugar consumption.

Overall incomes, including for farm workers, would be expected to rise as productivity increases accelerated the process of economic transformation; but there would be important transitional challenges. If unskilled farm and nonfarm labor were perfectly substitutable, labor would move seamlessly out of agriculture, with the returns to labor rising in both sectors. The simulation indeed shows quite rapid structural transformation, with nearly 11 percent of farm workers shifting from farming to other activities. However, transforming farm labor into nonfarm labor is often quite difficult, in large part because the educational opportunities for rural youth tend to be much more limited than for urban youth, and specialized agricultural skills are often less useful in employment outside agriculture. Such "frictions" and other forms of labor market rigidities are well recognized in the literature. (See, for example, Gollin, Lagakos, and Waugh 2014; Herrendorf and Schoellman 2018; and Hicks et al. 2017). To account for these differences, a constant elasticity of transformation (Powell and Gruen 1968) parameter of 0.9 is used by default within the model. This is below the 1.32 value used by Ianchovichina and Martin (2004); the 2.2 estimated by Sicular and Zhao (2004, 257) for China; and the 3.7 estimated by Wang and Matthews (2011), using more recent data for China.

The baseline results suggest that limited movement of labor out of agriculture in response to the productivity shock would lower real wages in agriculture and returns per worker. This challenge can only be overcome if farm labor can more readily transition into remunerative nonfarm work. To explore this hypothesis, a range of simulations was performed raising the elasticity from the baseline value of 0.9 to 25 (Table 4.2). The results confirm that greater mobility indeed offloads the downward pressure on real agricultural wages, and wages would actually rise for elasticities of transformation of 2 and above, well within the degree of labor mobility observed in the literature. With very high mobility (at an elasticity of 25), real agricultural wages would increase by almost five percent. Real farm income per worker, however, would decline even though returns to labor would rise. This is because elasticities of demand for food are low, so the decline in prices would exceed the increase in the quantity of food demanded, pushing down total returns from food production, and hence the returns to agricultural land

TABLE 4.2: Impact of Labor Mobility on Real Farm Wages

	LABOR ELASTICITY OF TRANSFORMATION			
	0.9	2	10	25
Real Farm Income per Worker	-4.5	-3.4	-2.2	-2.0
Real Farm Wage Rate	-3.4	0.1	4.0	4.7

Source: Authors, using model simulation results.

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[19] The gain of 1.6 percent in real national income is significantly higher than the 1.1 percent implied by a 30 percent increase in productivity applied to the share of agriculture in the world economy of 3.5 percent.

One key message that emerges from this analysis is the need to invest in human capital and skill development, and to implement rural development policies that help to create new and better nonfarm employment opportunities. Since these simulations are run over close to a generation, there is time to make investments in the skills of farm children so they will have more employment options during their working lives. With improved educational opportunities, an enabling business environment that encourages new businesses and employment opportunities to emerge, and other rural development policies, the barriers to mobility out of agriculture would decline considerably.

The results when *only* developed countries, or *only* developing countries adopt improved technologies show smaller impacts than when all countries do it on a concerted basis (See Scenarios 4c and 4d in Table D.3). However, in contrast with approaches where unilateral action is undermined to some degree by "leakage" to nonadopting countries, the sum of the gains from individual adoption are greater than the gains from full adoption. This is because a country that adopts productivity-enhancing practices gains market share from those that do not.

An outstanding question is why countries continue to underinvest in agricultural R&D and in supporting wider adoption of new technologies despite high returns on investment. The puzzle of carefully documented and consistently high returns to investment yet persistently low allocations of resources to agricultural R&D and innovation was explored in detail in a recent World Bank study (Fuglie et al. 2020). This study identifies the implementation challenges for raising productivity and lays out a comprehensive agenda that calls for a combination of revitalizing public research, spurring private R&D, and promoting the adoption of available technologies, particularly by smallholders in developing countries. Briefly, these include simultaneous actions on both the supply and demand sides of the innovation puzzle. On the supply side, the priority is to increase investment in R&D. This would require (1) increasing publicly supported R&D for invention, adaptation, and dissemination of new technologies (for example, by increasing, stabilizing, and diversifying funding; incentivizing scientists and strengthening universities and public research institutions; aligning priorities with user needs; and partnering with foreign and international researchers); and (2) mobilizing the private sector to invest in research and innovation through market liberalization; regulatory reform; intellectual property rights; and catalytic and complementary public R&D. On the demand side, the priority is (1) to remove the constraints to smallholder adoption of technologies by addressing outstanding issues in the enabling environment and improving advisory services and access to finance and markets; and (2) to invest in human capital and capabilities.

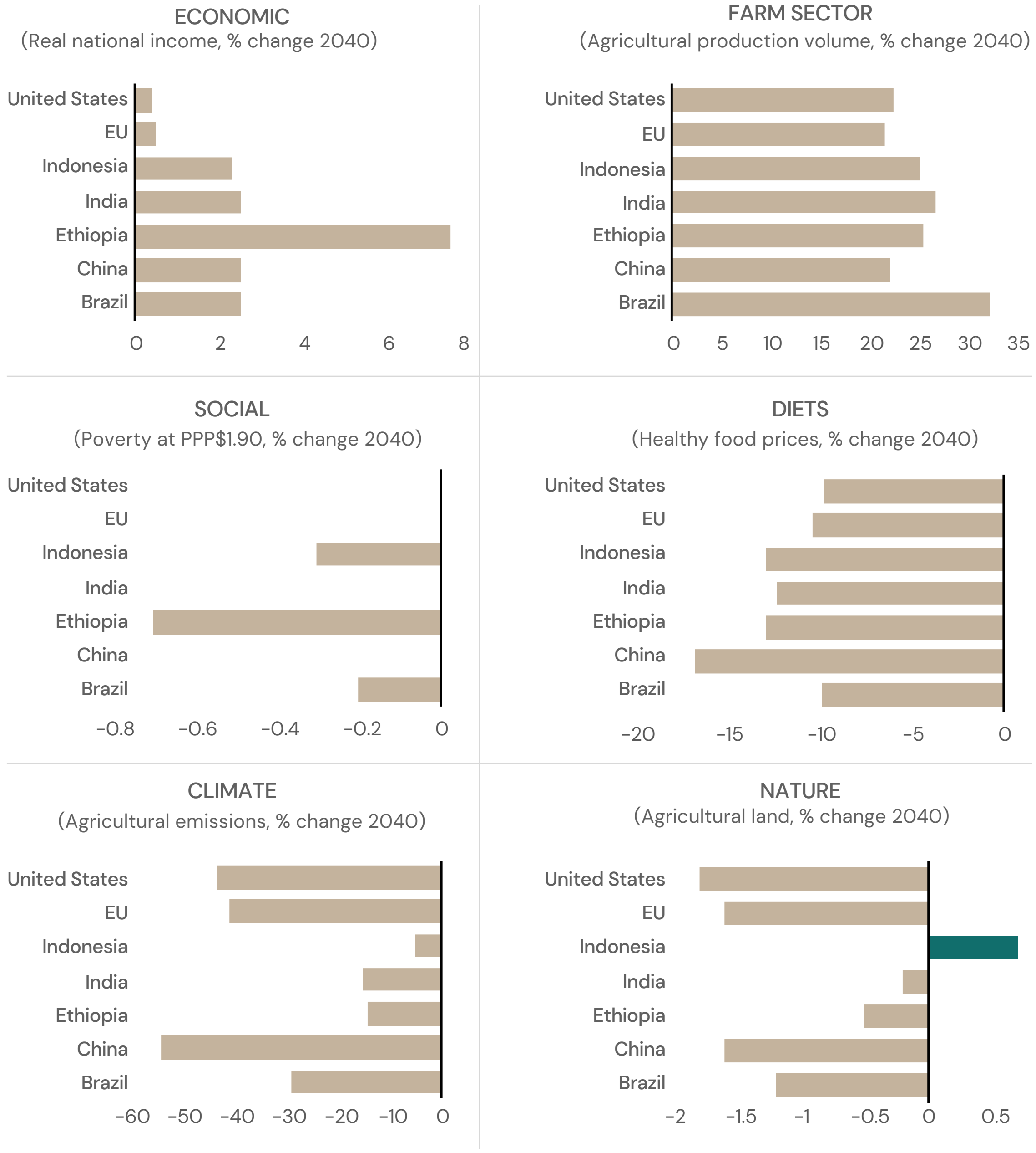
4.4.4 The Impact of Individual Country Actions

The rise in agricultural incomes and in employment when productivity declines, and the decline in incomes when productivity rises, may seem counterintuitive. But these outcomes are a natural consequence of the low income and price elasticities of demand for food, and the global nature of the experiments reported, as shown in Figure 4.7 and Table D.3. They are consistent with the results Matsuyama (1992) found for the world as a whole and for individual, closed economies—that when agricultural productivity rises, prices fall and employment declines.

To evaluate outcomes from individual country actions, which may be more likely to happen than a concerted global reform, the next set of experiments simulated the impact of country-specific productivity-increase and emission-reduction scenarios. The main results found for seven major agricultural countries (Brazil, China, Ethiopia, India, Indonesia, the EU, and the US) are summarized in Figure 4.8, with detailed results presented in Table D.4. These simulations provide results that are intuitive and generally consistent across the major countries. As with the productivity experiments in Figure 4.7, national real income would rise in each country; world prices would decline; agricultural production volumes would increase very substantially, especially for crops; food prices would decline and food consumption would rise; poverty would decline everywhere that measurable poverty remains in 2040, with a particularly large decline in Ethiopia; overall emissions would decline but by very different amounts per country; and agricultural land use would decline in every country except Indonesia. These outcomes are consistent with individual countries having incentives to adopt productivity and emission-reducing innovations. The fact that each country, and each farmer, has an incentive to adopt the improved technology to gain market share and to raise its farm returns, gives this approach an important advantage over alternative approaches—like conditionality or carbon-tax-based approaches—where individual countries and individual farmers have an incentive not to adopt.

In large countries, substantial increases in productivity would depress global prices, but not as dramatically as in the case of a global increase in productivity. The increases in output would be substantial, ranging from 25 to 35 percent for crops, and 17 to 29 percent for livestock. Output responses would have been even larger except for the declines in output prices, with output increasing not only because of the increases in output per unit of resources used, but by drawing additional resources into the sector (Martin and Alston 1997).

FIGURE 4.8: Impacts of Country-Specific Repurposing Scenarios (Percentage Change Relative to Baseline Projections for 2040)



Source: Authors using model simulation results.
Note: ***Brown bars*** indicate movement toward, and ***teal bars*** indicate movement away from achieving the related SDG(s).

Finally, in addition to the positive and desirable outcomes, an important shift seen in country-specific productivity scenarios is the impact on real farm incomes per worker. As indicated, when productivity rises in unison across all countries, it pushes prices down and reduces farmer returns to productivity growth. With country-specific productivity increases, as shown in Figure 4.8 (and Table D.4), real farm income per worker would rise for all the economies considered, except for China and the EU. In all cases, world prices would decline by much less than they do in the productivity and repurposing scenarios shown in Figure 4.8. In Brazil, Ethiopia, India, and Indonesia, the favorable impact of the increase in output would more than offset the more modest decline in prices, and real farm incomes would rise. For China, the EU, and the US, the price declines would be larger. The net result is that real farm incomes per worker would fall slightly in China and the EU, while farmers in the more export-oriented US economy would see a rise in per-worker income. Agricultural land use would decline in all of these countries except Indonesia. The impact on global emissions would differ substantially across countries. The decline in emissions from production would be particularly large in China, the EU, and the US, and the share resulting from land-use change would be particularly large in Brazil.

5

AVENUES FOR FURTHER POLICY ANALYSIS: IMPLEMENTATION

The repurposing agenda outlined here may sound simple to implement but it would require a great deal of additional careful analysis and research. This study makes a modest attempt to analyze the potential outcomes associated with alternative options for repurposing agricultural policies and support, but much work remains to be done. While a lot of thought has been given to allocating research resources toward increasing productivity, little attention has historically been paid to approaches that reduce the emission intensity of production.

It seems likely that increasing productivity and reducing emissions are strongly complementary research outcomes. Much of the emission generation from agriculture is the result of inefficiency in the production process. If, for instance, methane could be used to produce desired outcomes, rather than emitted into the atmosphere from ruminant digestion or flooding rice fields, productivity could potentially be increased substantially. The striking combination of lower emissions and higher productivity growth reported by Kinley et al. (2020) in their experiments with cattle suggest that this potential complementarity can be harnessed through research focused on these two goals. Another, less direct, indication that productivity growth and emission reductions are complementary comes from the generally lower emission intensities, particularly for beef, observed in developed countries relative to developing countries (see Table 3.6). The longer history of R&D in these countries has resulted in generally higher yields for crops and more rapid growth of livestock that have, in turn, reduced emissions from their production. These outcomes have occurred without a strong focus on emission reduction in the agricultural R&D programs of these countries. Going forward, the key is to identify the innovations that are the most effective in both reducing emissions and increasing productivity.

More general rethinking by economists and policymakers about the toolbox for dealing with collective action problems also seems to be required. The traditional toolbox focuses on internalization of the externalities and **pays little attention to identifying technical changes that might mitigate the problem of collective action.** Clearly, the set of technical changes that might contribute to solving the problem is very large. Increasing the efficiency of production can clearly help. Reducing food loss and waste can similarly help, by reducing the resources and inputs needed for production. The traditional environmental economist's concern that increasing the productivity of food production might increase emissions by lowering the cost of food and increasing demand is not warranted when agricultural productivity growth is broadly based. While the falling cost of food does increase demand, the low demand elasticity means that the demand for agricultural land is also likely to decline, bringing about an associated reduction in emissions from land-use change. Thus, a 30 percent reduction in emission intensity and a 30 percent increase in productivity would result in a roughly 40 percent reduction in overall emissions.

While some technological progress is the result of decisions by profit-making entrepreneurs, public research remains critically important. Governments will need to play a more direct and active role in promoting R&D that reduces emissions from agriculture. Some of this is currently being done by governments in beef, dairy, and sheep-producing countries, partly to contribute to environmental goals, and perhaps partly out of concern that market access may in the future be restricted by policies such as border carbon adjustments.

A focused repurposing agenda will also require greater attention to the implications of higher agricultural productivity for farm labor. As observed in the simulations reported in this paper, large-scale increases in agricultural productivity put downward pressure on farm prices that increase the importance of helping farm workers who are no longer needed in agriculture to leave the sector. Doing this successfully will require removing, as much as possible, impediments to the movement of labor out of agriculture such as those that are frequently included in land tenure contracts. There is also a need for a more positive agenda. Improvement of educational opportunities for rural children will become more important as the need for agricultural labor declines and outmigration becomes more likely.

While a productivity-focused approach to lowering emissions is beneficial for producers, adopting countries, and the global commons, other approaches, such as the use of carbon taxes or conditionality, which raise production costs, create disincentives for producers. Frequently, these higher costs will result in pressures for policies to reduce the replacement of imports by products that are produced without these disincentives, or to avoid the contraction of export sectors that are being squeezed by higher costs. One frequent proposal for dealing with these problems is to introduce a border carbon adjustment (BCA) that compensates import-competing firms for their increased costs (Martin 2022). One challenge for this approach is that most emissions from agricultural production are process emissions, rather than emissions from combustion. While carbon taxes can be finely calibrated—by fuel type and emission content—to create incentives both to change production techniques and to reduce output, this is not the case with the process emission from agriculture. This forces a carbon tax on agriculture to rely solely on changing output levels, making it less effective than a carbon tax on emissions from the combustion of fossil fuels. If a BCA is to be introduced, it would be vitally important to cover export-oriented production as well as import-competing production.

The range of policy approaches considered in this paper on repurposing support could be complemented by other measures, such as incentives for dietary change, which was emphasized by Springmann et al. (2017). Given the urgency of the need to reduce GHG emissions from agriculture (Clark et al. 2020), it seems likely that more than one approach will be required.

Finally, when a repurposing agenda is being undertaken, it is important to be aware that the specific policy needs will likely differ substantially among countries. Many countries will need to adapt new and more productive technologies for their own individual contexts before they can be successfully adopted. Individual countries adopting more productive and lower-emission technologies at a higher-than-average rate are likely to have a greater need for support for their farmers in adopting new technologies and in dealing with the resulting contraction in demand for farm labor. Country deep-dives involving considerable research and analysis are likely to be needed to ensure that the interventions make their greatest contribution to the economy, the environment, and to pressing social needs as well.

6

CONCLUSIONS

The results of this study provide new perspectives on policy questions regarding the repurposing of current agricultural support measures. Clearly, there is vast scope for improving current agricultural support measures, particularly for achieving the SDGs related to reducing poverty, improving resilience, and increasing sustainability. However, it is essential to be strategic about the type of reforms to be pursued if those goals are to be achieved.

These findings highlight clear trade-offs among the environmental, economic, nutritional, and social objectives associated with the "simple" option of removing domestic support. The key messages that emerge from this analysis are that, even if it were politically feasible, the abolition of current domestic support would have significant impacts on GHG emissions at the individual country level and even at the sector level: specifically, in the crops sector. But the impact on global GHG emissions will fall far short of what is needed to appreciably curb agriculture's contribution to climate change. There are several reasons for this—most notably that the support rates have been determined on political economy grounds that are unrelated to the environmental impacts of support—but also that some support is provided by countries with relatively low emissions per unit of output. In addition, with sustained and growing demand for agricultural products, there would be shifts in the structure of production across countries, but the overall effect on the level of production would be relatively small. As a result, the aggregate impact on GHG emissions would also be relatively small. Finally, the findings suggest very low transfer efficiency of current domestic support. Each dollar of public expenditure for domestic support contributes only 35 cents in value added, making a powerful case for finding better ways to support producers.

Abolition of border measures would actually increase emissions very slightly. This is because the predominant positive support measures combine support for output with a disincentive to consumption. If current protection were simply removed, the results suggest that the stimulus to global demand would slightly outweigh the loss of incentives to production in protected markets, raising the incentive to produce emission-intensive goods.

When *repurposing* rather than removing support for agriculture, the results show significant potential for some of the options to deliver large "triple wins." The results for various repurposing options, however, also caution against simplistic redesign of policies. Simple rearrangements of current domestic support would tend to have quite limited effects on emissions. In particular, replacing the current highly variable set of subsidies with a uniform set would have little impact on emissions. And transferring all subsidies to low-emission cropping activities would, paradoxically, *increase* emissions due to the global land-use change that would result.

Making support "conditional" on farmers' willingness to provide environmental services could be attractive in terms of emissions reduction. However, some of these options may result in lower productivity. For instance, if farmers were merely asked to reduce chemical input use or shift to organic agriculture, the productivity loss would imply significant reduction in national income and agricultural production, while poverty and the cost of healthy diets would increase, and agricultural land use for agriculture would increase at the expense of forest habitat. Balancing a reduction in emissions with productivity loss, especially in developing countries, is a major challenge.

Repurposing support toward investments that are targeted at productivity-enhancing and emissions-reducing technologies holds the greatest potential for delivering "triple wins" for a healthy planet, economy, and people. Repurposing a relatively small share of the current domestic support funded from public expenditures (which represents about 1 percent of present agricultural value added) toward the development and diffusion of emissions-reducing and productivity-enhancing innovations would improve human welfare while substantially reducing global emissions. Such technologies appear to have the greatest potential for reducing poverty, lowering the cost of healthy diets, and reducing the amount of land needed for agriculture. From the macroeconomic perspective, this repurposing also has the strongest positive impact on real national income and structural transformation; that is, reducing agricultural employment as labor transitions to other sectors of the economy. Policies that lead to the development of new technologies with higher private productivity also have the advantage of not requiring concerted action. Countries that choose to adopt more productive and lower-emission technologies will tend to gain market share, avoiding the problems of carbon leakage that plague approaches based on the use of current technologies.

Notwithstanding the impressive results from the repurposing options discussed in this global modeling study, current agricultural support measures need to be carefully scrutinized in individual country contexts. The "triple win" scenario considered in this study is based on investing only about 29 percent (about $70 billion) of current domestic support for agriculture. But the volume repurposed need not be limited to this level. *A key insight from this study is that current agricultural support is a very blunt, and largely counterproductive instrument for fighting climate change and addressing the remaining challenges to global food security and nutrition.* Current support for agriculture distributes much of its benefits to the relatively well-off and generates substantial inefficiency and inequity by excluding efficient producers from developing countries. There is great potential for achieving major gains on these fronts by repurposing support toward public investments that facilitate the widespread adoption of productivity-enhancing and emission-reducing technologies for agri-food systems. Furthermore, these policies are likely to have strongly positive international spillovers. Innovations that reduce environmental impacts and raise productivity are likely to either be rapidly adapted in other countries or provide them with a basis for developing technologies for their own agroecological environments.

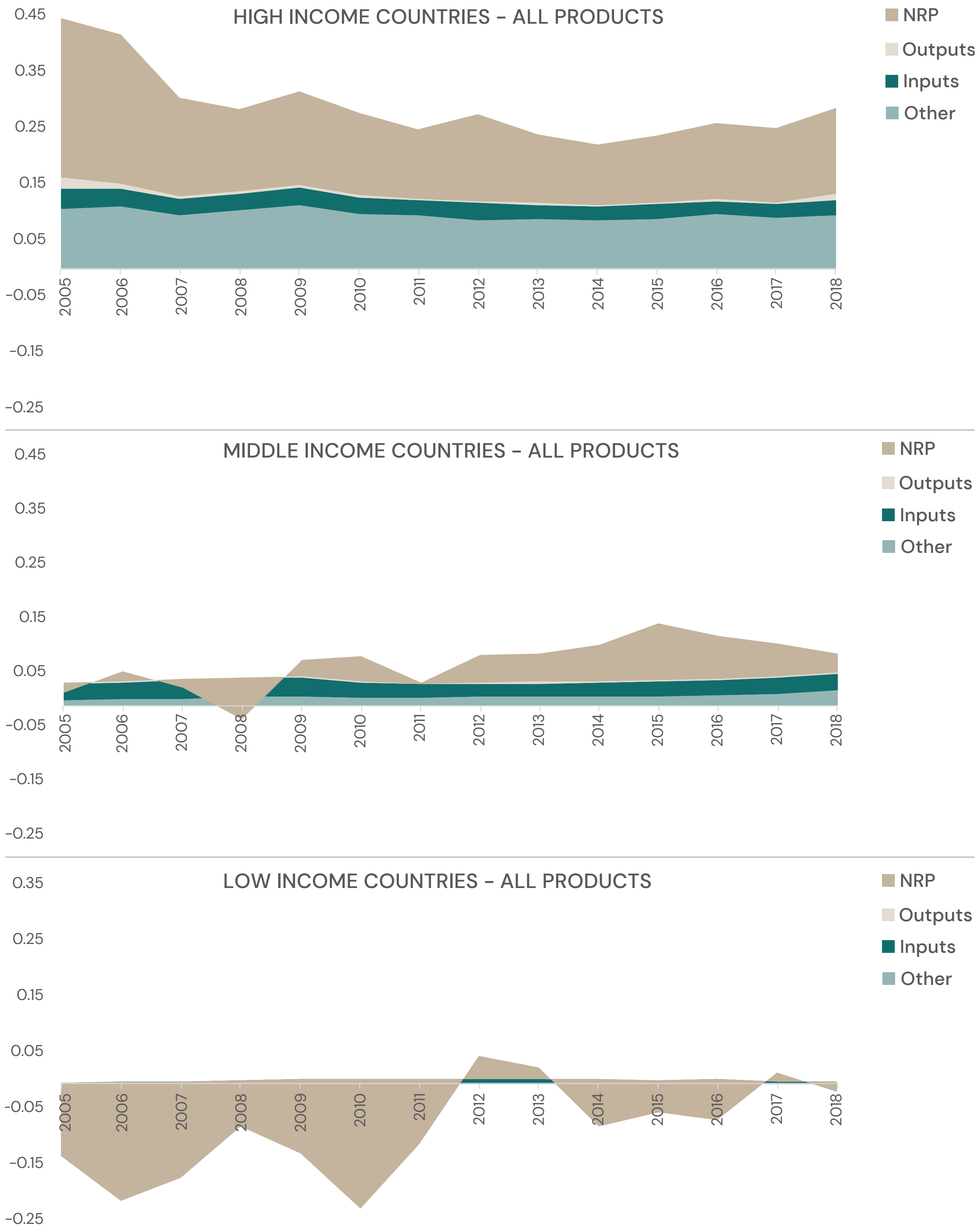
Nevertheless, even the best design of the proposed policy reforms undoubtedly will face considerable political hurdles. Agricultural support policies are the prerogative of national governments. Overcoming national resistance to agricultural policy reform will be a huge challenge. National farm and agricultural policies have a long history in most countries and have developed well-established entitlements and vested interests. Recognition of the major private and societal gains to be achieved, and multistakeholder engagements to discuss the potential trade-offs associated with policy options and to devise acceptable strategies should help earn political support for smart repurposing of the existing support at the national level.

For reforms to foster sustainable global development, a combination of effective policy coordination and technological innovations that are attractive to both individual producers and governments is needed. At present, agricultural support is distributed unevenly across nations. Poorer nations have less fiscal space with which to provide agricultural support. Also, their national agricultural research systems generally have weaker resource capacity for developing high-productivity and sustainable farm technologies and practices that are relevant to the local context, and their farmers and other food producers face bigger obstacles in adopting those practices. Hence, to be most effective at the global level, a more even-handed diffusion of both technologies and financial resources is needed so that countries can reap the benefits of agricultural policy reform and contribute more strongly to solving global challenges.

International coordination is vitally important for achieving the needed reductions in global emissions from agriculture. Climate change and environmental sustainability are global challenges that transcend borders, and national policies have strong international spillover effects. Policymakers are well-placed to scrutinize and rethink domestic policies. For the health of people, economies, and the planet, nations and food system actors *must* come together behind a concerted strategy for resetting global food system incentives to address the existential threats posed by climate change and unsustainable food systems.

APPENDIX A.
TRENDS IN SUPPORT

FIGURE A.1: Trends in the Nominal Rate of Protection by Income Level



APPENDIX B.
METHODS FOR DERIVING THE DATABASE, AND THE EMISSIONS MODELING FRAMEWORK

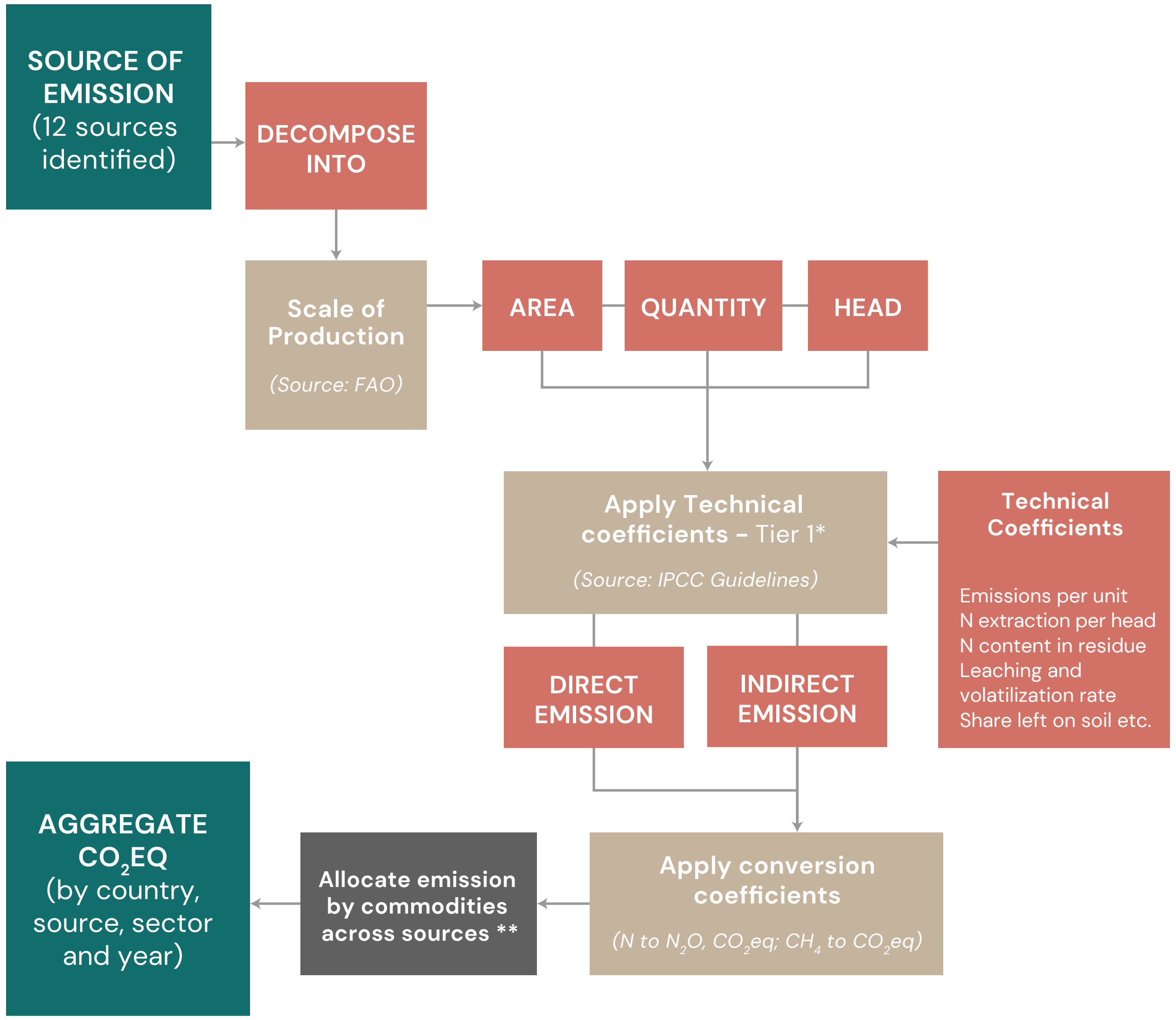
In this study, wherever possible, a full matrix was derived by reverse engineering the FAO emissions data to ensure that the total matched the FAOSTAT estimates. Where this was not possible, as in the case of emissions from pesticides, a similar IPCC Tier 1 methodology was used to generate comparable estimates.

Emission sources were identified using 11 FAOSTAT-based categories, plus emissions from agricultural pesticides. The first step was to define the activity levels associated with commodity outputs, such as the amount of area used for rice cultivation. The second was to calculate the emission coefficients (ECs) for CH_4, CO_2, and N_2O by activity level using, wherever possible, the FAOSTAT database. Finally, emissions of N_2O and CH_4 were converted to CO_2 equivalents, using 310 and 21 for N_2O and CH_4 respectively.

In many cases, the FAOSTAT emissions database provided implied emission factors by activity and emission source, such as the amount of area harvested in rice cultivation, and the nitrogen content of manure. In some cases, it provided the base activity data, such as area of organic soil cultivation, and the number of head of livestock for enteric fermentation and manure management. In other cases, such as burning crop residues, only the data on biomass burned are provided, rather than data on which crops were burned. In such cases, base activity data were imported from the FAOSTAT crop and livestock production database for the crops whose residues are frequently burned—maize, rice, sugar cane, and wheat.

For synthetic nitrogen fertilizer, the activity data regarding the agricultural use of nitrogen is missing. Fertilizer use data are obtained from two sources—FAOSTAT, and the International Fertilizer Association (IFA) (www.ifastat.org). FAOSTAT gives the total fertilizer volume for many countries, while IFA's data regarding fertilizer use by crop provides the nutrient content of fertilizer by crop for 54 countries. Fertilizer use data from FAOSTAT were scaled to match IFA numbers for all countries; this was done by mapping the characteristics of IFA countries to the countries listed in FAOSTAT. Finally, emissions were estimated by multiplying fertilizer volume by the emission coefficients given in the FAOSTAT database. For the final version of the database, the base activity (or index) data were retained in order to estimate the average amount of emissions per index type (land, animals, output, fertilizer, and energy). The process for creating this new database is presented schematically in Figure B.1

FIGURE B.1: Creation of GHG Agricultural Emissions Database by Source, Location, Commodity, Production Stage, and Technology



Source: Laborde et al. 2021.
Notes: * Tier I: Default emission factors from IPCC guidelines (2006). ** Using disaggregation space and linkage matrix.

The allocation of emissions from enteric fermentation and manure management between products such as meat, milk, and wool, from the livestock that produce them (such as buffalo, camels, cattle, goats, and sheep) is in line with the value of their products. The livestock numbers were then linked to emissions using data from the FAOSTAT emissions database. In the final step, emissions data were produced by country, emission source, and commodity.

APPENDIX C.
THE MODELING FRAMEWORK

The International Food Policy Research Institute (IFPRI)'s global computable general equilibrium (CGE) model, MIRAGRODEP, provides the core of the modeling framework used in this study. It is an extension of the widely used MIRAGE multisector, recursive dynamic CGE model of the global economy (Decreux and Valin 2007), which allows for a detailed and consistent representation of the economic and trade relations between countries.

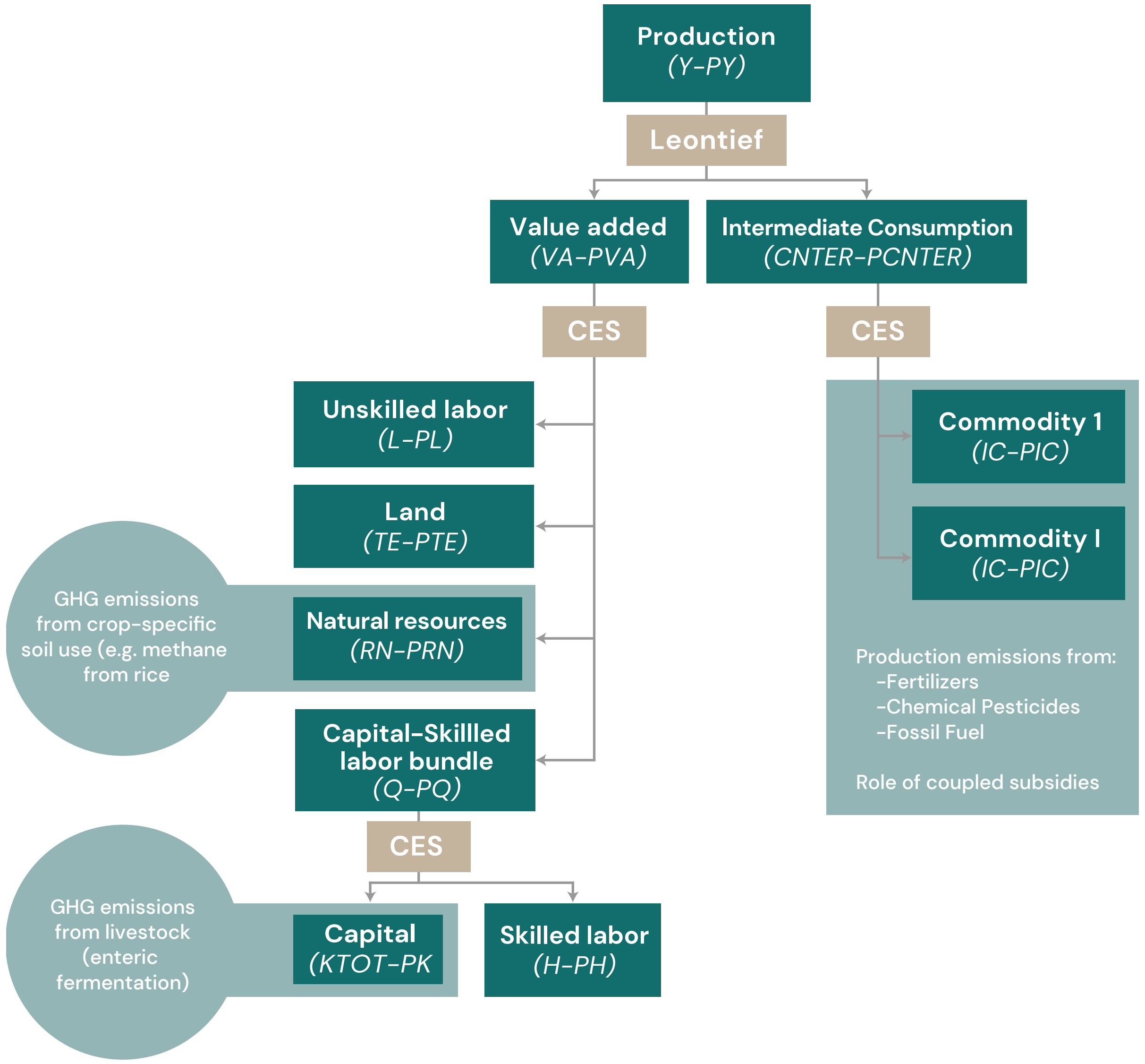
In each country, a representative consumer maximizes a CES–LES (Constant Elasticity of Substitution–Linear Expenditure System) utility function subject to an endogenous budget constraint in order to generate the allocation of expenditures across goods. This functional form replaces the Cobb-Douglas structure of the Stone-Geary function (that is, LES) with a CES structure that retains the ability of the LES system to incorporate different income elasticities of demand (Stone 1954), with those for food being typically lower than those for manufactured goods and services. The demand system is calibrated on the income and price elasticities estimated by Muhammad et al. (2017). Once the total consumption of each good has been determined, the origin of the goods consumed is determined by another CES nested structure, following the Armington (1969) assumption of imperfect substitutability between imported and domestic products.

On the production side, demands for intermediate goods are determined through a fixed-coefficient (Leontief) production function that specifies intermediate input demands in fixed proportions to output. Total value added is determined through a CES function of unskilled labor, and a composite factor of skilled labor and capital. This specification assumes alower degree of substitutability between the last two production factors. In agriculture and mining, production also depends on land and natural resources.

The underlying database used for the analysis is Pre-Release 1 of the GTAP v11 database for 2017 (www.gtap.org). This database includes 141 regions/countries and 65 products. It includes updated social accounting matrices for all individually specified countries, and updated estimates of agricultural support measures based on measures of average domestic support provided by the Organisation for Economic Co-operation and Development (OECD), and adjusted to include the impacts on the bilateral protection rates of major trade preferences. A realistic baseline was constructed, aligned with the United Nations' demographic projections and updated IMF economic growth estimates to bring the base year values (2017) to those of the actual years of simulation (2021–25) and on to the comparisons between reference and simulated outcomes in 2040.

The data on agricultural support were adjusted in line with the OECD's (2016) categories, distinguishing, in particular, agricultural border measures and subsidies that influence output or input decisions (coupled subsidies). The model was augmented with a post-solution module based on the new emission database presented in Appendix B, which links GHG emissions to outputs and inputs of agricultural activities within the model. These links are presented schematically in Figure C.1. The combined model was then used to assess the impacts of policy reform on emissions of CH_4, CO_2, and N_2O, and these results were combined to generate changes in emissions in CO_2 equivalents.

FIGURE C.1: Linking Emissions to Production in MIRAGRODEP



Source: Laborde et al. 2021.

The macroeconomic assumptions used for the analysis were designed to be relatively "neutral" to avoid situations in which macroeconomic adjustments such as real exchange rate changes could outweigh the impacts of interest, and to allow focusing on the impacts of agricultural support policies on emissions. These assumptions were that:

3. The analysis is based on macroeconomic projections to 2040 implemented annually in a recursive-dynamic model.
4. Investment is savings-driven, and the real exchange rate adjusts to keep the current account constant relative to the national GDP.
5. Aggregate real public expenditures are kept constant, and a consumption tax is adjusted to keep the government budget balance fixed as a share of GDP.
6. Land-use change varies across agroecological zones as defined for each region specified in the model, and follows the procedure outlined in Hertel et al. (2009), where land is reallocated between forest and various types of agricultural land in response to changes in returns.
7. Total employment as a share of the active population is constant. The active population is defined by the 15-to-60-year-old group in the United Nations Department of Economic and Social Affairs (UNDESA) projections.

The modeling approach for land builds on the agroecological zone (AEZ) approach of Hertel et al. (2009). Competition for land between forestry and agricultural uses within 16 agroecological zones is represented using a constant elasticity of transformation (CET) specification. Land is also reallocated between agricultural activities in response to changes in relative prices. Emissions from land use and land-use change arise from the conversion of land from forestry to agricultural uses; transitions between grassland and cropland; cultivation of organic soils; and CO_2 sequestration. The model considers only land use and land-use change that was created by changes in agricultural incentives, and thus generates estimates of emissions from the conversion of forest to agricultural land that is less than the gross estimates of land conversion away from forests reported by the Food and Agriculture Organization of the United Nations (FAO).

The poverty analyses reported in the paper were conducted using the POVANA household modeling framework documented in Laborde, Martin, and Vos (2020). To make this relevant to the 2020–2040 projection period for this study, household incomes within the model were projected forward in line with the trends of economic growth in each country. This reduced the poverty rate in the benchmark to 3.5 percent at the traditional World Bank extreme poverty line value of $1.90, and to 10 percent at the $3.20 poverty line. (Both poverty lines are expressed per person per day, and in purchasing power parity dollars, PPP$).

APPENDIX D. DETAILED SIMULATION RESULTS

TABLE D.1: **Global Impacts of Removing Components of Agricultural Support** (% change in each indicator by 2040 with respect to baseline)

	ALL DOMESTIC SUPPORT (1A)	OUTPUT SUBSIDY (1A.1)	INPUT SUBSIDY (1A.2)	FACTOR PAYMENT (1A.3)	CROPS ONLY (1A.4)	LIVESTOCK ONLY (1A.5)	DEVELOPED ONLY (1A.6)	TRADE BARRIERS & DOM SUPPORT (1B)
Macroeconomic								
National Real Income	0.05	0.01	0.01	0.02	0.03	0.01	0.02	0.09
Farm Sector								
Real Farm Income per Worker	-4.51	-0.66	-0.59	-3.37	-3.76	-0.78	-2.43	-3.54
World Prices	2.93	0.74	1.05	1.12	2.66	0.30	1.63	4.38
Production Volume – Crops	-1.31	-0.40	-0.57	-0.35	-1.30	-0.02	-0.35	-1.23
Production Volume - Livestock	-0.49	0.01	-0.28	-0.22	0.12	-0.61	-0.32	-0.35
Social								
Farm Employment	-0.53	-0.15	-0.60	0.22	-0.49	-0.03	0.29	-1.51
2040 Poverty Rate at PPP$1.90	0.01	0.00	0.01	-0.01	0.01	0.00	-0.01	-0.02
2040 Poverty Rate at PPP$3.20	0.05	-0.01	0.07	-0.02	0.05	0.00	-0.03	0.05
Nutrition/Diets								
Dairy Cons Per Capita	-0.42	-0.04	-0.24	-0.14	0.23	-0.66	-0.25	0.55
Fats Cons Per Capita	-0.94	-0.54	-0.01	-0.40	-0.95	0.01	-0.91	-2.68
Sugar Cons Per Capita	-1.24	-0.17	-0.97	-0.09	-1.29	0.04	-0.39	4.91
Veg & Fruit Cons Per Capita	-0.48	0.04	-0.31	-0.21	-0.50	0.02	-0.21	0.02
Healthy Diet Food Prices	1.70	0.08	0.83	0.79	1.40	0.33	0.89	1.15
Climate								
Energy in Agriculture – MtoE	-1.04	-0.18	-0.55	-0.32	-0.75	-0.29	-0.35	-0.91
Emissions from Production, % of ALU	-0.59	-0.03	-0.47	-0.09	-0.40	-0.20	-0.11	-0.20
Emissions from Land-Use Ch., % of ALU	-0.89	-0.33	-0.28	-0.31	-1.55	0.24	-0.39	-0.35
Total Emissions – Megatons CO_2 eq.	-103.1	-25.2	-52.3	-28.4	-136.0	2.6	-35.0	-38.5
Total Emissions - % of ALU	-1.48	-0.36	-0.75	-0.41	-1.95	0.04	-0.50	-0.55
Nature								
Agricultural Land	-0.06	0.00	-0.08	0.04	0.09	-0.17	0.01	-0.02
Cropland	-0.19	-0.06	-0.04	-0.10	-0.38	0.12	-0.10	-0.08
Pasture	0.01	0.03	-0.11	0.10	0.32	-0.32	0.07	0.01

Note: ALU refers to emissions from Agricultural Production and Land Use. MToE = million tons of oil equivalent energy use.

TABLE D.2: **Results by Selected Countries for a Scenario of Abolition of All Subsidies** (% change by 2040 in each indicator with respect to the baseline)

	WORLD	DEVELOPED	DEVELOPING	BRAZIL	CHINA	EU	INDIA	USA
Macroeconomic								
National Real Income	0.05	0.05	0.04	0.26	0.03	0.11	0.03	0.02
Farm Sector								
Real Farm Income per Worker	-4.51	-11.36	-2.70	0.76	-5.03	-23.07	-2.37	-9.36
World Prices	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93
Production Volume – Crops	-1.31	-2.56	-1.02	0.66	-1.83	-3.97	-3.06	-5.06
Production Volume – Livestock	-0.49	-1.10	-0.07	0.81	0.19	-3.00	-0.82	0.15
Social								
Farm Employment	-0.53	0.25	-0.60	1.04	-1.07	-1.01	-2.62	-1.69
2040 Poverty at PPP$1.90	0.01	0.01	0.01	-0.03	-	-	0.06	-
2040 Poverty at PPP$3.20	0.05	-0.01	0.06	-0.06	-	-	0.29	-
Nutrition/Diets								
Dairy Cons Per Capita	-0.42	-0.49	-0.37	-0.17	-0.06	-0.60	-0.35	-0.13
Fats Cons Per Capita	-0.94	-1.16	-0.87	-0.98	-1.42	-0.98	0.64	-1.70
Sugar Cons Per Capita	-1.24	-0.93	-1.46	0.33	-0.49	-0.07	-3.98	0.15
Veg & Fruits Cons Per Capita	-0.48	-0.54	-0.45	-0.64	-0.33	-0.58	-1.23	-0.73
Healthy Diet Food Prices	1.70	2.17	1.44	1.37	1.09	3.19	1.91	2.40
Climate								
Energy in Agriculture – MtoE	-1.04	-1.43	-0.83	0.83	-0.60	-3.07	-2.08	-1.55
Emissions from Production, % of ALU	-0.59	-1.52	-0.38	0.74	-0.30	-6.29	-1.21	-2.42
Emissions from Land-Use Ch., % of ALU	-0.89	-4.52	-0.07	-0.29	5.67	6.83	-0.02	-29.73
Total Emissions – Megatons CO_2 eq.	-103.1	-77.8	-25.3	1.81	22.5	1.46	-19.2	-83.8
Total Emissions - % of ALU	-1.48	-6.04	-0.44	0.45	5.37	0.53	-1.23	-32.15
Nature								
Agricultural Land	-0.06	-0.15	-0.01	-0.03	0.85	-1.28	-0.01	-0.15
Cropland	-0.19	-0.50	-0.06	0.01	0.32	1.39	-0.01	-2.44
Pasture	0.01	0.01	0.01	-0.05	1.05	-6.50	0.00	1.42

TABLE D.3: **Global Impacts of Repurposing Simulations** (% change in each indicator with respect to baseline)

	UNIFORM SUPPORT	2A FOR NON-CO_2 INT. PRODUCTS	CONDI-TIONALITY	3 ONLY FOR DEVELOPED	3 ONLY FOR DEVELOPING	4. REPURPOS-ING FOR GI	4. AS "MANNA FROM HEAVEN"	GI -PUB FUNDED	4B ONLY FOR DEVELOPED	4B ONLY FOR DEVELOPING
	2A	2B	3	3A	3B	4	4A	4B	4C	4D
Macroeconomic										
National Real Income	-0.01	-0.03	-0.81	-0.16	-0.63	1.61	1.71	1.57	0.33	1.31
Farm Sector										
Real Farm Income per Worker	-2.28	-1.16	2.02	1.20	0.81	-8.39	-4.54	-4.79	-2.77	-2.22
World Prices	-0.63	-2.03	12.71	4.47	7.41	-20.85	-23.21	-23.24	-10.72	-16.12
Production Volume - Crops	-0.05	1.41	-6.28	-1.12	-5.19	16.06	18.02	17.95	2.99	14.80
Production Volume - Livestock	2.40	-0.69	-4.66	-1.49	-3.19	11.47	12.19	12.14	3.66	8.41
Social										
Farm Employment	0.25	0.18	4.65	0.98	3.53	-10.50	-9.79	-9.83	-2.49	-7.99
2040 Poverty at PPP$1.90	-0.01	-0.01	0.58	0.00	0.57	-1.00	-1.02	-0.99	-0.02	-1.01
2040 Poverty at PPP$3.20	-0.06	-0.06	0.58	-0.01	0.58	-0.97	-1.05	-1.02	0.04	-1.07
Nutrition/Diets										
Dairy Cons Per Capita	3.20	-0.74	-6.37	-2.02	-4.32	16.41	17.15	17.07	5.14	12.14
Fats Cons Per Capita	-0.65	-0.18	-3.91	-1.00	-2.86	8.65	9.82	9.77	2.77	7.42
Sugar Cons Per Capita	3.58	13.57	-10.20	-3.90	-6.27	27.53	29.37	29.32	11.28	18.33
Veg/Fruit Cons Per Capita	0.09	1.14	-4.40	-1.05	-3.34	11.95	12.79	12.73	2.87	9.98
Healthy Diet Food Prices	-0.49	-1.98	10.01	3.39	6.21	-17.63	-19.06	-19.12	-7.60	-13.34
Climate										
Energy in Agriculture - MToE	0.98	0.72	-4.34	-1.33	-2.92	10.47	11.96	11.90	3.81	8.72
Emissions-Production, % of ALU	0.49	-0.05	-19.17	-3.42	-15.49	-24.14	-23.48	-23.55	-6.72	-17.41
Emissions - Land Use, % of ALU	-1.14	0.31	4.59	1.42	3.11	-16.31	-15.09	-15.22	-4.79	-10.47
Total Emissions – Mtons CO_2 eq.	-45.2	18.3	-1018.8	-139.3	-865.0	-2825.9	-2694.5	-2708.5	-803.4	-1947.9
Total Emissions - % of ALU	-0.65	0.26	-14.58	-1.99	-12.38	-40.45	-38.57	-38.77	-11.50	-27.88
Nature										
Agricultural Land	0.02	0.00	0.62	0.27	0.35	-2.15	-2.04	-2.05	-0.80	-1.21
Cropland	-0.22	0.03	0.45	0.10	0.34	-1.72	-1.49	-1.50	-0.44	-1.09
Pasture	0.13	-0.02	0.70	0.35	0.35	-2.36	-2.31	-2.33	-0.98	-1.27
Forest Habitat	0.04	-0.03	-0.23	-0.08	-0.15	0.40	0.39	0.40	0.15	0.32

TABLE D.4: **Impacts of Country-Specific Repurposing Scenarios: Productivity-Enhancing and Emission-Reducing Farm Practices in Individual Countries**
(% change in each indicator by 2040 with respect to baseline)

	BRAZIL	CHINA	ETHIOPIA	INDIA	INDONESIA	EU	UNITED STATES
Macroeconomic							
National Real Income	2.5	2.5	7.5	2.5	2.3	0.5	0.4
Farm Sector							
Real Farm Income per Worker	4.8	-0.3	6.7	1.2	1.6	-1.2	3.0
World Prices	-2.7	-4.0	-0.2	-2.3	-0.4	-3.4	-4.1
Production Volume - Crops	34.9	25.2	26.7	29.1	25.9	32.7	34.0
Production Volume - Livestock	28.8	18.0	22.8	23.5	23.4	16.7	17.2
Social							
Farm Employment	4.1	-5.6	-3.7	-3.0	-3.1	-1.6	-2.6
2040 Poverty at PPP$1.90	-0.2	-	-0.7	0.0	-0.3	-	-
2040 Poverty at PPP$3.20	-0.2	0.0	-3.0	-0.7	-0.8	-	-
Nutrition/Diets							
Dairy Cons Per Capita	14.7	14.5	23.1	22.1	11.5	8.4	7.7
Fats Cons Per Capita	3.6	10.4	-0.5	-3.6	9.6	2.3	3.2
Sugar Cons Per Capita	23.8	21.3	35.7	20.0	21.8	19.7	16.4
Veg & Fruits Cons Per Capita	9.4	12.5	8.7	11.4	5.4	3.5	4.1
Healthy Diet Food Prices	-9.9	-16.8	-12.9	-12.3	-12.9	-10.4	-9.8
Climate							
Energy in Agriculture - MToE	30.2	19.4	21.9	24.9	24.3	20.6	21.9
Emissions-Production, % of ALU	-17.4	-44.7	-13.3	-14.6	-7.7	-33.3	-32.0
Emissions - Land Use, % of ALU	-11.1	-8.6	-0.5	-0.3	2.8	-7.1	-10.8
Total Emissions – Megatons CO_2 eq.	-116.1	-223.6	-51.5	-233.7	-25.4	-110.5	-111.6
Total Emissions - % of ALU	-28.5	-53.3	-13.9	-15.0	-4.9	-40.4	-42.9
Nature							
Agricultural Land	-1.2	-1.6	-0.5	-0.2	0.7	-1.6	-1.8
Cropland	-0.1	-0.3	-0.5	-0.1	0.8	-0.1	0.5
Pasture	-1.6	-2.0	-0.6	-0.8	0.3	-4.5	-3.4

APPENDIX E.
POLITICAL ECONOMY CHALLENGES OF REPURPOSING AGRICULTURAL POLICIES AND SUPPORT

Transforming agricultural policies and support is likely to involve many serious challenges. Given the deeply political nature of these decisions, simply identifying the ways in which the current structure of support fails to achieve specified economic goals is not likely to be enough to secure reforms. Support measures tend to be in place for particular commodities because of asymmetries in political power between those gaining and those losing from these measures (Grossman and Helpman 1988). Most successful proposals for reform are based on an understanding of the political economy forces that gave rise to the existing measures and the ways in which reform might contribute to the mitigation of emissions. These proposals would necessarily have to be context- and country-specific, and would thus require deeper country-level engagements to identify those pathways and options that may be feasible to implement.

Some reforms attempt to redesign policies in ways that continue to serve the powerful interests that were supported by the initial policies, while reducing the adverse impacts on other affected parties whose strength has increased. Only rarely are policy reformers able to introduce reforms that withdraw benefits from strong interest groups. Major reforms to support policies, such as the reform of the EU's Common Agricultural Policy (CAP) (Swinnen 2015) tend to involve changes in the way in which assistance is provided to powerful economic groups; or changes in either the cost of providing support or recognition of the rising power of other economic groups. In the seminal case of the CAP reform, for instance, the dramatic increase in the cost of providing support when the EU became a net exporter of many products—and hence market price support stopped generating tariff revenues and required funding export subsidies—was an important source of pressure for reform. Another was pressure from trading partners—both unilaterally and through the World Trade Organization (WTO)—against the use of export subsidies.

The rise of interest in repurposing agricultural support is associated with increased concern about environmental problems such as global warming, the need to improve nutritional outcomes, and a desire to increase biodiversity (Just Rural Transition 2021). A key question is how public support for these broader goals may best be channeled into political support that will bring about concrete political change. One big problem for achieving vitally important goals such as improving sustainability is the public-good nature of these goods. A reduction in global emissions that reduces global warming by one degree would provide benefits to all. (In other words, "my benefiting from this reduction does not diminish the benefit to others.") Perhaps more importantly no person and no country can be excluded from the benefit. This creates the well-known problem of the tragedy of the commons, in which it is in the interest of individuals and countries to overconsume a resource, potentially leading to its collapse (Frischmann 2018).

Three approaches to dealing with such collective action problems are typically considered:

1. Agreements that use taxes or subsidies to internalize the associated externalities (Pigou 1932)
2. Allocating property rights (Coase 1960)
3. Allowing communities to create rules for resource management (Ostrom 1990).

A fourth approach that may play an important role is technological change. For example, advances in contraception technology seems to have played an important role—along with the desire to invest in children in higher-income societies—in resolving the seemingly intractable Malthusian specter of global overpopulation and resource collapse. Geoengineering approaches have also been proposed as a potential means of dealing with global warming (Royal Society 2009).

The usual approach to dealing with collective action problems that spill over between countries—whether of international security, product or service standards, or market functioning—is to create an international institution or a body of rules, such as the United Nations, the Universal Postal Union, or the World Trade Organization. Attempts to do this for sustainability through agreements such as the Kyoto Protocol have been unsuccessful because of a lack of enforcement powers, with this agreement having been replaced using the much more flexible architecture of the Paris Agreement.

Attempts to deal with the climate change problem have used all four of the approaches considered. The Kyoto Protocol created targets by country for six main greenhouse gases. This used the Coasian approach of allocating property rights with a view to limiting emissions. Had these rights been freely transferable between countries, they would have mimicked the operation of a Pigovian tax, but with the revenues allocated to the governments in line with their allocations of quotas. Emissions trading systems and carbon pricing systems have been used in a number of countries and cities (World Bank 2020), and resource management systems at the local level have been used to avoid deforestation and the associated GHG emissions (Cardenas 2016).

Agricultural support policies and policies designed to mitigate GHG emissions are very different. However, there are potentially important links between the two, through reforms to agricultural support policies that:

1. Reallocate support toward low-emission agricultural activities, and away from emission-intensive activities.
2. Make receipt of support conditional on the adoption of low-emission production methods.
3. Reallocate some support resources toward the development of production methods that have lower emissions and higher productivity.

Reallocation of support away from high-emission activities runs into the political economy problem that some activities have much greater ability to generate political support. It is of course important to assess whether this approach can, in fact, generate substantial reductions in emissions. Approaches that make the receipt of benefits conditional on low-emission production methods have clear appeal in some cases. If a much lower emission technology is available at low cost and the threat of withdrawing support is large enough, then it might be possible to greatly reduce emissions through this approach. However, there are serious challenges with it, including slippage that reduces the reduction in emissions achieved, and the risk of non-additionality, whereby farmers receive payments for doing what they would have chosen to do anyway (Mamun, Martin, and Tokgoz 2021).

Approaches that reallocate some funding from subsidies toward approaches that reduce emissions and that, ideally, also increase productivity appear to have a great deal of potential. Many sources of emissions from agriculture, such as methane emissions from ruminants, are both a source of potent GHG emissions and an abject waste of a potentially valuable resource. It is not surprising that innovations designed to reduce these emissions also appear to raise the efficiency of production (Kinley et al. 2019). Some countries with high GHG emission intensities in their agriculture sector have begun to support research on ways of reducing these emissions (see, for example, the NZ Agricultural Greenhouse Gas Research Center).

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