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Impacts of Agricultural Policies on Productivity and Sustainability Performance in Agriculture: A Literature Review

Gwendolen DeBoe, OECD

This report reviews the evidence base on how agricultural policies impact environmental sustainability and productivity of the agriculture sector, including the potentially contradictory signals policies may send. It considers impacts for specific policy types, classified according to the OECD's Producer Support Estimate (PSE) classification for agricultural support. At the farm level, key pathways for environmental impacts identified in the literature are firstly incentivising a change in agricultural production at the intensive margin, extensive margin or entry-exit margin, and secondly the dynamic impacts of land use choice. Beyond this, policies can also affect agriculture's environmental performance by stimulating (or stifling) the provision of environmental services. Environmental impacts from agricultural policy depend on several factors. Individual responses to economic incentives created by agricultural policies vary, producing variations in environmental impacts. Variation also occurs due to location-specific physical factors, including landscape characteristics, as well as the cumulative effects of decisions across actors and across time. Finally, impacts may differ across scales.

Keywords: Agricultural support, Environment, productivity, sustainability

JEL Codes: Q15, Q18

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Executive Summary

A key agricultural policy question for many governments is how to design and implement policies that incentivise agricultural management practices which stimulate agricultural productivity growth and sustainable resource use. Responding to this question requires understanding how current and potential new policies perform in these respects. This report offers a synthesis of theoretical and empirical findings from the literature on the impacts of agricultural support policies on sustainability and productivity performance in agriculture. It considers impacts for specific policy types, classified according to the OECD's Producer Support Estimate (PSE) classification for agricultural support. It does not attempt to assess the significance of agricultural policy impacts relative to impacts from other sources (e.g. market price fluctuations, non-agricultural policies).

The theoretical literature acknowledges that agricultural policies can produce both negative and positive farm- and sector-level economic impacts. This review focusses on economic impacts in terms of changes to farm-level technical efficiency (TE) and total factor productivity (TFP). Four key pathways via which policies affect TE and TFP are identified: changing relative prices; increasing or reducing income constraints; altering risk exposure and incentivising or dis-incentivising structural change.

Agriculture is one of the most significant sources of environmental pressures worldwide. At the farm level, key pathways for environmental impacts identified in the literature are firstly incentivising a change in agricultural production at the intensive margin, the extensive margin or the entry-exit margin, and secondly the dynamic impacts of land use choice. Beyond this, policies can also affect agriculture's environmental performance by stimulating (or stifling) the provision of environmental services such as carbon storage, preservation of rural landscapes, the resilience to natural disasters, or pollination.

Environmental impacts from agricultural policy depend on a number of factors. First, individual responses to economic incentives created by agricultural policies vary, which leads to variations in environmental impacts. Second, variation occurs due to location-specific physical factors, including landscape characteristics. Third, impacts depend on the cumulative effects of decisions across actors and across time. Finally, impacts may differ across scales.

Studies examining policy impacts on farm-level TE are far more common than those examining TFP. The main findings from the literature in this area are:

- All studies except one find a negative relationship between *farm dependency on support* (i.e. share of support payments in revenue, output value etc.) and *TE*.
- Most studies find a negative relationship between support *levels* (i.e. payments per farm, per hectare, etc.) and *TE* and *TFP*. However, there are some exceptions in specific countries; studies for Denmark, Ireland, Spain and Sweden report more positive impacts than negative ones, while studies for Germany, Portugal and the United States report an equal number of positive and negative findings. This could reflect several factors. First, different policy types are more- or less-studied in different countries. Second, impacts differ by farm type, and therefore country results are likely to differ with dominance of farm types.
- For crop farms, coupled payments (e.g. payments linked to current output, receipts, crop area, livestock numbers), agri-environmental payments (usually payments for farmers to voluntarily abide by environmental constraints) and total payments most often have a negative impact on farm level TE or TFP, while decoupled payments and Less Favoured Area (LFA) payments tend to have a neutral (or statistically non-significant) impact. The result for coupled payments

also holds for dairy farms and non-dairy livestock farms. In contrast, decoupled payments and environmental payments most often have a positive impact for livestock farms (both dairy and non-dairy). Overall, studies of total payments show that significantly positive links between support and farm TE are much more common for livestock farms than for crop farms, and that this is also the case across policy groups, except for LFA payments (neutral or negative) and coupled payments.

Empirical evidence on environmental impacts is more diverse and scarcer than for efficiency or productivity impacts. Nevertheless, some general findings emerge:

- Policies which incentivise *expansion* of agricultural areas or conversion of fallow or low-intensity agricultural land uses towards more intensive agricultural uses can cause severe environmental harm. In particular, market price support and coupled payments encourage intensification in fertile agricultural areas, increasing environmental pressures, and therefore tend to have negative impacts on water quality and greenhouse gas emissions. They may have negative or positive impacts on biodiversity depending on whether they promote crop diversity versus monoculture. Given the finding that coupled support generally has a negative impact on farm TE and TFP, as well as negative environmental impacts on highly productive land, and that coupled payments cannot easily be targeted, there appears to be no clear support in the reviewed literature for maintaining these kinds of payments from a productivity or environmental sustainability perspective. However, where such support is reduced, potential dynamic farmer responses such as abandoning agricultural land and intensifying production on remaining land are important considerations, which may warrant targeted policies.
- Policies which incentivise *contraction* of agricultural areas directly (e.g. land retirement policies) or indirectly (e.g. policies which, depending on context, may incentivise substitution away from land toward other agricultural inputs) can produce positive environmental impacts via directly reducing or eliminating pressures from agriculture on specific land parcels. However, if not managed well, contraction of agricultural land can lead to land abandonment which can also have substantial negative environmental impacts in some cases. Reviewed studies show that 'passive restoration' of abandoned agricultural land does not necessarily lead to improved environmental outcomes in all cases. Contraction of agricultural land may be linked to intensification on remaining land, too, which can lead to negative environmental impacts via increased pressures from agricultural activity in those areas. Therefore, the reviewed literature suggests that policymakers may need to be more pro-active about managing land use transitions resulting from specific policies or from policy change.
- Environmental impacts of decoupled payments seem to depend mostly on the type and effectiveness (i.e. environmental stringency) of accompanying mandatory conditions, rather than on direct incentives stemming from the payments themselves.
- Studies examining decoupling reforms with and without mandatory constraints show that, in general, decoupling has positive economic impacts. Agri-environmental payments are also generally found to have a neutral or small positive impact on economic performance. However, there is limited evidence that existing mandatory constraints successfully mitigate negative environmental impacts of agriculture. There is also evidence that agri-environmental schemes quite often fail to incentivise additional production of agri-environmental goods and services, with many existing examples found to be of limited environmental effectiveness. This suggests that the design of mandatory constraints and agri-environmental schemes could be improved to deliver better environmental performance without sacrificing economic performance.

This report reviews the evidence base on how agricultural policies impact environmental sustainability and productivity of the agriculture sector, including the potentially contradictory signals policies may send.

The review was conducted by first constructing an overall conceptual approach, which is implemented via the structure of this report. This approach consists of:

- Identifying the theoretical pathways via which agricultural policies may impact on productivity and sustainability performance in agriculture – Section 1.
- Using the OECD's PSE classification of agricultural support, presenting evidence from around 130 empirical studies on the impacts of different kinds of agricultural support on productivity (and the related concept of technical efficiency) and sustainability performance in agriculture – Section 2.
- Presenting evidence on how impacts vary dynamically and spatially – Section 3.
- Identifying gaps in the evidence base, with recommendations on directions for future research – Section 4.

In each section, the review was approached by conducting online searches of OECD publications (OECD iLibrary) and the peer-reviewed literature via Google Scholar and other databases such as EconLit. Bibliographies in key papers were also searched to identify further papers of interest. In addition, certain grey literature (for example, policy evaluations published by governments) were also used. Greater detail on the literature search procedure is available at Annex A.

The review provides a non-statistical (i.e. non-econometric) meta-analysis of studies examining the impacts of different kinds of agricultural payments on productivity and technical efficiency at the farm level, together with environmental impacts.[1] Collection of data for this part of the analysis follows Minviel and Latruffe (2017[3]), who undertook an extensive survey and statistical meta-analysis of the literature examining the effects of public support on farm technical efficiency, using data up to 2014. Beginning with the supplementary online appendix provided by these authors, this review augments Minviel and Latruffe's study by collecting further observations from *ex post* studies on technical efficiency policy impacts, as well as findings on productivity and environmental impacts.

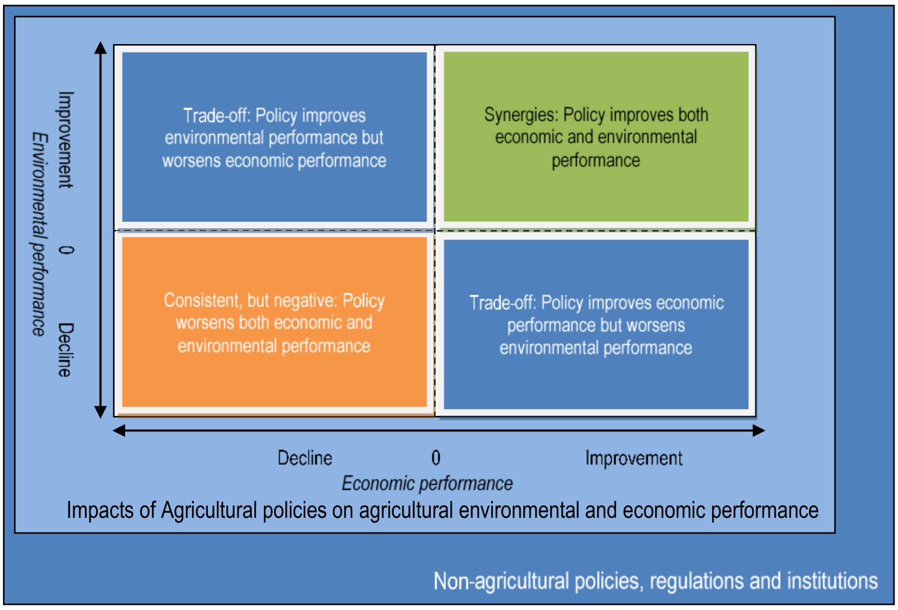
1. Pathways for agricultural policy impacts: A conceptual framework

A key policy question for many governments is how to design and implement policies that incentivise agricultural management practices which would stimulate both agricultural productivity growth and environmental sustainability, while also determining whether there would be synergies or trade-offs between productivity and sustainability objectives.

While there is a range of policy tools beyond agricultural policies which are available to governments (e.g. environmental regulations), if agricultural policies can be designed to promote synergies between economic and environmental performance, there will be less need to use other policy mechanisms to counteract negative effects of agricultural policies. This is likely to lead to improved policy coherence overall, for example between agricultural policy and environmental policy. Further, it is also likely to deliver the achievement of economic and environmental objectives for agriculture at lower cost compared to the case where additional mechanisms are needed to redress negative agricultural policy impacts. Figure 1.1 provides an overview of these possibilities.

[1] Environmental impact information is much more heterogeneous than data on technical efficiency or productivity, and could relate to pressure indicators (e.g. nutrient or greenhouse gas emissions, land use change) or environmental outcomes (e.g. habitat, biodiversity, water quality).

Figure 1.1. Synergies and trade-offs between economic and environmental impacts of agricultural policies



1.1. Economic impact pathways

Agricultural policies can in theory produce both positive and negative economic impacts. Beginning at the level of individual decision-making on-farm, four main pathways are identified in the literature (Ayouba, Boussemart and Vigeant, 2017[4]; Brady et al., 2009[5]; Ifft, Kuethe and Morehart, 2015[6]; Koundouri et al., 2009[7]; Minviel and Latruffe, 2017[3]; Moro and Sckokai, 2013[8]; Rizov, Pokrivcak and Ciaian, 2013[9]; Serra, Zilberman and Gil, 2008[10]; Kumbhakar, Lien and Hardaker, 2014[11]; OECD, 2001[12]); (Zhu and Oude Lansink, 2010[13]; Sipiläinen, Kumbhakar and Lien, 2014[14]; OECD, 2010[15]; Kuosmanen and Kuosmanen, 2019[16]):

- Changing relative prices of inputs and outputs, affecting farmers' choice of what to produce and how to produce it (e.g. purchased input use; land use; labour use, including on-farm versus off-farm labour decisions; technology choice, etc.).
- Increasing or reducing income constraints (income or wealth effects), which may in turn affect investment decisions and input use, particularly decisions about labour allocation and dynamic input use decisions, and may reduce incentives to produce efficiently or adopt productivity-enhancing innovations (effort effect).
- Increasing or reducing risk exposure (insurance effect), which may reduce incentives to produce efficiently or adopt productivity-enhancing innovations, or incentives to adapt to risks such as climate change (moral hazard effect, potential for adaptation or maladaptation).
- Incentivising structural change (farm entry and exit, changes in farm and market structure and innovation or technical change).

Impacts via these main pathways may be the product of various specific mechanisms: for example, policy impacts via changing relative prices of inputs will be a combination of at least income and substitution effects. Moreover, impacts via these main pathways may offset or reinforce one another. Individuals' responses to agricultural policies can also be mediated by a range of factors, including: individual or farm characteristics (e.g. natural capital, education levels, age, attitude towards environmental outcomes, risk profile, access to technology, production or compliance costs, etc.); market settings (e.g. degree of competition); institutional settings (e.g. the types of agricultural policies used and the coherence of various policy measures, policy eligibility criteria and timing, property rights, legal frameworks, and cultural institutions); and exogenous (to the individual) shocks such as climate change impacts, and interactions with other policies and regulations (e.g. policies and regulations governing taxation, trade, labour markets, environmental outcomes, etc.) (Just and Antle, 1990[17]; Lingard, 2002[18]; Moro and Sckokai, 2013[8]). This means that individual responses to specific agricultural policies are likely to differ. Differences also may be spatially correlated due to location-specific factors, particularly natural capital and landscape characteristics (Brady et al., 2009[5]).

Further, direct effects on farmers' decision-making via these pathways can be dynamically amplified or mitigated by feedback mechanisms, as the aggregated effect of individual decisions changes market outcomes. For example, at a regional, national or international level, the sum of individual production decisions can affect commodity and land prices, which feed back into individuals' further decisions (Banga, 2016[19]; Galko and Jayet, 2011[20]). At a sectoral or regional level, agricultural policies can also alter the relative competitiveness of different farming methods (e.g. organic versus conventional production methods), or of farming on land with specific physical characteristics (e.g. High Nature Value or Less Favoured Area land). Links might also be in the opposite direction: for example, Hailu and Poon (2017[21]) identify that less efficient firms may be more likely to enrol in voluntary payment programmes, which may in turn increase their profitability or reduce risk of exit.

This work does not attempt to assess the significance of agricultural policy impacts relative to impacts from other sources (e.g. market price fluctuations, non-agricultural policies). However, it should be recognised that both productivity and environmental outcomes in agriculture are influenced by other drivers than agricultural policy, including other kinds of policy, but also non-policy factors such as technology (Kompas and Che, 2006[22]), farmer characteristics and preferences (including risk preferences (Koundouri et al., 2009[7])), consumer preferences, climate conditions and variability (Sheng, Mullen and Zhao, 2010[23]), etc. These drivers are not the focus of this review, but may influence productivity and environmental outcomes for agriculture directly or via mediating the impacts of policy drivers.

All in all, theoretical impact pathways are many and complex, and many authors caution against attempting to draw overly generalised policy conclusions and argue that the direction, let alone the magnitude of policy impacts is essentially an empirical matter (Just and Antle, 1990[17]; Kumbhakar, Lien and Hardaker, 2014[11]; OECD, 2011[24]; Serra, Zilberman and Gil, 2008[10]; Zhu and Oude Lansink, 2010[13]). Nevertheless, despite the inability to make generalised theoretical predictions about the overall policy impacts, the theory remains an essential tool for guiding and interpreting empirical assessments. It also motivates study of how impacts vary across contexts. Ayouba et al. (2017, p. 2[4]) provide a neat summary of the various economic impact pathways affecting farms that are of interest to policy-makers:

> *"Although subsidies can affect farms through many channels, there are two fundamental scenarios. The first scenario is optimistic and suggests that… subsidies may lead farmers to innovate and to better organise their production process and sometimes may lead them to adopt more efficient technologies and practices. The second scenario is somewhat pessimistic as it supposes that subsidies demotivate farmers and leads to less vigilance, resulting in debatable production decisions. In the latter case, subsidies allow farmers to operate below the production frontier (i.e. they are inefficient). In such a case, farmers may stay in the market, and consequently, [the policy] sends a negative signal: it does not encourage farmers to efficiently use their resources and it introduces distortions in the agricultural commodities market."*

This review focuses primarily on economic impacts in terms of farm- or sector-level agricultural productivity, and the related concept of technical efficiency, with a view to identifying policies which generate consistent or inconsistent signals in relation to agricultural productivity and sustainability. For this review, these concepts are defined as follows (**Error! Reference source not found.**):

- Full *technical efficiency* characterises a production process where the maximum possible output has been achieved, given a fixed set of inputs and given a certain technology (OECD, 2001[25]).
- *Total factor productivity* is a measure of productivity, defined as a ratio of outputs to inputs, which includes all factors of production (Coelli et al., 2005[26]).

However, it should be acknowledged that there are many different kinds of economic impacts produced by agricultural policies. A large selection of varied literature analyses diverse economic impacts, such as the impact on production, land use, trade, rural development, agricultural incomes, risk, innovation and competitiveness (OECD, 2010[27]; OECD, 2009[28]; Martini, 2011[29]; Moreddu, 2011[30]; OECD, 2013[31]). The OECD also conducts annual monitoring and evaluation of agricultural policies in OECD member countries, and is undertaking work on how agricultural polices affect, and are affected by, factors such as risk, productivity and innovation in agriculture (OECD, 2018[32]).

1.2. Environmental impact pathways

Agriculture is one of the most significant sources of environmental pressures worldwide. Agricultural policies can similarly produce both negative and positive environmental impacts. Negative environmental impacts of agricultural policies occur via several pathways. At the farm level, key pathways identified in the literature (e.g. (Eagle, Rude and Boxall, 2016[33]; Just and Antle, 1990[17]; OECD, 2004[34]; OECD, 2010[15]; OECD, 2005[35]; OECD, 2010[27]; OECD, 2013[31]; Mayrand et al., 2003[36]; Henderson and Lankoski, 2019[37]) are:

- Incentivising an increase in production on the *intensive* margin:
    - increased input use intensity, particularly use of synthetic pesticides, herbicides and fertiliser can lead to increased toxic chemical, nutrient and greenhouse emissions per unit of utilised agricultural area (UAA) or per unit of output;
    - indirect effects from increasing livestock numbers per UAA unit can increase environmental degradation associated with livestock, including ruminant GHG emissions, soil erosion (e.g. gully formation due to livestock), spread of invasive species in grazing lands, nutrient emissions from manure and urine patches, etc.
    - increased water use (e.g. for irrigated agriculture) can result in a range of environmental impacts, including salinity, surface and groundwater depletion, and biodiversity loss due to loss of freshwater habitats.
- Incentivising an increase in production on the *extensive* margin or *entry-exit* margin:[2]
    - expansion of agricultural areas (or conversion of fallow or low-intensity agricultural land uses towards more intensive agricultural uses) can cause severe environmental harm, by destroying habitats and causing significant biodiversity loss, decreasing carbon sinks, increasing erosion, etc.

[2] Extensive margin refers to land-use allocation between different agricultural activities; entry-exit margin refers to land entering or leaving agriculture (OECD, 2010[15]).

  - however, if not managed well, contraction of agricultural land can lead to land abandonment which can also have negative environmental impacts including negative impacts of invasive species, increased risk of wildfire, erosion (if abandoned land lacks adequate soil cover).
- dynamic impacts of land use choice such as impact of cropping choices (spatial and temporal diversity), tillage practices, frequency and type of crop rotations, farm entry and exit decisions, etc.[3]

Agricultural policies may also produce positive environmental impacts. Pathways for positive impacts include incentivising the *opposite* of the effects described above; such pathways can be characterised as incentivising the reduction of negative impacts of agriculture.[4] Further, agricultural activity can also produce valuable environmental goods (OECD, 2011[24]). Thus, another avenue for policies to influence agriculture's environmental performance is to incentivise production of *environmental goods*, also referred to as "ecosystem services" or "multifunctionality" (e.g. (Kirchner et al., 2015[38]; Merckx and Pereira, 2015[39]).[5] Examples of environmental goods that can be produced by agriculture are carbon storage, preservation of rural landscapes, resilience to natural disasters (such as flooding, landslides, fire and snow damage), pollination and soil functionality (OECD, 2018[32]), as well as habitat provision and control of invasive species.

Environmental impacts of agricultural policies are mediated by a number of different factors. First, environmental impacts vary because individual responses to economic incentives created by agricultural policies vary, as described above. Second, environmental impacts of individual decisions vary due to a wide range of location-specific physical factors, including landscape characteristics (soil type, slope, aspect, proximity to water bodies or aquifers, precipitation, attenuation capacity of land and receiving water bodies, etc.) (Bärlund, Lehtonen and Tattari, 2003[40]; Lingard, 2002[18]). Environmental impacts also depend not only on individual actions but on the cumulative effects of decisions across actors and across time. Further, they may depend on physical thresholds and complex bio-physical linkages such as links between biodiversity, habitat availability and water quantity and quality (Eagle, Rude and Boxall, 2016[33]). Finally, environmental impacts may differ depending on whether they are considered at a local, landscape, regional, national or global scale. Thus, as was the case for economic impacts, many authors stress the complexity of causal pathways and the need to assess impacts empirically, taking into account specific policy and physical contexts (OECD, 2010[15]; Lingard, 2002[18]; Just and Antle, 1990[17]).

[3] Dynamic impacts can operate via a change the intensive, extensive or exit-entry margins, or some combination of the three.

[4] In economic terms, in this case the policies can be characterised as reducing incentives for the agricultural sector to produce environmental "bads".

[5] Merckx and Pereira (2015[39]) express concern, however, that policy-makers have used the concept of multifunctionality to promote an understanding in which agriculture is seen as *necessary* to provide certain environmental goods (e.g. biodiversity), in order to justify high levels of support. This could be seen as a combination of focussing on agricultural production of environmental *goods* at the expense of environmental *bads* and at the expense of alternative landuse options (the authors focus on "rewilding") which may deliver "better" (e.g. higher quality) environmental goods.

2. Evidence on policy impacts on efficiency, productivity and the environment

Given the varied direct and indirect pathways and the mediating role of individual and location-specific characteristics described in the previous section, the direction and magnitude of the impacts of specific agricultural policies on the economic (efficiency or productivity) and environmental performance of agriculture are an empirical matter.

This section provides an overview of the theoretical and empirical evidence in the literature on the economic and environmental impacts of agricultural policy types. It uses a categorisation based on the OECD's Producer Support Estimates (PSE) classification of policy types, including use of PSE labels where relevant to differentiate productivity or sustainability policy impacts. This classification is based on the economic features of policy measures, which are important for the potential impacts of policies on production, income, consumption, trade, and the environment. Within the PSE classification, policy measures are classified into seven categories, which identify the transfer basis for the policy, whether the basis is current or non-current, and whether production is required or not. The PSE categories are:[6]

A. Support based on commodity outputs
B. Payments based on input use
C. Payments based on current A/An/R/I, production required
D. Payments based on non-current A/An/R/I, production required
E. Payments based on A/An/R/I, production not required
F. Payments based on non-commodity criteria
G. Miscellaneous payments.

It is acknowledged that the PSE classification has some drawbacks when analysing environmental impacts of policies, in that the PSE categories and labels do not distinguish between different kinds of constraints or other policy design features which could be expected to have different environmental impacts (OECD, 2016[41]). Therefore, where possible this review identifies how environmental impacts differ within as well as across PSE categorisations.

Wherever possible, this section provides quantitative evidence on the number of findings of policies' negative, neutral or positive economic or environmental impacts, using a database which summarises around 950 individual findings from the literature. This database extends the work of Minviel and Latruffe (2017[3]), who undertook an extensive survey and meta-analysis of the literature examining the effects of public support on farm technical efficiency, using data up to 2014 (195 individual findings). Annex A provides a description of the literature search and analysis process, and Annexes B to E together provide a database of the different types of findings.[7]

[6] Within the PSE categorisation, A, An, R and I respectively indicate *area*, *animal number*, *receipts*, and *income.* Corresponding to these PSE characteristics, there are also PSE "labels" including current commodity production and payment limits (Limit/No limit), payment rates (Fixed / Variable), input constraints (with, mandatory or voluntary, on animal welfare, the environment, etc.), payment eligibility (based on area, animal number, receipts, income), commodity(ies) (single, group, all), and production exceptions (with or without). See http://www.oecd.org/agriculture/topics/agricultural-policy-monitoring-and-evaluation/documents/producer-support-estimates-manual.pdf, accessed March 2019.

[7] Annexes B to E present the following types of findings:

- Annex B: Modelled economic and environmental impacts of EU CAP reform scenarios
- Annex C: Technical efficiency impacts
- Annex D: Farm-level productivity impacts
- Annex E: Environmental impacts

It should be noted that the majority of observations contained in the Annexes for this review are drawn from studies analysing policies in European countries or the United States. Empirical evidence from other countries on how policies affect agricultural productivity (or technical efficiency) and sustainability is relatively scarce. Nevertheless, the empirical findings summarised in this report, together with the theoretical literature, form a resource that provides useful insight for policy beyond the countries for which empirical findings are available.

This review relates only to agricultural support measures which form part of the OECD PSE categorisation. It is acknowledged that other support policies, (e.g. innovation policies relevant for agriculture, captured in the OECD's classification as part of the General Services Support Estimate (GSSE)), and other types of policies (e.g. environmental regulations or taxes), may also affect producer decision-making and ultimately productivity and sustainability outcomes in agriculture. In relation to the latter, the OECD is undertaking a companion literature review which examines the environmental and economic impacts of environmental policies for agriculture (OECD, 2019[42]).

2.1. Overview of impacts

Guidance on which policy impacts occur in which contexts is needed in order for policy-makers to design and implement effective and efficient policies. The OECD (2011, p. 8[24]) has previously recommended caution when making broad generalizations about the impacts of agricultural policies: "not all government transfers (support) are harmful to growth and the environment; not all environmentally motivated subsidies are beneficial for the environment; and the absence of government support is no guarantee that the desired level of environmental performance will be achieved." Therefore, a high level overview is first presented, which shows how the evidence varies by study area (country or region) and farm type (crops, dairy, non-dairy livestock and mixed). This is followed by more detailed consideration of evidence for each policy type (Sections 1.2.2 to 1.2.7).

2.1.1. Evidence on farm-level productivity and efficiency impacts

In general, *ex post* empirical evidence on economic impacts relates to farm-level technical efficiency or productivity;[8] while both theoretical and empirical appraisals of other economic impacts (e.g. impacts on farm income, investment, value of agricultural production, international trade flows etc.)[9] are found in the literature (see, for example, (OECD, 2001[43]; Martini, 2011[29]), there is a broad body of empirical work which assesses farm-level technical efficiency or total factor productivity impacts.

Table 2.1 summarises 314 empirical findings on policy impacts on farm-level technical efficiency and total factor productivity. The first and second columns provide a mapping between policy groups identified in the literature and OECD PSE categories. In some cases, while authors use terms such as "coupled support" or "agri-environmental payments", they do not include sufficient policy details to determine the relevant PSE category; in these cases multiple PSE categories are listed.

[8] Generally, most studies examine total factor productivity (sometimes referred to as multifactor productivity). In other cases, only the term "productivity" is used. Unless otherwise stated, in this report a reference to "productivity" should generally be understood to refer to total- or multi-factor productivity (TFP). All studies included in the Annexes for this review which consider productivity use a holistic conception of productivity (generally TFP) rather than partial measures such as labour productivity. As such, the findings are comparable across studies.

[9] Some additional economic impacts are reported in Annex B, which presents findings from studies which use scenario modelling to evaluate the economic and environmental impacts of various policy reform scenarios. These studies are not included in Table 2.1, as they do not study efficiency or productivity impacts.

Table 2.1. Agricultural policy impacts on farm-level technical efficiency and total factor productivity

OECD PSE category	Policy group (based on categorisations used in the literature)	Significantly negative	Neutral or not significant	Significantly positive	No. observations
		(% of observations for policy group)			
	Farm level technical efficiency effects—payment per physical unit [a]				
A2, C	Coupled payments	48%	31%	21%	42
B2	Subsidised Credit	0%	100%	0%	1
E	Decoupled payments	28%	40%	32%	25
C or F2	Agri-environmental payments	46%	21%	32%	28
B1	Input and operational support	100%	0%	0%	1
B2	Investment support	11%	33%	56%	9
C (with mandatory constraint)	LFA payments (EU)	17%	83%	0%	18
B3, C or F3	Rural development payments (EU) [c]	0%	100%	0%	3
C2 (with mandatory constraint)	Set-aside payment (EU)	0%	20%	80%	5
NA	Total support payments [d]	53%	11%	36%	36
NA	Policy reform [e]	13%	56%	31%	16
	Farm level technical efficiency effects—payment dependence [b]				
A2, C	Coupled payments	100%	0%	0%	15
NA	Total support payments [d]	90%	5%	5%	40
	Farm-level productivity effects				
A2, C	Coupled payments	83%	4%	13%	23
E	Decoupled payments	36%	14%	50%	22
C or F2	Agri-environmental payments	0%	67%	33%	3
B1 or C	Subsidised Insurance	100%	0%	0%	2
B2	Investment support	80%	20%	0%	5
C (with mandatory constraint)	LFA payments (EU)	75%	0%	25%	4
C2 (with mandatory constraint)	Set-aside payment (EU)	67%	0%	33%	6
	Other	50%	50%	0%	2
	Policy reform [e]	0%	75%	25%	8

Note: N=314. NA = Not available. LFA = Less Favoured Area.
a Observations relate to where support is modelled as *payment per physical unit* (e.g. per farm or per hectare.
b Observations relate to where support is modelled as *payment as a share of farm output, revenues, receipts,* etc. See Annex A for details.
c Observations on Rural Development payments are sourced from Latruffe and Desjeux, (2016[44]) (France) and Marzec and Pisulewski, (2017[45]) (Poland), neither of which provides information allowing for a precise PSE classification of payments. d 'Total payments' refers to studies which use an explanatory variable such as 'total support per hectare' (support per physical unit) or 'total support as share of farm income' (support dependence); i.e. different support types are not distinguished. This category is not an aggregate of other support types shown in the table. e All "policy reform" observations relate to reforms to decoupled agricultural support, except observations from (Lambarraa et al., 2009[46]) and (Mary, 2013[47]), who each use a dummy variable approach to investigate the impact of the EU Agenda 2000 CAP reforms.
Source: Authors, based on Annex C and Annex D.

As is clear from the table, studies of policy impacts on farm-level technical efficiency are far more common than studies examining productivity (either at the farm level or for the agriculture sector as a whole). Technical efficiency is one important element of productivity, but does not include consideration of other elements contributing to productivity, namely allocative efficiency or technological change over time. Therefore, in places where this study refers to technical efficiency in considering the impact of policies on economic performance, one needs to bear in mind that this presents a somewhat incomplete picture.

Box 2.1. Total factor productivity and efficiency

Total factor productivity (TFP), also called multifactor productivity (MFP), is a measure of the ratio of total outputs relative to total inputs. As such, TFP is a single measure designed to capture how efficiently a farm uses total inputs to produce outputs.

Improvements in TFP (TFP growth) reflect changes in technology, production organisation and scale (e.g. economies of scale), operating environment (including policy settings) and industry composition (e.g. farm entry and exit when TFP is measured at an aggregate level). Technological change and efficiency improvement are important sources of productivity growth. *Technological change* is defined as a shift in the frontier of the production function. *Efficiency improvement* can be further decomposed into technical efficiency and allocative efficiency:

- *Technical efficiency* is a physical or technological concept and considers the relationships between inputs and outputs, without considering costs or prices. Technical inefficiency arises when actual or observed output from a given input mix is less than the maximum possible. Technical efficiency gains are thus a movement towards “best practice”,[1] in the sense a production process has achieved the maximum amount of output that is physically achievable with current technology, and given a fixed amount of inputs.
- *Allocative efficiency* is an economic concept which takes prices (e.g. of inputs and outputs) into account. It occurs when the input-output combination is cost-minimising and/or profit-maximising. Allocative inefficiency arises when the input mix is not consistent with cost minimisation; that is, when farmers do not equalise marginal returns with true factor market prices. In the case of a multiple-output industry (such as agriculture), one may also consider the allocative efficiency of the output mix.

Partial measures of productivity and efficiency can also provide useful insights, for example to examine labour markets or land markets. Also, where data availability is an issue, may be easier to calculate than more holistic measures. However, they can be misleading indicators of technological progress because they do not reflect changes in the use of other inputs. Unless otherwise stated, in this review a reference to productivity should be interpreted as referring to TFP.

It should be noted that the concepts of productivity and technical efficiency are conceptually different from financial performance indicators such as revenue, income and profit, in particular in the short run. While this review primarily focuses on policy impact on productivity (and technical efficiency) and environmental sustainability, in some cases other impacts are also reported, such as policy impacts on agricultural gross margins, agriculture value-added plus payments, and average farm profit per hectare.

1. In technical terms, that production is occurring on the production possibilities frontier
Source: OECD (2001[25]), Coelli et al, (2005[26]), Latruffe (2010[48]), Kimura and Sauer (2015[49]) and Fan (1999[50]).

The most commonly-examined type of support is *coupled support* (80 of 314 observations). This likely reflects that the majority of examined studies were conducted using data between 1996 and 2006,[10] and often were concerned with evaluating the impact of existing policy regimes which relied on coupled payments, in order to comment on the need for, and likely impact of, various options for reform. Coupled payments had a negative impact on productivity for 83% of observations, and on farm-level technical efficiency for 63% of observations.[11]

The second most commonly used variable is *total support*.[12] However, within this cohort of studies, authors differed in how this variable is specified in econometric models. Total support (generally referred to as "total subsidies" or "total payments" in the literature[13]) is specified as a share of total farm income for roughly half observations; or otherwise specified as value per physical unit (e.g. value per farm, value per hectare). When specified as a share of income – i.e. when *dependence* on support is the unit of analysis – the relationship is negative for 90% of observations; this falls to 53% when total support is specified as value per physical unit. Minviel and Latruffe (2017, p. 22[3]) likewise find that modelling total support using support dependence "increases the probability of obtaining a significantly negative effect and decreases the probability of obtaining a significantly positive or non-significant effect on farms' technical efficiency", and posit that this explains why some authors find a negative effect whereas others (who model support payments per physical unit) do not.

While it provides a useful overview, Table 2.1 obscures variation across countries or regions of analysis and across farm type. In general, most studies which distinguish impacts by farm type relate to farm-level technical efficiency.[14] Figures 2.1 to 2.5 provide a breakdown by country and by farm type (crops, dairy and non-dairy livestock), for the subset of studies for which this information is available.

Figure 2.1 shows that, when support is modelled as an amount per physical unit (generally per farm or per hectare), technical efficiency impacts of agricultural policies are most commonly studied for France, followed by Ireland and Sweden. In general, for each country negative relationships are more common than positive; however, there are some exceptions. Denmark, Ireland, Portugal, Spain and the United States show more neutral or positive impacts than negative impacts. This could reflect several factors. First, different policy types are more- or less-studied in different countries; for example, in Ireland the highest number of observations relate to decoupled payments, whereas for France most observations

[10] Average starting and ending years for datasets for studies yielding observations relating to technical efficiency or productivity.

[11] It is worth noting that Minviel and Latruffe's (2017[3]) set of 195 observations included 14 observations on coupled payments, 8 (57%) of which showed a significantly negative impact on technical efficiency. However, their ordered probit regression results showed that, after accounting for other variables, "coupled payments…decrease the probability of obtaining a significant negative impact; in addition, coupled payments increase the probability of obtaining a significant positive impact" (pp. 220-221[3]). While this result may depend on the relatively small number of observations, it shows that caution is needed when making inferences based simply on the number of positive or negative results. Ideally, a meta-analysis of our dataset which extends that of Minviel and Latruffe should be undertaken; however this is beyond the scope of the current literature review.

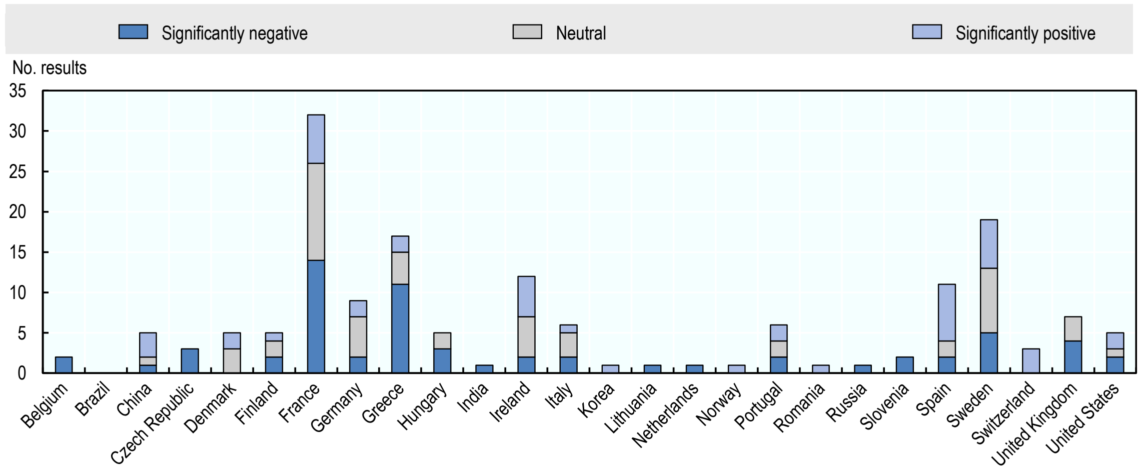
[12] All reviewed studies using total support ("total subsidies") as an explanatory variable used technical efficiency as the dependent variable; none used productivity as the dependent variable.

[13] The use of the term "subsidies" is pervasive in the literature. However, wherever possible, this review uses the more neutral terms "support" or "payment".

[14] Within the set of reviewed studies, only Mary (2013[47]) and Kazukauskas, Newman and Sauer (2014[198]) provide results on productivity impacts by farm type. See Annex D.

relate to coupled payments. Second, as shown below, impacts differ by farm type, and therefore country results are likely to differ according to the dominance of farm types.

Figure 2.1. Agricultural policy impacts (payment per physical unit) on farm-level technical efficiency – all policy types

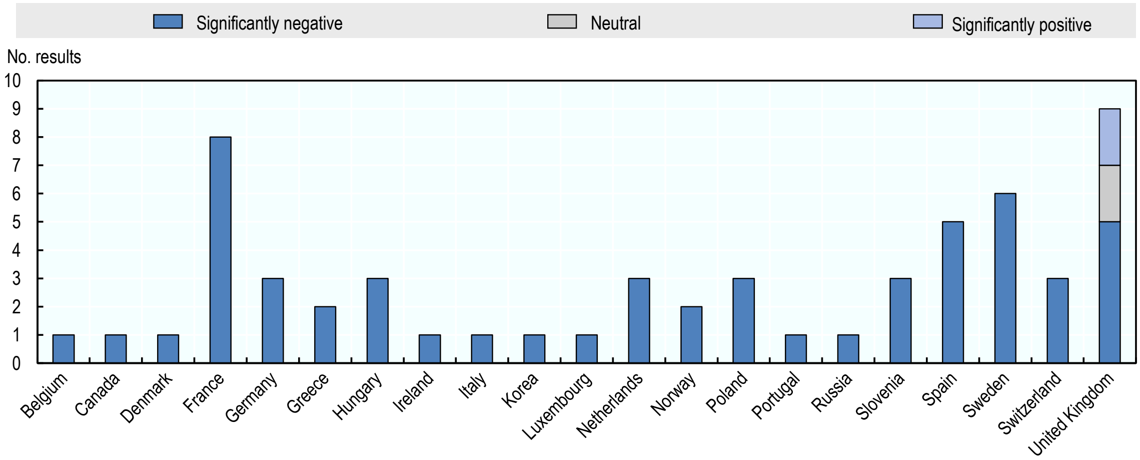


Note: Includes all policy groups. N=161.
Source: Annex C.

Figure 2.2 shows data for studies which investigate the *dependence* of farmers on support, as measured by the share of support payments in total farm revenues or value of output (or, in a few cases, gross margin). When policy impacts are modelled in this way, overwhelmingly a statistically significantly negative impact on farm-level technical efficiency is found. The fact that a negative relationship is found so consistently across studies from a wide range of countries suggests that policy makers should be cautious about using agricultural support to significantly supplement farm incomes, as in doing so they appear to be decreasing the ability of farms to be efficient, and perhaps profitable, without support.

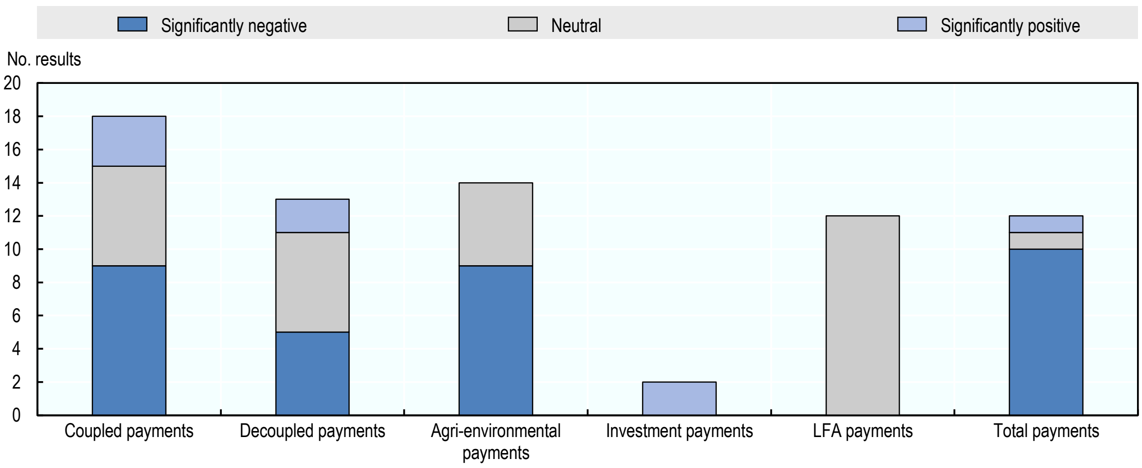
Figure 2.3 shows that, for crop farms, coupled payments, environmental payments and total payments more often have a negative impact on farm level technical efficiency, while decoupled payments and LFA payments tend to have a neutral (or statistically non-significant) impact. The result for coupled payments also holds for dairy farms (Figure 2.4) and non-dairy livestock farms (Figure 2.5), while LFA payments tend to have a neutral or negative impact. In contrast, decoupled payments and environmental payments most often have a positive impact for livestock farms (both dairy and non-dairy). Overall, studies of total payments show that significantly positive links between support and farm technical efficiency are much more common for livestock farms than for crop farms, and that this is also the case across policy groups, except for LFA payments (neutral or negative) and coupled payments (Figure 2.3, Figure 2.4 and Figure 2.5).

Figure 2.2. Agricultural policy impacts (dependence on support) on farm-level technical efficiency - all policy types



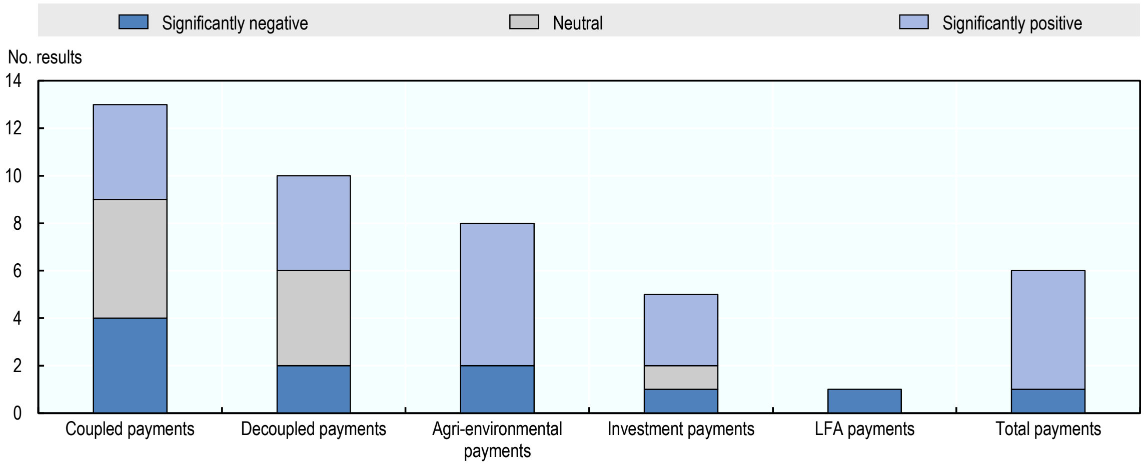
Note: Includes all policy groups. N=59.
Source: Annex C.

Figure 2.3. Agricultural policy impacts (payment per physical unit) on farm-level technical efficiency - by policy type, crop farms



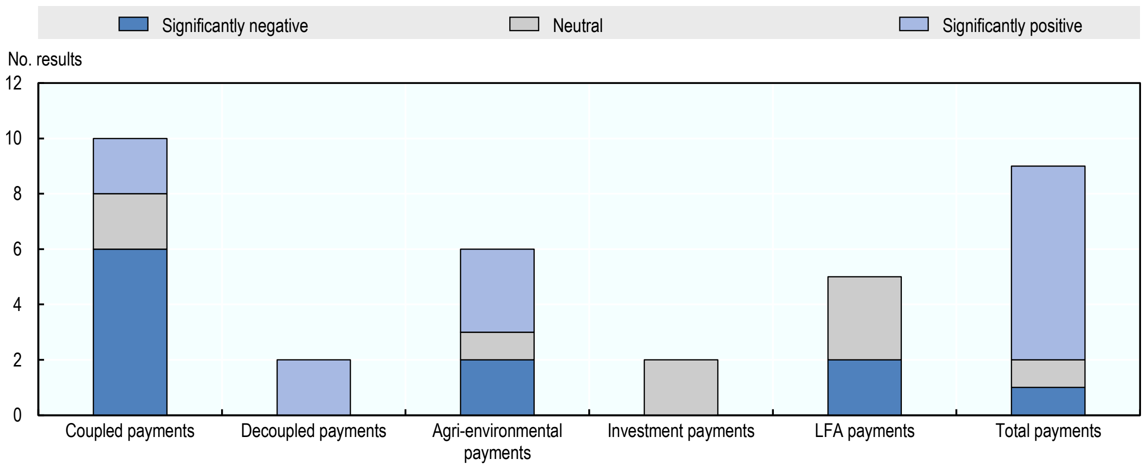
Note: N=71. 'Total payments' refers to studies which use an explanatory variable such as 'total support per hectare'; i.e. different support types are not distinguished. This category is not an aggregate of other support types shown in the chart.
Source: Annex C.

Figure 2.4. Agricultural policy impacts (payment per physical unit) on farm-level technical efficiency by policy type, dairy farms



Note: N=43. 'Total payments' refers to studies which use an explanatory variable such as 'total support per hectare'; i.e. different support types are not distinguished. This category is not an aggregate of other support types shown in the chart.
Source: Annex C.

Figure 2.5. Agricultural policy impacts (payment per physical unit) on farm-level technical efficiency by policy type, non-dairy livestock farms



Note: N=34. 'Total payments' refers to studies which use an explanatory variable such as 'total support per hectare'; i.e. different support types are not distinguished. This category is not an aggregate of other support types shown in the chart.
Source: Annex C.

2.1.2. Evidence on environmental impacts

Empirical evidence on environmental impacts is both much more diverse and much more scarce than for economic impacts (OECD, 2010[15]); in fact, with the exception of studies which assess impacts on greenhouse gas emissions (measured as CO_2-equivalents or methane), there are few instances of studies which use the same environmental indicator to measure the environmental impact of interest. For example, studies analysing the potential water quality impacts of agricultural policies at the farm or landscape level employ input expenditure indicators, input application indicators (e.g. application per hectare), nutrient loadings indicators (e.g. N surplus, ammonia emissions, nitrate from manure or mineral fertilisers, etc.), or water quality impact indicators (e.g. N leaching to domestic marine waters or a "Water Pollution Index"). As such, it is difficult to make generalisations about findings from *ex post* studies on the overall environmental impact of agricultural policies, or to systematically report by area of environmental impact. Accordingly, available evidence on environmental impacts is presented by policy type, throughout the following sections.

Key findings of environmental impacts which are consistent across studies (many of which use *ex ante* scenario modelling to examine proposed or potential changes in the EU Common Agricultural Policy) are:

- Coupled payments generally have *negative impacts* on water quality and greenhouse gas emissions; authors attribute this to coupled payments incentivising intensification. They may have *negative or positive impacts* on biodiversity depending on whether they promote crop diversity versus monoculture.
- Partial decoupling (i.e. introducing a policy mix that entails both coupled and decoupled support elements) tends to have a *neutral or negative impact* on biodiversity indicators. This is due to incentives to homogenise agricultural production and in some cases due to replacement of coupled payments with decoupled payments encouraging land abandonment. Effective design of cross-compliance[15] requirements or agri-environmental schemes could mitigate or reverse these negative impacts, indicating that it is important to assess the policy mix as a whole, and to dynamically assess the effects of policy reform.[16]
- Full decoupling (i.e. removing all market price supports and coupled payments, both with and without mandatory environmental conditions) *reduces* nutrient balances at the country level, by removing intensification incentives.
- Full decoupling *without* mandatory conditions (and in the absence of effective agri-environmental schemes) tends to increase agricultural land abandonment.

The majority of environmental impacts are studied via the use of scenario modelling which examine changes attributable to policy reforms (often involving a suite of agricultural and agri-environmental policies rather than isolating the impact of a specific policy), Section 3 and Annex B are devoted to summarising results from these studies.

2.2. Support based on commodity outputs (PSE Category A)

2.2.1. A1. Market price support

Market Price Support (MPS) policies create a gap between domestic farm-gate prices and border prices of specific agricultural commodities; they include tariffs and export subsidisation at the border, as well as import and export quotas and non-tariff trade barriers. Other MPS measures include domestic market

[15] 'Cross-compliance' refers to the imposition of "conditions related to the environment, identification and welfare of animals, or maintenance of public, animal and plant health on the granting of farm income support payments or withdrawing payments if these conditions are not met" (OECD, 2010, p. 7$_{[202]}$). This report generally considers only *environmental* cross-compliance.

[16] This is not to say that correcting a negative (perverse) policy signal by introducing another policy to correct it is necessarily the best option. Where policies intrinsically introduce negative incentives, a better option may be to reform that policy directly. In the case discussed here, it is not that decoupled support directly provides a negative incentive, but rather that, due to the previous policy mix encouraging intensification and farming on marginal land, there is the potential for negative consequences associated with land abandonment to occur when reform occurs.

interventions, such as direct price administration and quantitative restrictions on production and public stockholding (which are indirect price support measures). MPS (and payments based on output level) proportionally increase the final revenue received by producers, such that the more the commodity is produced, the higher the support (Mayrand et al., 2003[51]). In theory, MPS provides incentives for output expansion and input-use intensification, and will result in farmers modifying their management practices and output mix even with a fixed payment rate. The resulting environmental outcome of the MPS policy will be more or less harmful to the environment, depending on the environmental indicators attached to each commodity and site-specific factors (OECD, 2005[35]).

Representing 46% of total farm support in OECD countries in 2017 (OECD, 2018[52]), Market Price Support (MPS) policy measures are considered one of the most distorting and most environmentally harmful PSE measures (together with certain kinds of payments based on inputs—see below), because of the direct production incentives they create (Dewbre, Antón and Thompson, 2001[53]; OECD, 2011[24]; Mayrand et al., 2003[36]).

The literature suggests that MPS can have positive or negative effects on farm-level productivity and technical efficiency depending on the context. On the positive side, some researchers suggest that MPS, by maintaining higher prices and hence higher profits, spurs productivity growth via increasing producers' ability to adopt productivity-enhancing technology (see, for example, Rakotoarisoa (2011[54])). However, empirical evidence demonstrating this positive link is scant. Concerning long-term effects of MPS agricultural support policies, when high levels of MPS policy are maintained over time, (Hu and Antle, 1993[55]) also notes that the development of yield-enhancing and cost-reducing agricultural productivity technologies will be biased towards commodities associated with the highest level of support.

Kimura and Sauer (2015[49]) study the dynamics of dairy farm-level productivity growth. They find that policy factors strongly influence the dynamics of productivity growth, but differently in different countries. Broadly speaking, productivity growth occurs either due to technology adoption (in productivity frontier terms, an expansion of the frontier) or due to adjustments such as farm exit and consolidation which allow reallocation of resources towards more efficient farms (Kimura and Le Thi, 2013[56]). When MPS occurs in the form of production quotas, binding quotas "tend to slow down structural change of the sector and maintain inefficiencies. However, to what extent this occurs depends on the flexibility of quota transfer mechanisms" (Kimura and Sauer, 2015, p. 16[49]). In the Netherlands, for example, the tradeable quota system allowed producers to improve their productivity through reducing inputs, while the removal of quota changed the productivity growth dynamics to being more based on structural change.

The finding that reducing in MPS increases TFP in the relevant agricultural sector(s) occurs across multiple countries and contexts. For example, Sipiläinen, Kumbhakar and Lien (2014[14]) show that deregulation in Finland had positive impacts on productivity growth and that, in that context, MPS impacted negatively on farm-level productivity. Anderson and Martin (2005[57]) similarly find that trade reform (removing or lessening MPS) typically boosts factor productivity. Sheng and Jackson (2016[58]) study removal of market price support in the Australian dairy context, and find that this reform contributed positively to productivity growth in the industry (see also Section 3.4). Che, Kompas and Vousden (2006[59]; 2001[60]) study the effects of Vietnamese rice sector deregulation and trade liberalisation on rice sector TFP growth. In contrast to the previous examples, this research concerns the case of *negative* MPS – that is, where government policies act as an implicit tax on an agricultural sector via keeping domestic prices *below* world prices. The authors find that reforms significantly increased TFP, via impacts on factor markets, incentivising greater farmer effort, and inducing rice producers to adopt productivity-enhancing production practices such as multiple cropping. The authors attribute up to three fifths of observed productivity growth in the post-reform period to a so-called "incentive effect" of sweeping reforms. These reforms included the partial lifting of restrictions on markets for outputs, which caused rice producer prices to increase and converge towards border prices.[17]

In terms of environmental impacts, MPS have the effect that the higher these forms of support, the greater the incentive for monoculture, for increasing input use, and for increasing the use of environmentally-sensitive land, and the higher the pressure on the environment. Thus, in theory, MPS is usually expected to lead to negative environmental impacts.

Most studies on the impact of trade liberalisation on the environment agree that trade liberalisation would lead to a decline in the production of heavily supported commodities. Indeed, the removal of MPS instruments in some EU countries generally show positive impacts on natural resources, but results are mixed on some environmental outcomes (for example, Nowicki et al. (2009[61]) note the possibility of increased local ammonia emissions due to intensification in certain areas after liberalisation) and for some policies (for example, OECD (2010[15]) estimates that abolishment of milk quotas in Switzerland fails to successfully reduce nitrogen balances).

Serra et al. (2005[62]) explore the link between the European Union agricultural policy reforms and the use of agricultural pesticide. More precisely, they consider the EU CAP reform of 1992, which reduced some MPS and introduced some decoupled payments.[18] Their results show that pesticide use is always more elastic in response to price effects than in response to an area payment policy, indicating that a reduction in price support in favour of area payments is likely to reduce pesticide application rates. The authors do not attempt to estimate the environmental impacts associated with policy-induced pesticide use reduction; rather, they focus on whether changes in agricultural support have contributed towards achieving stated European policy targets for pesticide reduction, acknowledging that additional data would be required to conduct and environmental evaluation.

Lekakis and Pantzios (1999[63]) discuss the general view that abandoning price support policies will result in less damage to the environment, because of reductions in activity at the extensive and the intensive margins when crops are less profitable without price support. They argue that another possibility is that biodiversity and landscape ecology may instead suffer from lower prices (without MPS policies) because of land abandonment (see also Section 3.2 which considers this issue in more detail). This is the debate discussed above comparing the benefits of extensification versus intensification for the environment, which cannot in general be solved, according to these authors, without a more precise qualification of agricultural production technology and local environmental conditions. One context where this question has been extensively studied is rice paddy fields in Japan. In Japan, and in Asia more generally, rice fields can in some cases be viewed as substitutes for natural wetlands (Ramsar Convention, 2008[64]). Koshida & Katayama (2018[65]) undertook a meta-analysis of 35 studies examining the impacts of rice-field abandonment in Japan on biodiversity. The authors found that, while fallow rice fields supported an "equal or greater level of biodiversity than cultivated rice fields" (p. 1389[65]), the average effect of long-term rice field abandonment was generally negative for biodiversity indicators. This was particularly the case for complex rice paddy landscapes relative to simple landscapes, and for organisms closely associated with aquatic environment, such as amphibians and fish, rather than birds and mammals.

[17] The reforms were significantly broader than simply the elimination of price controls. See also Kompas et al. (2012[201]), who examine the role of land reform in addition to the earlier market reforms which are the main focus of Che, Kompas and Vousden's work.

[18] The authors refer to the policy reform as "partially decoupled", in the sense that some payments remain "tied to farmers' decisions".

Gray et al. (2017[66]) also considers the potential for land abandonment in the context of studying the potential effects of removing border protection (a form of MPS) in Switzerland. The study finds that “border protection is not the most efficient policy intervention” to achieve the policy objective of maintaining cultivated landscapes. Rather, the study concludes that “to maintain agricultural landscapes in a cultivated state, government support should be targeted to low productivity areas with the potential for abandonment”.

Henderson and Lankoski (2019[37]) study the environmental impacts of market price support (MPS) using both farm-level and market-level modelling approaches. This study focused on five key environmental indicators: greenhouse gas emissions, water quality (Nitrogen (N) runoff), N balance, P balance and changes to biodiversity. The farm-level approach modelled a range of farm types based on EU data, while the market-level approach modelled a broader number of cases drawing on data from a range of OECD countries. Their results consistently show negative impacts of MPS across almost all environmental indicators and farm types used in the analysis, in both modelling frameworks.[19]

2.2.2. A2. Payments based on commodity output

Payments based on output level (as well as MPS schemes above) proportionally increase the final revenue received by producers, such that the more the commodity is produced, the higher the support (Mayrand et al., 2003[51]; Guyomard, Le Mouël and Gohin, 2004[67]). Examples include the procurement of some crops, at national or regional level, sometimes associated with a quota; and the US loan deficiency payment, based on a variable payment rate per tonne, without production limits, on a crop by crop and year basis. The payment is the difference between the loan rate and the domestic market price, times the quantity eligible for each crop. This US system is subject to mandatory input constraints, assimilated to environmental cross-compliance.

The majority of studies examining productivity or technical efficiency impacts of coupled support do not identify whether payments are made based on output (PSE Category A2) or current receipts, income, area or animal numbers (PSE Category C). Given that the latter kind of payments are more dominant in OECD agricultural support measures, these studies are therefore analysed together under Section 2.4. Taken as a whole, these studies show an overwhelmingly negative relationship between coupled support and productivity, and most commonly a negative relationship between coupled support and technical efficiency.

Similarly, the majority of studies examining environmental impacts of coupled support do not distinguish between different types of coupled support, and so are again discussed together in Section 2.4. One article which looks specifically at the environmental impacts of policy-driven changes in agricultural commodity prices (including but not limited to payments based on commodity outputs) is Langpap and Wu (2011[68]). This study uses the example of corn for ethanol in the United States (Midwest), and combines economic and biophysical models to explore the way changes in the price of agricultural commodities impact land use and cropping decisions, and how such decisions in turn have an impact on the environment. Using parcel-level data, they determine the impact of output price changes on nitrate runoff and leaching, soil water and wind erosion, and carbon sequestration. Their results show that a policy increasing revenue proportional to output (as in MPS or with a proportional payment based on commodity output) will lead to a widespread conversion of marginal land to cropland, as well as significant changes in crop output mix and rotation systems, with large impacts on agricultural pollution.

[19] For the market-level analysis, MPS resulted in increased environmental problems across all indicators with the following exceptions: three (of eight) cases studied in the market-level analysis showed a small decrease in P balance. In the farm-level analysis, one (of four) cases showed a small improvement for the biodiversity indicator.

Table 2.2. Summary of farm-level efficiency, productivity and environmental impacts of market price support and payments based on output

Policy type	Effect on farm-level technical efficiency (ETE) and productivity (EP)	Environmental effects (EE)
A1. Market price support	• Trade-based MPS measures (e.g. tariffs): negative EP. • Production quotas: generally negative ETE and EP as binding quota constrains scale efficiencies. • Negative productivity impacts can be partially mitigated by allowing quotas to be traded. • Reforming policies producing *negative* MPS has also been found to improve productivity.	• Direct incentive to increase production associated with positive MPS likely to cause negative EE, e.g. via land clearing or intensification. • Reduction in (positive) MPS may lead to land abandonment, which may have negative impacts on biodiversity and landscape ecology, as well as further intensification on remaining agricultural land. These dynamic factors need to be carefully considered when pursuing policy reform; policy-makers may need to manage land use transitions resulting from policy reform more pro-actively and reforms may need to include specific measures to address specific environmental externalities.
A2. Payments based on commodity output	• Coupled output support: generally negative ETE and EP (see Section 2.4). • Long-term impacts: positive bias towards commodities which have high levels of MPS over time, for development of productivity-improving innovations.	• Direct incentive to increase production likely to cause negative EE, e.g. via land clearing, conversion of marginal land to cropland or intensification. • Reduction in output-based coupled support may lead to land abandonment, which may have negative impacts on biodiversity and landscape ecology, as well as further intensification on remaining agricultural land. These dynamic factors need to be carefully considered when pursuing policy reform; policy-makers may need to manage land use transitions resulting from policy reform more pro-actively and reforms may need to include specific measures to address specific environmental externalities.

Note: See also Section 2.4, which discusses coupled payments in more detail.

2.3. Payments based on input use (PSE Category B)

2.3.1. B1. Variable input use

This category of PSE policies includes subsidised irrigation volumes, or subsidised energy to pump irrigation (groundwater or surface), without production limits, fixed payment rate, without input constraints, and based on a group of commodities. This category also includes fuel tax concessions, without production limits, with fixed or variable rates, without input constraints, and based on an all commodities. According to Mayrand et al. (2003[51]), by reducing the cost of inputs, such payments provide farmers with direct incentives to intensify production, because a) the more the input is used, the higher is the support; b) the more the payment is specific to a variable input (fertiliser, pesticide), the greater the incentive for production intensification and the pressure on the environment. The impact of such PSE measures on production decisions and on the environment can be higher, equivalent or lower than a price or output payment as in A1 or A2, depending on the type of input on which the payment is based.

The expected impact of a policy based on payments for variable input use relies on an accurate description of production technology, which may include both productivity and environmental indicators at the farm level. Guesmi and Serra (2015[69]) perform a joint analysis of technical efficiency (including productivity) and environmental performance of Spanish farmers (Catalonia). They find that environmental and technical efficiency measures are strongly interrelated, so that an efficient use of chemical inputs improves both environmental and technical performance of farms. Zhu, Demeter and Lansink (2012[70]) and Latruffe et al. (2008[71]) both examine the effects of input and operational subsidies on technical efficiency of farms in a variety of European countries. Zhu, Demeter and Lansink focussed on dairy farms, while Latruffe et al.

considered both crop farms and mixed crop-livestock. In all cases, these studies found that the impact of this kind of support on technical efficiency was negative.

Subsidised crop insurance policies also fall into this PSE category if they are paid based on variable input (e.g. a subsidised insurance premium linked to fertiliser use). For further discussion of the economic and environmental impacts of subsidised crop insurance, see the relevant sub-section in Section 2.4.

Overall, the environmental effects of payments based on variable input use are generally negative if water, fertiliser and pesticide are subsidised. Henderson and Lankoski (2019[37]) study the effects of payments based on variable input use on key environmental indicators.[20] They find that these payments resulted in increased greenhouse gas emissions, higher nitrogen runoff, higher N and P balances and negative impacts on biodiversity, for almost all cases.[21]

In contrast, payments based on input use can have positive environmental impacts if environmentally-friendly inputs (or practices) are subsidised, such as soil and water conservation practices. The latter are often paid on the condition that farmers satisfy some constraints (e.g. related to water withdrawals, replacement, reduction) on input use (OECD, 2002[72]), and they can be targeted for specific environmental purposes; such payments are interesting candidates as complements to other agricultural policies, i.e. to offset negative environmental impacts of farming activities that may benefit from other forms of support (e.g. MPS). Constrained payments based on variable input use can also help to reduce production intensity, encourage production diversification or drive environmentally-sensitive land away from production. The environmental impacts of such payments (i.e. payments to 'environmentally-friendly' inputs or practices) depend on the type of constraints imposed by the measure, but they have the potential of reducing environmental pressure, and being one of the most environmentally-effective PSE measures.

In sum, the following points can be drawn from the literature:

- Payments based on input use distort production choices and most commonly are found to have a negative impact on farm-level technical efficiency.
- Payments based on input use which incentivise *increased* input use of water, chemicals (e.g. fertiliser, pesticides) or fuel spur intensification and generally cause negative environmental impacts. In fact, absent any offsetting conditions to address these impacts, these kinds of input payments may be among the most environmentally harmful.
- Payments based on incentivising increased use of 'environmentally friendly' inputs or practices relative to other inputs can have positive environmental impacts; in fact, they have the potential to be one of the most environmentally beneficial types of payments. Note that, to the extent that payments for 'environmentally friendly' inputs change relative input prices such that farmers take into account environmental externalities of input use, the resulting change in production choices should not be considered *distortive* but rather correcting a distortion created by the environmental externalities.
- Payments based on input use can incentivise land-use change: for example, Miao, Hennessy and Feng (2016[73]) show that subsidised crop insurance can have a significant impact on the

[20] This study uses a dual approach comprising market- and farm-level modelling. For the market-level model, payments based on input use affect multiple production inputs, including fertiliser, chemicals, energy, machinery and equipment. For the farm-level model, payments based on input use comprised a payment based on nitrogen fertiliser, concentrates, capital and labour use.

[21] For the farm-level model, negative impacts were observed for all indicators across all four cases studied, except in one case for biodiversity. For the market-level model, negative impacts were also observed in all cases except one of eight cases had a small decrease in N balance, and two had small decreases in P balances. The authors note that the positive results (i.e. *decreases* in N or P balances) are due to the payments supporting an increase in the output of a crop (soybean) with a negative N balance or a negative P balance.

conversion of grassland to farmland in the United States (Prairie Pothole Region), resulting in biodiversity loss and increased environmental pressures from agriculture.

- Input elasticities are an important factor: for example, support for low-toxicity pesticides (an "environmentally friendly" input) have been shown to not significantly alter the use of high-toxicity pesticides[22] (Skevas, Stefanou and Oude Lansink, 2012[74]), implying quotas or other regulatory measures may be more environmentally effective in these cases.

2.3.2. B2. Fixed capital formation

Payments based on fixed capital formation comprise policies such as support to farm infrastructure and irrigation investment, and also some agri-environmental payments leading farmers to invest in more sustainable soil or water management. This category of PSE payment schemes also includes interest concessions on investment loans (as in Brazil), consisting of a subsidised interest rate scheme, supporting farmers to build their capital stock at lower financial cost. The payment has a variable rate because it is indexed (from below) on a fraction of the interest rate on the financial market. There are no production limits nor input constraints, and all commodities (or agricultural systems) are concerned. Another special case of a payment policy based on fixed capital formation concerns tax exemptions based on the value of the farmer's property. Being proportional to land, it is of the fixed-payment type, and supports all commodities (irrespective of the ones actually produced on the farm).

A similar support policy concerns fixed-rate grants for on-farm infrastructure, as in Japan and EU countries, where support is granted to farmers to improve their land and production facilities, such as irrigation and drainage, and also irrigation infrastructure support schemes (e.g. as in Australia). Such payments could provide a direct way of improving farm productivity, without production or input constraints, although empirical evidence on the extent to which this occurs in practice is limited. Using data for EU Farms for the period 1990-2006, Desjeux and Latruffe (2010[75]) find that investment payments under the EU CAP had a positive impact on field crop farms' technical efficiency (TE), but a negative impact for dairy and no significant effect for beef cattle (note, however, that an aggregate category of "total investment subsidies" was used in this study, which may capture payments that are not in the PSE B2 category). In an assessment of the Welsh Farm Improvement Grant (FIG), Farm Enterprise Grant and Processing and Marketing Small Grant (PMSG) schemes, one study found that these forms of support have resulted in increased income on participating holdings, and, for FIG and the PMSG, that this came from an increase in output and a reduction in costs, implying a productivity improvement (Agra CEAS Consulting Ltd., 2003[76]).

Lakner (2009[77]) found a short-term negative impact of investment support for the TE of German organic dairy farms. This result concurs with Brümmer and Loy (2000[78]), who found a negative TE impact of investment support in the form of participation in farm credit programmes for conventional dairy farms in Northern Germany over the period 1987-1994. Other studies have similarly found a negative relationship between investment support and farm productivity for a range of settings: Czyzewski, Guth and Matuszczak (2018[79]) (effect of investment support on productivity of "moderately sustainable" farm types in the EU-28); Lankoski, Ignaciuk and Jésus (2018[2]) (effect of 40% cost-share payment for improved subsurface drainage on TFP of farms in the United States and Finland).

However, Lakner cautioned that the short-term negative impact of investment support could be offset by a positive impact in the long-run; however, his study was not able to investigate such possible dynamic effects. Moreover, other studies have found insignificant or positive technical efficiency impacts for different

[22] In this study, high-toxicity pesticides were defined as pesticides that exceed the acceptable level (under a standard application) for water organisms set by CTB (Dutch board for the authorisation of pesticides). The study equates "low-toxicity pesticides" which do not exceed this level with being "environmentally-friendly".

countries or different farm types (e.g. Thian and Wan (2000[80]), Manevska-Tasevska, Rabinowicz and Surry, (2013[81]) and Desjeux and Latruffe (2010[75])).

Payments based on fixed capital formation can in some cases incentivise switching production practices, such as changing to another source of fertiliser, conversion to organic farming, etc. Such switches are likely to impact both environment and productivity at the farm level. As an example of agri-environmental payments leading farmers to invest in more sustainable soil or water management, Feinerman and Komen (2005[82]) explore the case of arable farmer conversion to organic fertiliser in the Netherlands, which could be useful from an environmental perspective as excess manure from livestock farms could be productively used by arable farms rather than simply contributing to nutrient surpluses on livestock lands. Manure is compared with mineral (chemical) fertilisers in terms of nitrogen availability and uniformity, with consequences in terms of optimal input decisions and their associated environmental impact. Their results suggest that, in the absence of support, farmers prefer to apply nitrogen only via mineral chemical fertiliser; therefore, payments may be an important factor in encouraging a shift towards a more 'circular' system which uses less nutrients overall. Improved input management that can be supported by payments for fixed capital formation has interesting potential benefits in reducing water and air emissions and waste management costs, as demonstrated in Baerenklau, Nergis and Schwabe (2008[83]).

In theory, the environmental impacts of support to farm infrastructure depend on whether they are associated with limitations on input use (especially water, pesticides, fertilisers, land), and on whether they are associated with adoption of input-saving technologies. Support to farm investment for more intensive production practices might lead to negative environmental impacts, when enhanced production is dependent on increased input use and not linked to improved productivity. Moreover, investment support to adopt productivity-enhancing improvements may lead to positive environmental impacts if they are associated with reduced environmental pressure from agriculture (e.g. decreased use of natural resources for agricultural production), but could indirectly lead to negative environmental impacts if farmers dynamically increase or intensify production as they become more productive.

However, relatively few empirical studies attempt to directly measure the environmental impacts of investment support. Some exceptions are: Baudrier, Bellassen and Foucherot (2015[84]) found a negative impact on greenhouse gas emissions for French investment measures to save energy, encourage input-saving crop systems (together with support for capacity building and information). Lankoski, Ignaciuk and Jésus (2018[2]) found neutral or positive impacts of investment support for adaptive capital in Finland and the United States.

Several studies consider the environmental impacts of government support for irrigation infrastructure in the Murray-Darling Basin in Australia. In this context, investment support for irrigation infrastructure upgrades occurs in tandem with acquisition of water rights from consumptive users (farmers) to be returned to the environment.[23] The total volume available for consumptive uses is capped for each river system—termed 'Sustainable Diversion Limits' (SDLs)—so if a farmer wishes to increase their water take from the system they can only do so by acquiring additional water in the water market. This means that in this context an increase in water taken by one farmer can only occur if another farmer decreases their water taken; this is a key prerequisite for ensuring that investment support for irrigation infrastructure does not simply incentivise increased water use. However, the net impacts of these changes on environmental outcomes depends not only on the total volume of water *taken* (i.e. withdrawn) by consumptive users, but

[23] That is, government support for irrigation infrastructure investment is provided on the basis that at least a part of the "water savings" arising from the investment are reallocated from the consumptive pool for environmental use. An example of water savings is that an infrastructure upgrade replacing open irrigation channels with pipes could reduce water lost due to evaporation and seepage. For further information, see for example http://www.agriculture.gov.au/water/mdb/programs/basin-wide/ofiep, accessed August 2019.

also on factors such as changes in return flows (the volume of water that flows back to streams and helps replenish groundwater), and the impacts of changes in timing and location of consumptive water withdrawals on water quantity (e.g. by changing transmission losses[24]) and water quality. The impact of the government-supported irrigation efficiency projects on return flows is currently subject to debate (Productivity Commission, 2018[85]). A recent expert review (Wang, Walker and Horne, 2018[86]) found that the reduction in return flows was likely to be relatively small, but recommended continuing to monitor return flows (from all causes).

In summary, the following points on the impacts of payments for fixed capital formation (investment support) can be drawn from the literature:

- The effect on farm-level technical efficiency and productivity is not clear, as different studies have found positive, negative and neutral effects.
- Short-term negative impacts may be offset by positive impacts in the long run, and may explain differences in findings across studies.
- While the empirical evidence is limited, investment support aiming to improve environmental performance suggests this can be successful. However, environmental impacts may depend on local conditions and be contingent on farmers' dynamic responses.

2.3.3. B3. On-farm services

Technical and training assistance to farmers, as well as information services for agriculture belong to this category. It includes not only expenditures on the provision of such services directly to farmers regarding production aspects, but also conservation issues. No production limits nor input constraints are involved, and either all or a group of commodities are concerned. Also in this category are pest and disease control payments, without production limits or input constraints, as well as business improvement programmes (e.g. FarmBis in Australia[25]). Payments for on-farm services also include capacity building and information, which are beneficial to the environment if targeted towards improving the conservation practices of farmers.

Evidence in the literature generally shows a positive relationship between public agricultural research and extension and agricultural productivity (see, for example (Hall and Scobie, 2006[87]; Huffman and Evenson, 2006[88]; Jin and Huffman, 2016[89]; Sheng et al., 2011[90]). Environmental impacts can generally be expected to depend on how they affect production decisions: for example, extension services that lead farmers to adopt more environmentally-beneficial practices are expected to have a positive (or at least non-negative) impact on farm environmental performance.

This PSE category also includes the development and dissemination of agri-environmental indicators, which can be used to improve the assessment of environmental and productivity performance of farmers. The technical and training assistance in interpreting such indicators at the farm-level in decision-support tools is also interesting to consider for monitoring outcomes affecting other policies (and payments). OECD (2001[91]) discusses the development of policy-relevant indicators that may be constructed from capacity-building operations at the farm level, and used later to improve transparency and accountability of evaluation policies in European agriculture.

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[24] Transmission loss is water lost to evaporation, seepage, over bank flow etc. along the length of natural water courses. Losses vary with in-stream flow volumes and individual water course characteristics. If support for irrigation infrastructure prompts changes the location or timing of water take, environmental impacts may differ even if on-farm return flows after an irrigator takes water are the same before and after the change(s), because transmission losses may change.

[25] FarmBis ceased operation in June 2008.

Table 2.3. Summary of farm-level efficiency, productivity and environmental impacts of payments based on input use, fixed capital formation, and on-farm services

Policy type	Effect on farm-level technical efficiency (ETE) and productivity (EP)	Environmental effects (EE)
B1. Payments based on input use (variable)	• Generally negative ETE and EP as payment distorts production choices in favour of subsidised input use away from technically efficient input combinations.	• Payments based on water, pesticide, fertiliser or fuel use provide direct incentive to increase use of subsidised inputs and intensify production, which is likely to cause negative EE; if these types of payments are used, mandatory environmental constraints may help mitigate negative EE, but they need to be well-designed and binding. • Positive EE if “environmentally friendly” inputs (or practices) are subsidised, such as integrated pest management, soil and water conservation practices. • Can incentivise land-use change—e.g. incentivise conversion of grassland to crops, resulting in biodiversity loss and increased environmental pressures.
B2. Fixed capital formation	• Investment support: mixed evidence, both in general and also for investment for adaptive / environmental capital.	• EE depends on type of capital subsidised. • e.g. Subsidised irrigation infrastructure can incentivise increased water use; subsidised livestock management structures (e.g. off-stream watering, waterway fencing) can have positive EE.
B3. On-farm services	• Neutral or positive EP.	• Depends on how on-farm services changes farm management practices and input use. Positive EE if targeted towards improving conservation on-farm or facilitating adoption of environmentally-beneficial technologies.

2.4. Payments based on current A/An/R/I, production required (PSE Category C)

2.4.1. Payments based on current receipts or income

This category comprises the bulk of EU rural development payments and for least-favoured areas (LFA), dairy cows, suckler cows, cotton, olive oil, etc., in the European Union, and also LFA payments in Norway and Switzerland (Baudrier, Bellassen and Foucherot, 2015[84]; Lehtonen et al., 2007[92]; OECD, Sinabell and Schmid, 2011[93]). Examples include farmer income support schemes, some insurance schemes, and income tax concessions (in the United States). Also in this category are also concessions on export transactions of commodities. All commodities are supported with a fixed payment rate based on receipts or income, and without production limits or input constraints.

2.4.2. Payments based on current area or animal number

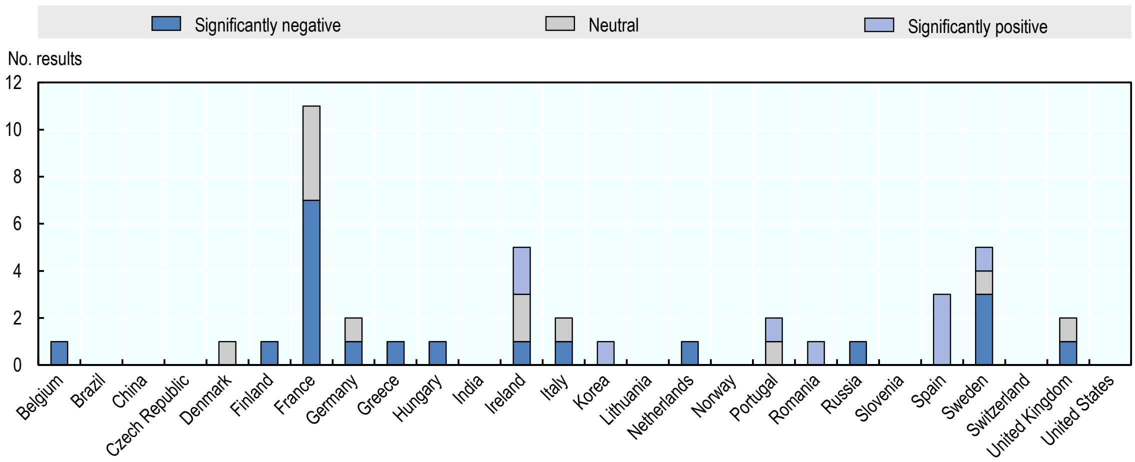
Coupled payments reduce the cost of land or livestock for current plantings or animal numbers (Mayrand et al., 2003[36]) and may be an incentive for farmers to keep environmentally-sensitive land producing commodities in an environmentally harmful way.

Examples of such payments include European CAP Pillar-I payments decoupled from output but based on current area or livestock numbers, and crop insurance payments as in Canada for voluntary crop insurance schemes, where between 70% and 90% of average yield are covered over a 10-15 year-period. The government subsidises about half of the insurance premiums, on a single commodity basis, and it is a variable rate system (depending on the difference between current and reference yield), based on total agricultural area covered by insurance.

Our database includes 87 observations from 22 empirical studies on the impacts of coupled payments on farm-level technical efficiency or productivity (not including LFA payments where they were identifiable—these are discussed below). The majority of these coupled payments appear to be payments based on current area or animal numbers, but the basis of payment is not always clear (see Annex C and Annex D for further detail). For productivity impacts, 83% of observations showed a negative relationship (N=23).

Figure 2.6 provides a breakdown of results relating to technical efficiency, by country, where the explanatory policy variable was payments per physical unit (i.e. per farm, per hectare, etc.). Of these, 48% of results show a negative impact, compared to 21% positive.[26] For the countries shown, positive technical efficiency impacts were only found for Ireland, Korea, Portugal, Spain and Sweden. These results can also be broken down by farm sector (dairy, non-dairy livestock and crop farms). Non-dairy livestock farms and crop farms were much more likely to show a negative impact than a positive impact, whereas for dairy farms, results were roughly evenly mixed.

Figure 2.6. Agricultural policy impacts (payment per physical unit) on farm-level technical efficiency – coupled payments, by country



Note: N=41. Includes all payments identified as "coupled", whether based on output, based on receipts, based on current area or current number of animals. Note that the precise basis of payment is not always made clear in these studies. Excludes LFA payments, where studies clearly distinguish LFA as a separate category to coupled payments.
Source: Annex C.

Coupled payments are generally held to be negative in environmental terms, with some controversies however. Farmers are likely to maintain or increase their cropped area or herd size, to qualify for payment entitlements, while possibly jointly reducing input intensity to improve their productivity.

Support coupled to production of specific commodities tend to encourage farmers to produce those commodities, and to produce or purchase inputs needed to produce them. For example, coupled support payments for intensive livestock production (pig, poultry) lead to increased production of maize, wheat, and oilseed (for fodder), which in turn favours increased use of fertiliser and pesticide on crop land. In the case of the European Union Common Agricultural Policy reform of 2013, some EU countries have added coupled payments to livestock production, with an impact on nitrogen surplus at the soil level which could be positive, negative or neutral depending on the country (Alliance Environnement, 2010[94]).

[26] It is acknowledged that the meta-analysis undertaken by Minviel & Latruffe (2017[3]) found that coupled support has a positive effect on technical efficiency (TE); however, this is with a much smaller sample which included 14 observations on the impact of coupled support on TE, compared to 64 observations on farm-level technical efficiency (42 where payments are specified per physical unit, 15 where dependence on payments is the explanatory variable, 7 where share of coupled in total support payments is explanatory variable) plus 23 on productivity in our database.

Payments based on current area or animal numbers also encourage monoculture in the same way as the payments based on output. However, the environmental impacts of such payments are potentially lower (compared to output-based support or market price support), as producers are not encouraged to increase yields (or animal numbers per hectare) and to produce as intensively as with these forms of payments.

Empirical evidence supports the view that coupled payments increase environmental pressures from agriculture. For example, Fares and Minviel (2017[95]), Koundouri et al. (2009[7]) and Lewandrowski et al. (1997[96]) all find that coupled payments are associated with increased fertiliser and chemical use. Cortus et al. (2009[97]) show that coupled payments under Canada's AgriStability programme exacerbated wetland drainage in the Prairie Pothole Region. Slabe-Erker et al (2017[98]) find that coupled payments are associated with increased pesticides in groundwater in Slovenia.[27] However, with the exception of Koundouri et al. (2009[7]), who specifically study area-based payments, these studies do not enable identification of the exact nature of coupled support (e.g. area-based payments versus payments based on animal number, payments coupled to output, etc.), rather they analyse the impact of coupled support as an aggregate payment category. It is therefore difficult to provide more specific evidence on environmental impacts for different types of coupled support from these studies.

One study which does clearly distinguish payment type is Henderson and Lankoski (2019[37]). The authors study the impacts of payments based on current crop area, and current animal numbers, using both farm- and market-level modelling. They find that the environmental impacts of both kinds of coupled payments diverge across modelling frameworks, with greater divergence for payments based on animal numbers than for crop area payments. However, across the cases studied, negative environmental impacts were more common than positive ones for both types of payments, with one exception: in the market-level model, the crop area payment resulted in a decrease in greenhouse gas emissions for six out of eight cases studied. In these cases, crop payments induced an increase in the competitiveness of crops vis-à-vis livestock, and in countries where cattle contribute to a large share of emissions, total agricultural emissions fell as a result.

Gottschalk et al. (2007[99]), Brady et al. (2009[5]) and Wier et al. (2002[100]) each undertake scenario modelling which compares the Agenda 2000[28] CAP payments with a baseline assuming prior CAP policies were applied up until the mid-2000s (baseline year differs across studies). In comparison to the previous policy package in which market price support played a role, these reforms were found to have generally positive environmental impacts, as evidenced by an increase in agricultural land set-aside, decreased use of fertiliser and pesticides and a decrease in greenhouse gas emissions from agriculture. However, decreases in fallow land and an increase in field size (due to the incentives of coupled payments) produced a decline in biodiversity. The general conclusion that can be drawn from these scenario analyses is that policy mixes which *include* coupled support but *do not include* market price support (MPS) (or only to a very limited extent) have improved environmental impacts in terms of greenhouse gas emissions and chemical use, compared to the case where MPS plays a significant role in the policy mix. However, biodiversity impacts may be worse, primarily due to negative impacts on landscape mosaic caused by larger fields.

[27] These authors also examined the impacts of coupled support on nitrates in groundwater, but results were inconclusive. This could be due to the short timeframes involved in the study (as the pathways via which nutrients enter groundwater may occur over many years), and warrants further investigation.

[28] The Agenda 2000 reforms reduced market price support, in favour of coupled support with accompanying mandatory conditions (cross-compliance). The Fisher Reforms of 2003 went a step further: "direct payments were transferred to the single farm payment scheme and finally decoupled from the current production" (Arovuori and Yrjölä, 2015[194]).

Mandatory environmental conditions such as cross-compliance (CC) can potentially mitigate the negative environmental impacts of coupled payments, but they need to be binding and well-targeted to the environmental impact of concern. This raises questions of whether these conditions are appropriately set, and whether they are appropriately enforced. For further discussion on mandatory conditions (greening and cross-compliance), see Section 2.6.

Subsidised crop insurance

Subsidised insurance (mostly in Canada and the United States, also in Spain and France) is included in PSE category C because they depend on area under crops for which producers decide to purchase insurance.

Sumner and Zulauf (2012[101]) present an analysis of the major economic motivations for subsidising crop insurance, and discuss the way insurance programmes may imply less diversified crops, use of marginal land and potential increase in input use. They identify three pathways through which crop insurance can affect agricultural production: first, by increasing net income per hectare and incentives to grow eligible crops as well as crops with higher support rates; second, by encouraging farmers to plant insured crops on arable land, which would not otherwise be considered due to potentially significant crop losses; and third, by reducing the probability of crop loss from low crop yields and prices, hence creating incentives for farmers to focus on increases in average productivity. Additionally, Burns and Prager (2016[102]) find that subsidised crop insurance may improve the economic viability of farms via reducing credit constraints and enabling farms to expand, while Young and Westcott (2000[103]) note that it may provide a more certain investment climate for producers and facilitate additional investment by producers who are liquidity or debt constrained. This can also lead to increased technology adoption by producers, although the long-term economic impacts as well as the environmental impacts of technology adoption depend on contextual factors.

Empirical assessments of the impact of crop insurance on farm productivity or technical efficiency are scarce. However, various empirical studies on the impact of subsidised crop insurance have identified that they have a limited impact on quantities produced for the commodities covered (Miao, Hennessy and Feng, 2016[73]), suggesting that productivity or efficiency impacts are likely to be limited.

Lankoski, Ignaciuk and Jésus (2018[2]) is one of the few studies which assess the impact of subsidised crop insurance on both economic and environmental farm performance. They evaluate the productivity and environmental (climate change) impacts of a stylised[29] crop insurance payment for yield risk using a farm-level model calibrated for data in the mid-western United States and Finland. They find that the policy decreases total factor productivity in both regions, but has a positive impact on climate change adaptation (although the result was close to neutral for the United States). The impact on climate change mitigation was, however, neutral for the United States and negative for Finland, providing evidence of trade-offs between different environmental objectives (see also below for further evidence on the environmental impacts of subsidised crop insurance).

[29] The authors note (p.12) that they “evaluate a generic crop insurance subsidy for area yield risk. Such a crop insurance product is not representative of the majority of crop insurance products available to and used by farmers in the Midwestern United States”.

The evidence on environmental impacts of subsidised crop insurance[30] is more substantial, but comes mostly from the United States and Canada; an overview is provided in Table 2.4. Eagle, Rude and Boxall (2016[33]) explain that environmental impacts of crop insurance (including publicly-subsidised crop insurance) depend on whether inputs such as fertiliser, pesticides and herbicides are risk-reducing (i.e. a substitute for insurance or other government-funded income stabilisation policies) or risk-increasing (i.e. complement to income stabilisation). If the latter subsidised crop insurance is likely to incentivise *increased* input use and produce unintended negative environmental impacts. This is one example of how subsidised crop insurance may produce a "moral hazard effect".[31]

Table 2.4. Overview of empirical findings of environmental impacts of subsidised crop insurance

Environmental indicator	Significant negative impact	Insignificant / neutral impact	Significant positive impact	Total
Agricultural landuse / Production			2	2
Climate change adaptation	1		2	3
Climate change mitigation	4	2		6
Fertiliser and chemical use	5	3	5	13
Nutrient loadings	2	2	2	6
Wetland drainage			1	1
Soil degradation	3	4	4	11
Total	15	11	16	42

Note: With the exception of climate change adaptation and climate change mitigation, a significant positive impact means the policy induces a statistically significant increase in environmental "bads" (pressures); the interpretation is the opposite for adaptation and mitigation as these are environmental goods.
Sources: Annan and Schlenker (2015[104]); Babcock and Hennessy (1996[115]); Cortus et al. (2009[97]); Claassen, Langpap and Wu (2016[117]), Goodwin, Vandeveer and Deal (2004[119]); Horowitz and Lichtenberg (1993[114]); Lankoski, Ignaciuk and Jésus (2018[2]); Miao et al (2016[120]); Mishra et al. (2005[121]); Smith and Goodwin (1996[122]); Smith and Goodwin, (2013[116]); Walters et al. (2012[118]); Wu (1999[112]).

Several studies find that subsidised crop insurance distorts the market for insurance, encouraging farmers to take risks which are likely opposite to actions needed to adapt to climate change (see, for example (Annan and Schlenker, 2015[104]; Antón et al., 2012[105]; Ignaciuk, 2015[106]; OECD, 2015[107]; OECD, 2016[108]; Wreford, Ignaciuk and Gruère, 2017[109]; Collier, Skees and Barnett, 2009[110]).[32] These results contrast with the modest positive climate change adaptation result obtained by Lankoski, Ignaciuk and Jésus (2018[2]), discussed above. Foudi and Erdlenbruch (2012[111]) also find that farmers opting for yield insurance are significantly less likely to adopt irrigation, suggesting that that yield insurance and irrigation

[30] While there is a broader literature analysing the impacts of crop insurance on farmers' decision-making, which spans multiple countries, evidence on the narrower subject of *environmental impacts* of *subsidised* crop insurance is much more concentrated in the United States and Canada.

[31] In general the "moral hazard effect" with respect to crop insurance is that producers are more likely to engage in risky behaviour when they are shielded from yield risk by some form of insurance. This may occur in the form of farmers decreasing input use in order to save costs when they are shielded from yield risk by some form of insurance; such reduced input use could be expected to *decrease* environmental pressures from agriculture. However, the case discussed above refers specifically to the case where fertiliser is *risk-increasing*, and so subsidised crop insurance allows farmers to pursue the potential upside risk associated with *increased* fertiliser application while being shielded from the downside risk by the insurance. In this case, the increased fertiliser application is expected to cause negative environmental impacts.

[32] Most of these studies do not yield results which are able to be easily incorporated into Table 2.4.

may be substitutes; based on this research, the link between subsidised crop insurance and climate change adaptation depends on whether or not adoption of irrigation is viewed as a positive climate change adaptation strategy. On balance, economic theory and empirical findings support the conclusion that subsidised crop insurance generally has a negative impact on climate change adaptation, and may even incentivise maladaptation.

Wu (1999[112]) found that subsidised crop insurance programmes in the US Central Nebraska Basin are likely to increase total chemical use, consistent with the notion that chemical use is a risk-increasing input. Chang, Mishra and Livingston (2011[113]) find a similar result with respect to agricultural fuel expenditure. In a more nuanced assessment, Horowitz and Lichtenberg (1993[114]) found that subsidised crop insurance can incentivise increased use of inputs for inputs which have a low marginal product at low rainfall levels (nitrogen in particular) but an insignificant effect for other inputs such as phosphorous and potassium which have small positive yield impacts under poor growing conditions. They also found that subsidised crop insurance increased per acre application of herbicides and pesticides (insecticides), which, they argue, is consistent with these inputs being risk-increasing rather than risk-reducing.[33] In contrast, Babcock and Hennessy (1996[115]) found US crop insurance programmes will generally lead to small reductions in nitrogen fertiliser applications for Iowa corn producers. Smith and Goodwin (2013[116]) found a similar result for wheat farmers in Kansas. Thus, input use incentives produced by subsidised crop insurance, and hence their environmental impacts in terms of chemical and nutrient pollution, are shown to be diverse and dependent on local contexts, particularly whether fertilisers (and other chemicals) are risk-increasing or decreasing, as well as farmers' risk profiles. Further study to understand these relationships is warranted, as it will help policy-makers determine likely policy impacts in their specific context.

Sumner and Zulauf (2012[101]) identify several channels via which subsidised crop insurance may impact environmental outcomes: increased incentives to put environmentally sensitive land into production and to intensify input use as average crop yields increase; incentives to prefer crops that may have more negative environmental consequences (such as cotton); incentives to use less risk-reducing inputs and practices. The authors review crop insurance programmes and the link with environmental outcomes, and conclude that subsidising crop insurance is encouraging the move towards crop production on marginal land, possibly resulting in environmental risks that would be less present were crop insurance not subsidised. Burns and Prager (2016[102]) find a small but significant positive effect of subsidised crop insurance on crop acreage for US corn, soybean and wheat operations, although they do not distinguish between marginal land or environmentally-sensitive and other land.

Claassen, Langpap and Wu (2016[117]) find that negative environmental impacts due to changes in cropping patterns under subsidised crop insurance would be rather modest on average for their study region, although they noted that even small increases in nitrogen loadings from agriculture could exacerbate impacts on human or ecosystem health in areas where concentrations are already high. The most significant impact estimated was an increase in wind erosion of just under 4%. The authors also studied how results varied spatially and across crop types. They found that while their results showed spatial heterogeneity of environmental impacts, differences were relatively small except for nitrogen leaching and soil wind erosion. Insurance-induced impacts on loss of soil carbon, nitrogen runoff and percolation, and water erosion are larger than average for corn-intensive crop rotations.

Miao, Hennessy and Feng (2016[73]) analyse the environmental impact of subsidised crop insurance (in the form of a variable input payment) for the US Prairie Pothole Region. They show that this kind of support

[33] Their argument proceeds as follows (p. 392[115]): "An input increases risk if it adds relatively more to output in good states than in bad ones, since that increases the discrepancy among states. In regions and/or crops where high pest infestations occur primarily when crop growth conditions are good, pesticides work by increasing output in good states of nature and are thus likely to be risk-increasing."

can have a significant impact on the conversion of grassland to farmland in this region, because of a concave relationship between crop prices and subsidised crop insurance land-use impacts. Similarly, Cortus et al. (2009[97]) find that Canadian agricultural risk management support payments result in increased loss of wetlands in the Canadian Prairie Pothole region. Thus, these studies indicate that subsidised crop insurance can have negative environmental impacts in the form of expanding crop production onto environmentally sensitive or high environmental-value land.

Negative environmental outcomes possibly resulting from increased subsidies to crop insurance programmes are also investigated by Walters et al. (2012[118]). They find a linkage between environmental impacts and insurance contracts, but also that environmental effects are small in general and, on average, as often beneficial as they are adverse.

Least Favoured area payments

Our database includes 21 observations on the technical efficiency impacts of Least Favoured Area (LFA) payments under the EU CAP, drawn from 5 studies (Martinez Cillero et al., 2017[123]; Lambarraa et al., 2009[46]; Latruffe, Guyomard and Mouël, 2009[124]; Manevska-Tasevska, Rabinowicz and Surry, 2013[81]; Quiroga et al., 2017[125]). This includes 18 observations where payments per physical units is the explanatory variable; 83% of these findings showed neutral or insignificant impact, with the remained finding a negative impact. The few studies modelling the impact of LFA payments as a share of total support payments produced similar results (1 neutral or insignificant result and 2 negative results). Thus, no study found a positive impact of LFA payments on farm-level technical efficiency. Mary (2013[47]) and Czyzewski, Guth and Matuszczak (2018[79]) study the effects of LFA payments on farm-level productivity, for France and EU-28 farms, respectively. They find a negative relationship except for farms designated as “moderately sustainable” in Czyzewski, Guth and Matuszczak, for which the effect is positive.

Several studies also examine the regional or national economic or environmental impacts of LFA payments. Zawalinska, Giesecke and Horridge (2013[126]) model LFA payments in Poland as a per-hectare payment to eligible landowners. They find that LFA payments incentivise retention of marginal agricultural land in production in regions which are predominantly agricultural and rural, but that the contribution to reducing land abandonment is small. Overall, they find that LFA payments lift national consumption by a small amount, but may negatively impact economic growth. Pufahl and Weiss (2009[127]) examine the environmental impacts of participating in LFA schemes for German farms, and find that while participation increases total average area under cultivation, it has an insignificant impact on share of grassland in cultivation, livestock density and fertiliser and pesticide expenditure.

Agri-environmental payments

Payments based on current area or animal numbers with production required also include some payments made under agri-environmental schemes (AES). One example is payments for agri-environmental measures for less intensive farming, such as extensive grassland farming in some EU countries (France, for example). The payment is of a fixed-rate type based on area, without production limits, with a voluntary restriction on inputs used (including a minimum proportion of total agricultural area under grassland, limits on fertiliser applications, registration of agricultural practices, no or very low pesticide use, etc.), and a duration limit of five years. Other examples include area-based agri-environmental payments to encourage farmers to adopt farming practices that are considered to be more environmentally sustainable, such as integrated pest management, conservation tillage, etc. (see also discussion on payments incentivising organic farming below).

Different agri-environmental mechanisms, together with their relative performance, are reviewed by Hodge (2013[128]), with the objective of identifying more cost-effective agricultural policies. The paper shows that reductions in Single Farm Payment (SFP) would require increasing resources allocated to payments for preventing land abandonment, and it concludes that more cost-effective policies may be achieved with more targeted mechanisms, e.g. transforming environmental standards associated with cross-compliance into regulations. Lankoski, Lichtenberg and Ollikainen (2010[129]) provide an analysis of the design of AESs aimed at reducing fertiliser use, explicitly accounting for spatial heterogeneity in agricultural landscape. Simulation results reveal that subsidising installation and maintenance of buffer strips is a very cost-effective policy for reducing nitrogen runoff, while being potentially more attractive for farmers because of its lower impact on farmer income than other policies.

A few studies examine the impacts of agri-environmental payments on farm-level productivity. Mary (2013[47]) finds an insignificant effect for French crop farms; Czyzewski, Guth and Matuszczak (2018[79]) find a positive effect for some farms in the EU-28 and an insignificant effect for others.[34]

Figure 2.7 presents 28 empirical results on the farm-level technical efficiency impacts of agri-environmental payments, by country.[35] The most common result (46% of observations) is a negative impact, but positive impacts also occur for 32% of observations. Thus, authors generally conclude that the overall result depends on scheme-specific factors. The special case of AESs with threshold effects is analysed in Dupraz, Latouche and Turpin (2009[130]), who consider biophysical processes such that environmental outcomes may change only if some farming practices apply on a minimal share of land area. If this threshold is not met, agri-environmental schemes may result in a net economic loss.

A small number of papers distinguish the environmental impacts of agri-environmental schemes (AES) (compared to other factors) (Laukkanen and Nauges, 2014[131]). Finn et al. (2009[132]) acknowledge the difficulty of assessing the actual environmental impact of agri-environment schemes (AESs). They propose a method for evaluating the environmental performance of AESs using multi-criteria analysis techniques. Table 2.5 provides an overview of empirical findings on the land-use and environmental impacts of AES. Almost all of the environmental effects (here measured in terms of various environmental pressures from agriculture) are neutral or positive.[36]

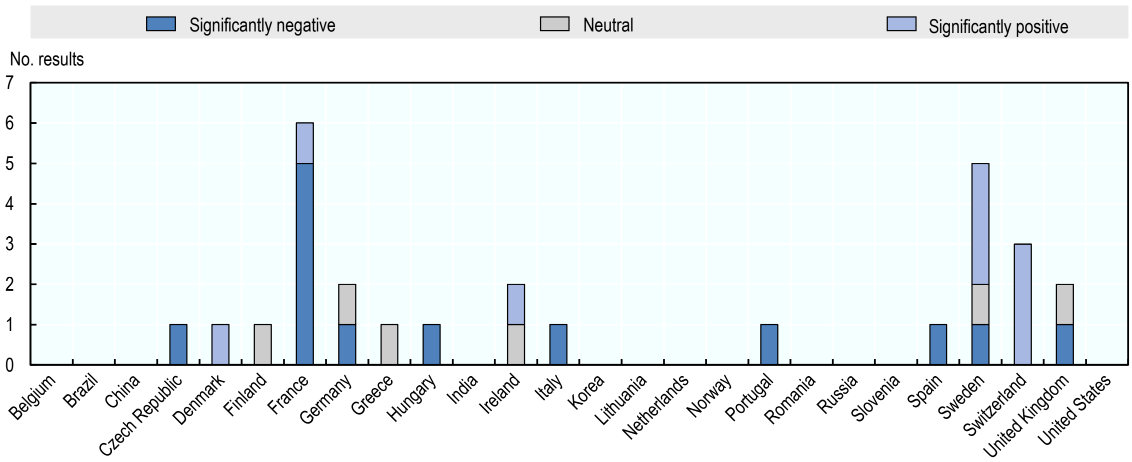
Beckmann, Eggers and Mettepenningen (2009[133]) examine decisions of European Union member states concerning the design of AES support schemes and measures. Across member states, the design of agri-environmental policies in a sub-national and decentralised way is very heterogeneous. The paper discusses the results of a survey in different member states, focusing on decentralisation and participation, and show that the way decisions are made, particularly in terms of the level of decision-making (subsidiarity), has an impact on the environmental effectiveness of AESs: agents involved in decision making for designing AESs are naturally more in favour of decentralisation and participation for tackling agri-environmental problems, while the agricultural administration and associations tend more to oppose participation at the local level.

[34] The authors use cluster analysis based on different models of support. One cluster is defined as having “moderately sustainable” support in which support for agriculture was provided primarily through single farm and area payments; productivity impacts of agri-environmental payments were positive for this cluster. Another cluster comprised a relative small number of farms characterised by receiving payments from a number of different mechanisms, and which had the highest share of payments based on public goods. Agri-environmental payments had an insignificant effect on productivity for this cluster.

[35] These studies generally do not provide sufficient detail to determine whether the AESs studied make payments based on area or on some other basis. Thus, while they are discussed here, they may be representative of other PSE categories.

[36] In the table, a *negative* finding for an environmental pressure should be interpreted as a *reduction* of that pressure, i.e. a positive result for the environment.

Figure 2.7. Agricultural policy impacts (payment per physical unit) on technical efficiency —agri-environmental payments, by country



Note: N=28.
Source: Annex C.

Oltmer et al. (2000[134]) undertake a meta-analysis of environmental impacts of agri-environmental policies in the European Union, to examine whether conditions for implementation of agri-environmental measures have an impact on farmer behaviour with respect to nitrogen fertiliser, livestock density and grassland area. Their results indicate that agri-environmental policies have a positive impact on the behaviour of the farmers who participate in agri-environmental programmes and generally is associated with reduced N fertiliser application.

Using a difference-in-difference matching approach, Arata and Sckokai (2016[135]) demonstrate heterogeneity of environmental impacts of AES in the European Union. They find that participation in AES produces neglible impacts on crop diversification and utilisable agricultural area (UAA) for Spain, France and Germany, but positive effects for the United Kingdom and Italy. Impacts on pesticide expenditure were insignificant (Spain and Germany) or negative (France, Italy, United Kingdom), and impacts on fertiliser expenditure was positive (Spain), negative (Germany, United Kingdom), or insigifnicant (France, Italy).

Chabé-Ferret and Subervie (2013[136]) study the impacts of seven different AES in France on sustainable farm management practices (crop diversification, cover crops, buffer strips, and conversion to organic farming). They find that the impacts of the different programmes type differ (in both direction and intensity), and that some are more effective and efficient than others.

Laukkanen and Nauges (2014[131]) provide an evaluation of greening farm policies applied to AESs aimed at reducing nitrogen loadings in Finland, by quantifying the impact of AESs on land allocation and fertiliser use decisions, and then quantifying the impact on nutrient loading. Compared to a counterfactual of no agri-environmental payments (but retaining other payments), they find agri-environmental payments *increase* total grain area by 2%, and *decrease* total set-aside area (-21%) and fertiliser application (-2%). Henderson and Lankoski (2019[37]) similarly find that a hypothetical agri-environmental payment based on area (with fertiliser use restrictions) results in reallocation of land from pasture and silage to cereals. Due to the input constraint, water quality and greenhouse gas emissions improve, but biodiversity suffers due to the land reallocation.

Pufahl and Weiss (2009[127]) use a propensity score matching approach to estimate the average environmental impacts of participation in German AES. They find participation increases the area of land under cultivation and the share of grassland within that area, and decreases the average cattle livestock density as well as expenditure on fertilisers and pesticides.

In the United States, Wu et al. (2004[137]) study the effects of agri-environmental payments for farms in the upper-Mississippi River basin. They find that payments for conservation tillage are more effective at reducing soil erosion than nitrate water pollution. Also, while crop rotation payments decreased N leaching, they increased N runoff; and conservation tillage payments had the opposite effect. These results demonstrate that there are multiple pathways via which agri-environmental payments affect water quality outcomes. See also Section 2.7, which presents results relating to the US Conservation Reserve Program.

Because so few studies simultaneously consider the economic (technical efficiency or productivity) and environmental impacts of agri-environmental schemes (AES), it is difficult to assess the extent to which AES represent a trade-off between sustainability and productivity objectives, or, on the contrary, a potential 'win-win' situation. It is clear from the evidence in this section that AES produce positive and negative impacts on both objectives in different contexts, and that negative economic results and positive environmental results are more common than the reverse.

Table 2.5. Land-use and environmental impacts of agri-environmental payments

Effects group		Significant negative impact	Insignificant / neutral impact	Significant positive impact	Total no. obs.
Land-use impacts	Crop area or production		2	1	3
	Crop diversification		3	2	5
	Grassland or set-aside	1	4	2	7
	Permanent grassland			2	2
	Utilisable Agricultural Area		3	2	5
Environmental pressures from agriculture	Fertiliser and chemical use	9	8	1	18
	GHG emissions	3			3
	Livestock intensity	1			1
	Nutrient loadings	2		2	4
	Soil degradation	3	1		4
	Total environmental impacts	18	9	3	30

Note: For environmental "bads" such as soil degradation, a negative impact means that payments decreased soil degradation, i.e. a positive environmental impact.

Sources: (Arata and Sckokai, 2016[135]; Baudrier, Bellassen and Foucherot, 2015[84]; Fares and Minviel, 2017[95]; Laukkanen and Nauges, 2014[131]; Pufahl and Weiss, 2009[127]; Smith and Goodwin, 2003[138]; Wu et al., 2004[137])

Payments incentivising organic farming

Payments based on current area or animal number, with production required, also include payments incentivising adoption of organic farming. These payments are generally based on the area under organic farming, do not impose production limits but do entail voluntary limits on inputs used (for environmental protection purposes). Empirical evidence on the impact of organic payments on farm efficiency is mixed, but a negative finding is more common.

Nastis, Papanagiotou and Zamanidis (2012[139]) examine the determinants of technical efficiency of organic alfalfa farms in Greece, using data from 2008. They find that, "on average, a given percentage increase in the ratio of subsidies to farm output decreases the pure technical efficiency score by the same percentage" (p. 287[139]). In their view, this indicates that organic payments lead to perverse incentives and raises doubts about the efficiency of such policies in raising farm level efficiency or incentivising sustainable agricultural development more generally.[37]

Lakner (2009[77]) analysed the impacts of different types of CAP payments and other factors on the technical efficiency (TE) of German organic dairy farms in the period 1995-2005. They found evidence of regional differences, with organic dairy farms in West and Northern Germany being more efficient than their Southern counterparts, and that both organic payments[38] and investment support negatively affected TE. The effect of organic payments, while significantly positive, was small.

Malá (2011[140]) notes that organic farms in the Czech Republic are typically less productive than conventional farms, owing to limits on technology and use of inputs that organic methods entail, but also perhaps due to an emphasis on the quality of the environment for livestock (at the expense of a focus on productivity, is implied).[39] Using data for organic and conventional crop farms over the period 2004-2008, the impact of "environmental subsidies" (which includes organic payments) and "other subsidies" on technical efficiency is examined. A significant negative impact is found for the former, while the latter is not significant. Malá finds that organic farms have lower productivity, but that support payments are a major factor in adoption of organic methods, even though they are shown to dis-incentivise improvements in technical efficiency. Thus, Malá concludes that organic producers are "not motivated to optimise their production behaviour" (p. 25[140]).

Sauer and Park (2009[141]) study the determinants of productivity and organic market exit decisions for organic farms in Denmark over the period 2002-2004. They note that the expected impact *ex ante* is unclear because the expected positive impacts of support payments on the ability to afford new technology might be outweighed by tighter labour constraints or disincentives to invest productively. In contrast to Lakner (2009[77]), their empirical results show a significantly *positive* impact of organic payments on technical efficiency and the rate of technical change. Further, they found that an increase in organic payments led to a decrease in farm exits from organic markets.

Breustedt, Latacz-Lohmann and Tiedemann (2011[142]) analyse the impacts of organic maintenance payments and the EU milk quota system by examining the profitability of organic farms versus conventional dairy farms in Bavaria under alternative policy scenarios. This analysis showed that organic payments positively impacted organic farm relative profitability both with and without milk quotas; however the effect was considerably weaker if the quota is removed. They therefore conclude that organic payments and market price support in the form of the dairy quote reinforce each-other.

Jaime, Coria and Liu (2016[143]) examine the relationship between the two pillars of the European Union CAP (Pillar I on market support and Pillar II on rural development) and the propensity of farmers to adopt organic farming systems and practices. The authors pay a particular attention to the 2003 CAP reform that modifies the relative importance of both pillars through the decoupling of agricultural payments. They

[37] The authors do not elaborate on their conclusion that their result "raises serious doubts about the efficiency of such policies…in terms of their impact on sustainable agricultural development at the macro level" (2012, p. 287[139]). Theoretically, payments which decrease farm-level technical efficiency imply an inefficient use of input and therefore reduce environmental sustainability of agriculture by incentivising keeping a greater amount of land in production. Inefficient use of inputs may also result in increased losses (pollution) to the environment, etc.

[38] Lakner refers to "agri-environmental payments" in the text but clarifies that this refers to organic payments: "[o]rganic farms receive per hectare premia according to the agri-environmental programs, which were offered by the EU (see EU-VO 2078/92 and EU VO 1257/99)" (p. 3[77])

[39] Manevska-Tasevska, Rabinowicz and Surry (2013[81]) similarly find that organic pig producers in Sweden are less efficient than their conventional counterparts, but that there are not significant differences in the technical efficiency between organic and conventional Swedish COP, milk and cattle farms.

consider the case of Sweden and their results show that the policy mix prior to the 2003 reform (dominated by coupled support)[40] has a negative impact on organic farming techniques adoption before the 2003 reform, but the effect is reversed after the CAP reform. While CAP Pillars I and II have a significant impact on non-certified organic farming practices, certified organic farming system adoption is only driven by agri-environmental payments.

The environmental impacts of organic payments are generally studied indirectly via analysing the environmental impacts of participation in voluntary organic programmes. While it is reasonable to consider that the payments available under such schemes are a key motivating factor, alternative motivations such as stewardship attitudes should also be acknowledged, as should questions relating to the additionality of outcomes achieved on land enrolled in organic schemes.

Table 2.6. Summary of farm-level efficiency, productivity and environmental impacts of payments based on current A/An/R/I, production required

Policy type	Effect on farm-level technical efficiency (ETE) and productivity (EP)	Environmental effects (EE)
C1. Payments based on current A/An/R/I, production required—current receipts / income)	• Coupled payments: negative ETE.	• Indirect incentive to increase herd size or cropping area, likely to cause negative local EE such as increased emissions per unit of land (to both air and water). • Incentive to maintain marginal land in production: environmental impacts of this depend on contextual factors.
C2(a). Payments based on current A/An/R/I, production required—current area)	• Coupled payments: generally negative ETE. • Subsidised crop insurance: generally negative ETE.	• Payments based on crop area provide direct incentive to expand area of production, likely to cause negative EE. • Subsidised crop insurance can incentivise expansion of production on marginal land, and intensification, which likely increases environmental risks; environmental impacts due to fertiliser and chemical use depend on whether these inputs are risk-increasing or risk-decreasing and farmers' risk profile. • Subsidised crop insurance can incentivise risk-taking behaviour and maladaptation in the context of climate change.
C2(b). Payments based on current A/An/R/I, production required—current animal numbers)	• Coupled payments: generally negative ETE.	• Direct incentive to expand herd of production, likely to cause negative EE. • Positive EE if payment is specifically for less-extensive livestock system.
C2(c). Payments based on current A/An/R/I, production required—agri-environmental schemes (AES) and organic payments	• Mixed evidence on ETE; effects depend on AES design and local conditions. • Payments for organic farming: mixed evidence on ETE, but a negative finding is more common.	• Neutral or positive EE depending on scheme design (neutral if scheme is ineffective due to issues such as low additionality, high leakage, poor enforcement, etc.). • Payments for organic farming: generally positive EE per unit of area, which may be offset in per output terms if organic farming also causes lower productivity, which appears to be common.

Note: Empirical studies on impacts of subsidised crop insurance and agri-environmental schemes do not always enable clear identification of PSE category.

[40] The authors describe the expected impact of the 2003 reforms for organic producers as follows: "[t]he reform intended to increase the uptake of organic farming in two ways. First, with the removal of the link between eligibility for Pillar One subsidies and choice of crops, producers acquired more freedom to choose crops that could be profitable when produced organically. Second, subsidies became independent from the level of production, implying that organic farmers (who were restricted by lower yields due to organic production standards) no longer had to accept reduced support through Pillar One."

In a meta-analysis of 71 studies from European literature evaluating the environmental impacts of organic programmes, Tuomisto et al. (2012[144]) find that most studies find organic schemes are generally associated with lower environmental impacts per unit of area. However, due to (in some cases) lower productivity, this positive result does not always hold in terms of improved environmental impact per unit of output. Moreover, there is wide variation in results across studies, due to different research methodologies and physical systems being evaluated. Overall, these authors concluded that there is "no single best farming system for all circumstances", and therefore that "[p]olicy needs to recognise and address this complexity and to develop in response to the evolving understanding of the environmental cost-effectiveness of alternative practices and the changing social priorities for environmental systems. Incentives and norms should be concentrated more on providing incentives for farmers to adopt beneficial practices over damaging practices. Such incentives should also recognise the alternative land use options." (p. 318[144]) It is also worth noting that some authors find evidence of environmental trade-offs associated with organic farming systems, mostly because producers adopting organic farming practices may substitute between inputs. For example, Tuomisto et al.'s analysis found that organic farms had "lower energy requirements, but higher land use, eutrophication potential and acidification potential per product unit." (p. 309[144]) While a review of environmental impacts of alternative agricultural practices is beyond the scope of this review (see, however, Clark and Tilman (2017[145]), for a recent meta-analysis), this potential for trade-offs among different environmental outcomes also partly explains the different results across studies.

2.5. Payments based on non-current A/An/R/I, production required (PSE Category D)

Examples of payments in this PSE category include the historical European Common Agricultural Policy payments based on past average crop yield at the regional level, structural milk producer income support in Norway, and the quota payments to dairy farmers in Iceland. The latter has production limits because of a quota, no input constraints, a fixed payment rate (because it does not vary with market price, cost or income), a payment based on receipts, and a single-commodity basis. The restriction is for a farmer to have at least five cows, and in the case of Norway this is achieved for almost all milking farms, so that the payment can be considered fixed.

There are limited empirical studies on the efficiency impacts of this kind of payment, perhaps because it is less-commonly used. An exception is (Ragnarsdóttir, Runólfsson and Árnason (2017[146]), who examine whether dairy farm support in Iceland causes economic inefficiency. Under this policy mix, dairy farmers receive a minimum price (i.e. market price support) plus a direct payment up to a certain pre-determined amount (i.e. a Category D payment). Analysing this system as a whole, the authors find that "the system of direct payments only distorts production if the direct payment quota is set above the level that farmers would choose without it..." (p.22). From this it appears that Category D payments may have different impacts on farmers' decision-making, and therefore efficiency depending on how the threshold is set.

Payments based on historical entitlements (past support area, animal numbers, production, income) and payments based on overall farming income (on the condition that overall farmer income is below a predefined level) have the potential for retaining environmentally-sensitive areas under production. However, they do not encourage production intensification and/or monoculture, as farmers are not obliged to plant, own or produce any particular commodity. Hence, they allow for individual choices on environmentally friendly production techniques. Therefore, the environmental impacts are small or lower than with the previous form of support (Mayrand et al., 2003[51]).

Table 2.7. Summary of farm-level efficiency, productivity and environmental impacts of payments based on non-current A/An/R/I

Policy type	Effect on farm-level technical efficiency (ETE) and productivity (EP)	Environmental effects (EE)
D. Payments based on non-current A/An/R/I, production required	• Limited evidence, showing payments can incentivise increased production above efficient levels; implies a negative ETE. Significance of effect appears to depend on how the payment is set.	• Neutral or slightly negative EE. • However, incentive to retain environmentally sensitive land in production may dis-incentivise conservation of these areas and lead to increased environmental risks over time.

2.6. Payments based on non-current A/An/R/I, production not required (PSE Category E)

PSE category E comprises what are generally referred to as "decoupled" payments. OECD (2001[12]) explains in detail that there can be different degrees of decoupling, while the literature shows that the environmental and economic impacts of decoupling are likely to depend on specific factors such as the type and stringency of related (mandatory or voluntary) conditions. The OECD PSE classification breaks down PSE Category E into a number of distinct sub-categories; these are examined in turn in the following sub-sections.

2.6.1. E1. Variable rates

Examples of such payments include US counter cyclical payments, based on historical area and yields (from 1998-2001 averages), the European Union Basic Payment Scheme (following the Single Payment Scheme after 2015); the US 2014 Agricultural Risk Coverage (ARC) and Price Loss Coverage (PLC) direct payments; the Korean and Japanese support payments to producers, but in those two countries, they make a very small fraction of total PSE. Some special conservation and wetland provisions are generally involved, so that mandatory input or land management constraints apply in the form of constraints agricultural use (fallow included). There are production or payment limits as well, since the variable-rate payment involves the difference between the target price and the trigger level (return per tonne added with the direct payment). For this particular payment type, there are exceptions as to which commodities are allowed (fruits and vegetables are excluded from the scheme).

Such decoupled payments with variable rates typically have a minor impact on farming practices and their resulting environmental outcomes, thanks to their income-stabilising effect. Such policies have been considered as an attempt to move away from MPS policy instruments. They allow farmers to follow market signals more directly in their production decision, including the choice not to produce at all. With such payments, there are no incentives for farmers to increase production at the intensive or extensive margin, and it is therefore expected that such policy will lead to improved environmental outcomes (when compared with MPS or payments based on variable input use). However, the income-stabilising effect may mitigate production risk, leading to retention of less productive farming practices. Single payment schemes can be seen as income and insurance "safety nets", leading farmers to become less risk-averse in their farming decisions. Some results point to the same conclusions: Chatellier and Delattre (2005[147]) and Devadoss, Gibson and Luckstead (2016[148]) analyse wealth and insurance effects that contribute to mitigate risk faced by farmers.

Brady et al. (2009[5]) investigate the impacts of decoupled agricultural support on farm structure and biodiversity in the European Union, a policy in which farmers are not required to produce to receive support payment, but they must keep their land in Good Environmental and Agricultural Condition (GAEC). To check whether output decreases together with landscape services produced jointly, the paper examines the long-term effects of the 2003 PAC reform for a sample of EU regions. Their results demonstrate that decoupling may have negative consequences on landscape and biodiversity under some circumstances, but such negative impacts can be offset by strengthening agri-environmental schemes of the CAP Pillar II.

2.6.2. E2. Fixed rates

This PSE category comprises support measures what are generally referred to as "decoupled payments".[41] Because they are not linked to current area, animal numbers or production (output), they are not expected to trigger production incentives (Mayrand et al., 2003[51]). Henderson and Lankoski (2019[37]) study the impacts of decoupled area-based payments using farm- and market-level modelling. They consistently find that under deterministic settings this payment has no impact on production decision on the intensive or extensive margins in any of the cases studied, and therefore zero environmental impacts, which they note is consistent with economic theory for risk-neutral producers. Indeed, as shown by Ifft, Kuethe and Morehart (2015[6]), fixed rate decoupled payments are known in advance and so are more likely to be capitalised into land values than coupled payments, meaning that they act more as a transfer to land (and therefore to landowners) rather than impacting production decisions (Brady et al., 2017[149]; Latruffe and Le Mouël, 2009[150]). However, certain kinds of payments that appear to be "decoupled" may nevertheless impact production decisions—an example is where payments are not made based on current area, animal numbers or output but are linked to current prices. Thus, differences in the degree of decoupling are possible (OECD, 2001[12]).[42] Sckokai and Moro (2009[151]) also show that the degree of decoupling may be affected by capital market imperfections.

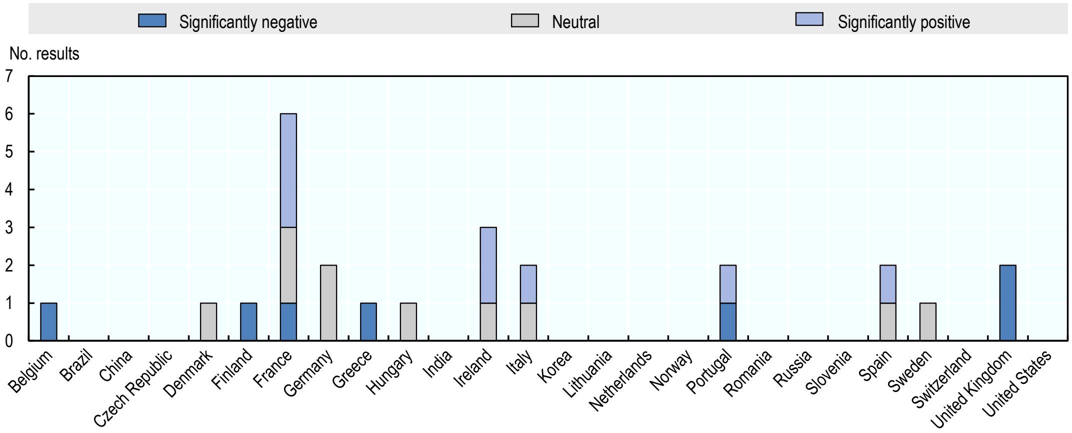
Rizov, Pokrivcak and Ciaian (2013[9]) examine the impact of decoupled payments on total factor productivity for 15 EU countries; Lankoski, Ignaciuk and Jésus (2018[2]) similarly consider the effects of a range of policy instruments on farm productivity in Finland and the United States, one being a decoupled crop area payment. Both these studies find heterogeneous impacts across countries: of these 15 observations, 9 are positive, 7 are negative, and one is insignificant. Czyzewski, Guth and Matuszczak (2018[79]) study the impact of the EU Single Farm Payment and Single Area Payment on farm-level productivity (log-productivity of intermediate consumption) and similarly find that impacts differ across farm types clustered according to types of payments received.

Figure 2.8 summarises 25 results from 6 studies which empirically examine the effects of decoupled payments on farm-level technical efficiency. This evidence shows that impacts are mixed (neutral for 40% of observations; positive for 32%; negative for 28%). Within these studies, negative results are more common for crop farms, and positive results are more common for livestock farms (including dairy and non-dairy) (Latruffe et al., 2016[152]; Quiroga et al., 2017[125]; Martinez Cillero et al., 2017[123]; Boussemart, Kassoum and Vigeant, 2012[153]; Ayouba, Boussemart and Vigeant, 2017[4]; Desjeux and Latruffe, 2010[75]). In addition, Latruffe et al. (2012[154]) and Carroll et al. (2009[155]) examine the impacts of decoupling policy reforms in the European Union and Ireland, respectively, using a dummy variable approach (dummy = 1 in 2005-2006, when the Single Farm Payment was introduced). These studies relate almost exclusively to livestock farms and show mixed results as well, although a neutral result is most common. Latruffe et al. (2016[152]) show that the impacts of decoupling reforms on technical efficiency can be mediated by factors such as access to credit. However, Overall results show that decoupling dampens impacts of support on technical efficiency (both positive and negative), as it is intended to do.

[41] Examples include the Single Payment Scheme of the European Union with fixed payment rates based on historical reference levels over the 2000-02 period. The payment is subject to payment limits, with cross-compliance conditions imposed, so that input constraints apply. The payment is based on past revenue, because entitlements are computed from the total reference amount divided by the number of past eligible hectares over the reference period. The regional Single Payment Scheme of the European Union is different however, because the per-hectare entitlement has a region-level reference. Another difference is that there are constraints on the type of commodities produced, and the payment is area-based (whereas the historical Single Payment Scheme was revenue-based).

[42] Several studies attempt to examine the degree of decoupling for various nominally "decoupled" policies. See, for example Goodwin and Mishra (2006[199]) and (2005[200]), and Young and Westcott, (2000[103]).

Figure 2.8. Agricultural policy impacts (payment per physical unit) on technical efficiency - decoupled payments, by country



Note: N=25.
Source: Annex C.

Decoupled payments, especially in the European Union, often come with some kind of environmental constraint (e.g. cross-compliance, greening). None of the above studies attempts to assess the question of whether efficiency (and environmental impacts) are caused by the payment itself, versus the constraint (or some combination). As explained in Section 1, there are multiple pathways via which support payments, even in the absence of constraints, can impact producer decision-making. In the context of decoupled payments with mandatory constraints, theoretical discussions in the literature mainly focus on: the "moral hazard pathway"—in which the decoupled payment itself, by providing another source of income incentivises reduced effort, thereby reducing productivity; the "binding constraint" pathway—in which the mandatory constraint rules out certain more productive production methods that producers would select absent the policy, thereby reducing productivity but possibly improving sustainability; and the "relaxed budget constraint" pathway, in which the payment enables producers to make productivity-or sustainability-enhancing investments. While some of the above studies conclude that one pathway or another appears to predominate, given their empirical results, none of the above empirical studies is truly able to test the relevance of these pathways; particularly to distinguish between the moral hazard and binding constraint pathways.

Scenario modelling, however, has explicitly tackled the question of how the impacts of decoupled payments differ depending on whether or not they are accompanied by mandatory constraints. Schmid, Sinabell and Hofreither (2007[156]) model a variety of CAP reform scenarios, two of which are full decoupling *with* and *without* mandatory Good Agricultural and Environmental Condition (GAEC) requirements. Similarly, Galko and Jayet (2011[20]), consider several CAP reform scenarios; the comparison most relevant for this discussion is between their scenario of full decoupling without mandatory set-aside and partial decoupling[43] with set-aside conditions.[44] Brady et al. (2009[5]) similarly consider full decoupling without

[43] In this section discussing scenario analyses, the term "partial decoupling" can be taken to refer to a policy mix involving both coupled and decoupled payments. None of these studies explicitly attempt to assess the degree to which notionally "decoupled" payments are truly decoupled in practice.

[44] The authors provide limited detail on their scenarios, explaining them as follows: "our model simulates a decoupling scheme close to the terms of the Luxembourg agreement, and a strengthened decoupling scheme, where no set-aside constraint is imposed and subsidy is not differentiated according to the use of the land is (referred as the "full decoupling" scenario)"; however they also state that "cross compliance has not been taken into account". (Galko and

GAEC versus partial decoupling without GAEC. All three studies use the CAP Agenda 2000-era policies as a baseline. Additionally, Pelikan, Britz and Hertel (2015[157]) study the global and regional economic and environmental effects of introducing the Ecological Focus Area (EFA) requirement, compared to a baseline of CAP policies prior to 2011 reforms (i.e. partial decoupling has already occurred),[45] while Cimino, Henke and Vann (2015[158]) simulate the impacts of introducing "greening" requirements (EFA plus crop diversification requirements) for farm income for Italian maize and durum wheat farmers. Gocht et al. (2016[159]) and Gocht et al. (2017[160]) both consider the marginal effects of introducing greening requirements (EFAs, crop diversification, and grassland measure) against a baseline of the 2013 CAP reform (i.e. decoupled direct payments) without greening requirements.

These studies show the following results:

- All decoupling scenarios have *positive* economic impacts (measured variously as agricultural gross margins, agriculture value-added plus payments, and average farm profit per hectare) compared to the baseline scenarios, with the exception that negative impacts are found in Brady et al. for the Västerbotten region in Sweden (all scenarios). However, scenarios modelling decoupling *without* environmental constraints do not always have a higher positive economic impact than those in which constraints are present; results are mixed on this point. Further, Galko and Jayet also model a scenario entailing partial decoupling *with* constraints *and* dynamic price feedbacks,[46] and find that the positive economic impact here is higher than in the full decoupling without constraint scenario. Thus, it is not clear that adding environmental constraints to decoupled payments necessarily has a negative economic impact; i.e. generally, these studies conclude that the overall economic impact of decoupled payments accompanied by mandatory constraints is projected to be positive, although results on the magnitude of gain relative to decoupled payments *without* constraints is more mixed.
- Introducing decoupling has generally *positive* environmental impacts for water quality related variables compared to the baseline. Modelling of decoupling without constraints shows generally a *greater* positive impact on water quality variables than decoupling with constraints, generally because the constraints modelled prevent conversion of agricultural land to alternative uses such as forestry which generally have lower water quality pressures than agricultural land uses.
- Results were more mixed in terms of greenhouse gas emissions, both compared to baseline and when comparing alternative decoupling scenarios. In particular, Schmid et al. found decoupling without constraints produced greater reductions in methane emissions, whereas Galko et al. showed mixed performance compared to baseline and between decoupling scenarios for different specific greenhouse gases and in total.

Jayet, 2011, pp. 606, 610[20]) Thus, it is not entirely clear whether cross-compliance requirements are present in the full decoupling scenario.

[45] Pelikan, Britz and Hertel (2015, p. 2[157]): "In its proposal of October 2011 to reform the Common Agricultural Policy (CAP) for 2014–2020, the EU Commission included a minimum farm-level share of so-called 'ecological focus area' (EFA) as one of several compulsory measures for receiving direct income support under the CAP (EU Commission, 2011)."

[46] Specifically, the authors include a scenario which incorporates estimates of price changes resulting from decoupling reforms for key EU agricultural commodities, obtained from a partial equilibrium model. These results are compared with a scenario with fixed prices to study the dynamic effects of decoupling reforms.

- Decoupling scenarios had a *negative* impact on biodiversity indicators compared to the baseline, generally due to encouraging land conversion to grassland. Decoupling without constraints had a worse effect than decoupling with constraints (see also discussion on agricultural land abandonment in Section 3.2.). Taken as a whole, greening requirements were found to negatively impact gross margins of farms studied; however the greening payment itself was sufficient to fully offset this decline for wheat producers but not for maize producers (Cimino and Vanni, 2015[158]).
- For specific greening requirements:
  - Introduction of EFA requirements produces small improvements for greenhouse gas and water quality indicators for the European Union as a whole; however there is strong spatial heterogeneity of impacts; environmental gains were mostly in intensive agricultural areas, due to increased idle land in these regions. However, EFA requirements also stimulated changes in crop prices which in turn caused intensification in more marginal areas, with consequential increases in water quality pressure from agriculture (nutrient balances). Further, Pelikan, Britz and Hertel found evidence of leakage effects at the global level.
  - Crop diversification requirements were found to have almost no environmental impact.
  - The grassland measure, because it promotes homogenisation of land types, tends to have a negative impact on biodiversity; however it reduces water quality pressures and soil erosion.

To conclude, these empirical scenario analyses show a complex picture: decoupling reforms generally have produced positive economic and environmental impacts, but the evidence on the success of existing mandatory constraints (particularly the EU GAEC condition) is not clear.[47] This suggests that the design of mandatory constraints could be improved to deliver better environmental performance without sacrificing economic performance. Alternatively, several studies find that the incentives to homogenise land-use caused by decoupled payments such as under the EU Single Payment Scheme should be balanced not by mandatory constraints (as these are considered ineffective environmentally). Rather, they should be balanced or even replaced by agri-environmental schemes (AES) (and similar programmes focussing on rural development objectives) which take a public goods approach and pay farmers directly for agri-environmental practices deemed to produce environmental benefit ("practice-oriented AES") or for producing environmental goods ("results-oriented AES") (Brady, 2010[161]; Reger et al., 2009[162]; Brady et al., 2009[5]). However, authors also note the need to improve the design of existing AES (Burton and Schwarz, 2013[163]; van der Zanden et al., 2017[164]).

See also Section 3.2, which discusses the spatial heterogeneity of impacts, and the sub-section within 2.4 on agri-environmental payments.

[47] Other studies support this ambiguous finding; Alliance Environnement, (2007[195]) show that environmental cross-compliance (to receive CAP payments) has no effect on farm practices in cases where regulatory requirements are already in place. However, Aviron et al. (2009[196]) showed a successful example where cross-compliance requirements led to improved biodiversity in Switzerland.

Table 2.8. Summary of farm-level efficiency, productivity and environmental impacts of payments based on non-current A/An/R/I, production not required

Policy type	Effect on farm-level technical efficiency (ETE) and productivity (EP)	Environmental effects (EE)
E1. Payments based on A/An/R/I, production not required (variable rate)	• Generally neutral ETE, since payments typically have a minor impact on agricultural production decisions.	• No direct incentive to increase production at intensive or extensive margin, therefore likely neutral or low EE. • However, counter-cyclical payments may incentivise keeping environmentally sensitive land in production which may dis-incentivise conservation of these areas and lead to increased environmental risks over time.
E2. Payments based on A/An/R/I, production not required (fixed rate)	• Decoupled crop area fixed payments: neutral or positive ETE. • No clear evidence that introduction of mandatory constraints reduces productivity or efficiency. Mixed evidence on overall economic impacts of mandatory constraints.	• No direct incentive to increase production at intensive or extensive margin, therefore likely neutral or low positive EE. • Decoupled payments (especially in conjunction with mandatory conditions requiring minimum land management) can lead to extreme homogenisation of agricultural landscapes, with consequential declines in biodiversity. • Evidence on success of mandatory constraints added to decoupled payments to improve sustainability is not clear.

2.7. Payments based on non-commodity criteria (PSE Category F)

2.7.1. F1. Long-term resource retirement

This PSE category includes payments accompanying schemes for farmers for the change from arable crop to permanent pasture and forest (often referred to as “land conversion” or “land retirement”). The European Union afforestation payment scheme is an example of such a policy, where farmers are encouraged to save land for forestry-based activities. There are no production or payment limits but input constraints correspond to the policy conservation objective. Another example is the US Conservation Reserve Program (CRP) that involves 10 to 15-year agreements for resource conservation purposes. The payment is under the form of rental amounts paid on a yearly basis.

Several studies point out that where land conversion or retirement schemes incentivise conversion of land that is only marginally productive for agriculture, they may produce an overall increase in productivity (Mcconnell and Burger, 2011[165]; Yao and Li, 2010[166]). However, (Bostian, Dupraz and Minviel (2015[167]) point out that some schemes (they use the example of wetland conservation schemes in France) require producers to maintain converted agricultural lands, which is costly. Hence, overall impacts on productivity as well as profitability depend on both the relative productivity of the land being retired, and on the extent to which payments compensate producers for any increased costs involved.

In terms of environmental impacts, one of the richest sources of empirical evidence are the set of studies evaluating the environmental benefits of the US CRP. Goodwin and Smith (2003[138]) find that participation in the US CRP significantly decreased soil erosion, but had an insignificant effect on fertiliser usage. USDA FSA (2011[168]) also documents a range of environmental benefits, including enhancing wildlife habitat, improving water quality. Enhancing soil productivity and reducing downstream flood damage. Miao et al. (2016[120]) examine the CRP, accounting for its interactions with the federal crop insurance programme. They find that, while the CRP does produce environmental benefits, it is not a cost-effective policy, although it was intended to balance costs and benefits. Empirical results show that increasing the CRP acreage and environmental benefits can be achieved by adopting a cost-effective enrolment design and integrating subsidised crop insurance into the CRP Environmental Benefits Index.[48]

[48] In particular, the authors conclude that, “were saved crop subsidised insurance included in the index, then incentives for optimal land allocation would be strengthened because the inclusion would mitigate potential dissonance across the suite of agro-environmental policies” (p. 595).

2.7.2. F2. A specific non-commodity output

In this category, payments are mostly associated with voluntary contribution of farmers to environmental services and conservation of ecosystem services (Claassen and Ribaudo, 2016[169]). For example, the Swiss scheme for hedges and rustic groves includes payment over 50% of cultivated land area with input restrictions (no fertiliser, no pesticide, grass strips), and it is restricted to farms with more than three hectares with a fixed payment rate. This is similar to the Swiss payment scheme for floral fallow, cultivated with indigenous species and no chemical inputs. There are different "production" conditions however, as harvest is allowed every two years, but it cannot be used as fodder crops (for biodiversity protection purpose).

Cost effectiveness of green payment schemes, as an example of payment schemes based on non-commodity criteria, is examined by Sauer and Wossink (2013[170]), who propose an evaluation of marginal costs for the provision of market outputs and non-market ecosystem services. Allowing for complementarity, substitutability or competition between agricultural production and non-market ecosystem services provision, they empirically show that most farms in their sample produce agricultural output and ecosystem services in a complementary relationship, which suggests that the green payment schemes studied do not involve a tradeoff between productivity and sustainability, but rather a positive synergy.

Lankoski, Lichtenberg and Ollikainen (2008[171]) explore innovative policies for water quality regulation, in the form of tradable permit for effluent emission trading. They derive optimal adjustments of point source and nonpoint source effluent trading ratios for heterogeneity in marginal environmental damage at the watershed level. A simulation experiment using data from a river valley in Finland reveals that, as expected, farmers are the largest category of permit suppliers, with benefits from effluent trading from regulation being unevenly distributed among agents as well as among point sources.

2.7.3. F3. Other non-commodity criteria

While PSE Category F includes a sub-category of "other non-commodity criteria", for lack of references in the empirical literature, this category is not discussed here.

Table 2.9. Summary of farm-level efficiency, productivity and environmental impacts of payments based on non-commodity criteria

Policy type	Effect on farm-level technical efficiency (ETE) and productivity (EP)	Environmental effects (EE)
F. Payments based on non-commodity criteria	• ETE highly dependent on specific payment structure. • Payments incentivising long-term resource retirement can have positive ETE where they incentivise retirement of marginally productive land.	• Positive if payment is for land-use change towards less intensive uses (e.g. payments for afforestation or wetland reconstruction). • Positive if payment is for production of environmental good (e.g. environmental markets).

2.8. G. Miscellaneous payments

For lack of references in the empirical literature, this category is not discussed here.

3. Dynamic and spatial impacts of agricultural reforms

As identified in Section 1, policy impacts on farmers' decision-making can be dynamically amplified or mitigated by feedback mechanisms, as the aggregated effect of individual decisions changes market outcomes. A significant body of work uses scenario analysis (e.g. positive mathematical programming, computable general equilibrium analysis etc.) to examine such dynamic impacts of policy reforms, and also to consider how impacts vary spatially. These studies attempt to show the marginal impact of tweaking or reforming the policy mix—for example to introduce decoupling, to add mandatory constraints (e.g. greening requirements), or to explore the potential impacts of removing agricultural support altogether. The majority of these studies focus on scenarios to inform the reform of the European Union Common Agricultural Policy. Annex B provides an overview of the modelled economic and environmental impacts of 38 CAP reform scenarios; the following subsections consider in turn what the results from these studies reveal about spatial and dynamic impacts of policy reform.

In addition to these *ex ante* studies, some empirical evidence is available about the dynamic impacts of policy reforms from countries which have enacted reforms which almost entirely remove agricultural support. In particular, studies of reforms enacted in Australia and New Zealand between 20 and 30 years ago provide a valuable source of information about long-term policy impacts.

3.1. Dynamic structural impacts of decoupling agricultural support from production

When high levels of support are maintained over time, structural change may be impeded in the agriculture sector. Further, if support remains coupled to production, innovation (e.g. to produce higher yield varieties) could be biased in favour of particular crop types or production methods receiving the most support. At the same time, support may be capitalised into land values which may enhance underlying pressures for farm consolidation and intensification (OECD, 2005[35]) and may reduce producers' ability to make productivity-enhancing or environmentally-friendly investments in a context where higher land prices result in increased farm debt.

Policy reform (e.g. decoupling) may cause dynamic structural effects such as farm entry or exit, changing farm size (e.g. consolidation), and introducing new options for production mix (i.e. policy reform might not only cause substitution between existing crop or livestock types, but allow for new products to be produced or new production methods to be used).

Brady et al. (2017[149]) find that direct payments[49] slow the pace of structural change. Zawalinska, Giesecke and Horridge (2013, p. 285[126]) similarly find that that direct payments in the form of LFA payments in Poland "might act to slow down growth-promoting structural change by hampering a much needed outflow of people from agriculture to more productive non-agricultural occupations". The "desirability" of this impact depends on local context. For highly productive areas, retarding structural change may slow productivity growth and act as a barrier to further economic development. However, in marginal areas, it may lead to avoiding the abandonment of agricultural land and the maintenance of landscapes that are valuable for biodiversity, tourism and the maintenance of rural communities. Kuosmanen and Kuosmanen (2019[16]) also show that the *level* of support matters in terms of structural impacts: using a novel decomposition of industry-level TFP growth that does not depend on market shares, they find that in the case of the Finnish agricultural sector, rapid structural change occurred *despite* the use of decoupled payments "geared to

[49] The authors do not distinguish between coupled and uncoupled direct payments; rather, they refer to "[EU CAP] Pillar I direct payments" as a general category. However, since the reforms of the mid-2000s, the majority of Pillar I payments have been decoupled from production. See http://www.europarl.europa.eu/factsheets/en/sheet/109/first-pillar-of-the-common-agricultural-policy-cap-ii-direct-payments-to-farmers, accessed September 2018.

slowing down consolidation" (p. 19[16]). In particular, the authors find that decoupled payments influence farmers' "ability" to continue agricultural production, and also affect prospective farmers' entry decision-making.

3.2. Evidence on spatial heterogeneity of impacts

Gottschalk et al. (2007[99]) examine intended and unintended agricultural policy impacts on biodiversity using a spatially explicit socio-economic and biodiversity modelling framework applied to the Lahn-Dill area, a low-intensity farming region of Germany. They find that there is a need to spatially target policies, and that in future payments should be made via locally-calibrated agri-environmental schemes. Reger et al. (2009[162]) study the same region (Dill catchment) and find that coupled payments produced land abandonment, particularly in low-productive areas but also for arable land use in more productive areas, with intermediate results for habitat values. Decoupled payments supported conversion to a grassland-dominated landscape with low values of all habitat diversity indices. Removal of support resulted in "complete abandonment or afforestation of agricultural land and extremely low values in all habitat diversity indices".

Kirchner et al. (2015[38]) use an integrated modelling framework to examine spatial variability of policy and climate change impacts on ecosystem services and economic development in agricultural lands. They find that climate change impacts differ spatially, producing intensification in favourable areas and extensification in marginal areas, and also that climate change impacts dominate over policy impacts in "regions and sectors vulnerable to changes in temperatures and precipitation" (p. 171). Overall, the authors find evidence of a trade-off between what they refer to as *provisioning* ecosystem services (biomass production) and other types of ecosystem services such as ecological integrity, climate regulation and cultural services.

Giannakis, Efstratoglou and Psaltopoulos (2014[172]) consider the impacts of Common Agricultural Policy scenarios using a dynamic framework integrating agriculture, environment, rural economy and human resources in a Greek rural area. Their results indicate that different CAP scenarios can generate very different impacts, supporting the idea that policies should take into account regional features when designing agricultural and rural development policy actions.

Brady et al. (2009[5]) show that biodiversity impacts can have a non-linear relationship with landuse and land cover attributes such as landscape diversity (for example as measured by landscape mosaic). This is in part due to the diminishing marginal biodiversity benefits of any particular habitat type. Thus, if a policy change stimulates landuse changes that improve landscape diversity (mosaic) overall for a particular region, there may still be negative biodiversity impacts for that region if there is a decline in habitat types—such as pasture—which are both relatively scarce and have high ecological value. According to Brady et al. (2009, p. 579), "even a small reduction in the area of pasture causes a relatively large reduction in species". These authors find that decoupling produces *reduced* biodiversity, despite *increased* landscape diversity as measured by landscape mosaic metrics. This seemingly-contradictory finding is driven by changes in the area of pasture, which is relatively scarce and also the most ecologically productive habitat: "[a]s such, even a small reduction in the area of pasture causes a relatively large reduction in species" (p. 579).

Brady et al. (2012[173]) model a number of policy reform scenarios and find that each has its relative strengths and weaknesses (Annex B reports key results from these simulations). They therefore conclude it is difficult to maximise the value of different landscapes to society using simple or general management rules, because such rules "represent extremes rather than an optimal balance." (p. 17). For example, agricultural land abandonment can be avoided by targeting payments to specific land management practices or requirements; however, GAEC requirements (e.g. mowing) are not enough to preserve a diversity of land types. Decoupling on its own (with GAEC), while effective in encouraging extensive agriculture (and therefore reduce the environmental pressures that intensive agriculture produces) can lead to "extreme homogenisation" of land types because "farmers switch a large area of arable land from intensive silage and pasture to arable grassland managed according to the minimum GAEC obligation", with a resulting decline in biodiversity and mosaic value (which also has social value—for example aesthetic values for tourism).

Bärlund, Lehtonen and Tattari (2003[40]) found that environmental policy impacts are quite complex and can occur via several potentially competing physical pathways. In particular, they find that the direction of change of soluble P loadings from surface runoff can differ from deposited P (sediment). The authors also emphasise that studies which estimate policy impacts on nutrient leaching still only show *potential* water quality impacts, as actual impacts such as eutrophication and turbidity depend on location- and time-specific factors.

3.3. Land abandonment

As the analysis of different support types in Section 2 showed, one of the most commonly-identified consequences of policy reform away from market price support and coupled payments is a decrease in agricultural area and consequential increased agricultural land abandonment. *Ex ante* modelling of policy reform to reduce or remove decoupled payments also suggests that such reform is likely to result in increased abandonment as well (in the absence of an increase in alternative support such as payments via agri-environmental schemes) (Acs et al., 2010[174]). Land abandonment is an issue particularly in landscapes that have a long history of agricultural use, especially in Europe and Japan, but can also be an issue in other contexts ((Batáry et al., 2015[175]; Beilin et al., 2014[176]; Ito et al., 2016[177]).

The environmental consequences of land abandonment are complex: on the one hand, water quality generally improves and contribution to carbon emissions generally declines, especially if land abandonment is associated with cessation of livestock production. Other potential benefits include revegetation, soil recovery, nutrient cycling and improved diversity and wilderness (Rey Benayas, Nicolau and Schulz, 2007[178]).

On the other hand, land abandonment (in the absence of effective policies for managing abandoned land) can have severe impacts on biodiversity, both in terms of reducing habitat or habitat quality for indigenous species and also allowing invasive species to flourish, as well as increasing fire frequency and intensity, reducing water provision, and loss of cultural and amenity value (Rey Benayas, Nicolau and Schulz, 2007[178]; MacDonald et al., 2000[179]; Koshida and Katayama, 2018[65]). In a global review of 276 published studies on the issue, Queiroz et al. (2014[180]) find that "countries in Eurasia and the New World reported mainly negative and positive effects of farmland abandonment on biodiversity, respectively". In a statistical meta-analysis of studies considering impacts of rice field abandonment on biodiversity in Japan, Koshida and Katayama (2018[65]) found that biodiversity impacts at local scales differed according to landscape type and according to the taxa considered, but that on average rice field abandonment has negative biodiversity impacts. The authors conclude that the impacts of farmland abandonment are highly context specific, and that assumptions that 'passive restoration' (or 'passive rewilding') can effectively restore ecosystems may be incorrect in some cases.

Abandoned land may also be subject to soil degradation impacts such as erosion, dryland salinity, desertification and decreased soil organic carbon (these impacts depend on location-specific factors) (see, for example, Rey Benaya, Nicolau and Schulz (2007[178])). Beyond environmental impacts, it is also worth noting that land abandonment also is generally associated with negative socio-economic impacts for marginal rural communities. (Lasanta et al., 2017[181]; Renwick et al., 2013[182]).

Renwick et al (2013[182]) found evidence of existing "hotspots" of agricultural abandonment in the European Union, mainly in mountainous regions. Using scenario modelling to consider the effects of potential future reforms, these authors find that a full removal of Pillar I supports under the CAP and trade liberalisation would further exacerbate land abandonment, with around 8% less farmed land in the EU overall; this result is confirmed by (Brady et al., 2017[149]) who also study the effects of removing Pillar I payments. However, this overall figure masks significant variation: in hotspot areas, and for certain farm types, reductions are far greater, and could cause significant negative impacts on rural livelihoods and the environment.

Lasanta et al. (2017[181]) find that land abandonment is more policy-driven in flat areas, whereas in mountainous regions there has been a long-term trend towards abandonment, sometimes over decades, in some cases beginning in the 19th century. These authors find that there have been several waves of land abandonment in the European Union, and that the second wave occurring at the end of the 20th century is attributable to the CAP in western European countries (particularly the now-ceased set-aside and land retirement components), and to the disappearance of the Soviet Union in eastern European countries. However, the authors find that more recent policies including agri-environmental schemes, support for extensive livestock production systems and support for marginal areas has a positive impact (i.e. slowing or reversing the rate) on land abandonment.

Beilin et al. (2014[176]) develop a useful systemic framework for analysing economic, social, policy or institutional and physical factors contributing to agricultural land abandonment (ALA) in three case studies within OECD countries: Poowong, Australia; Castro Laboreiro, Portugal and Hållnäs, Sweden. They distinguish three mechanisms:[50] "pressures", which drive agricultural land and abandonment; "frictions", which mitigate the pressure; and "attractors", which are physical characteristics related to the suitability of land for agricultural activities. Agricultural and other policies can directly or indirectly all three types of mechanisms, and therefore the relationship between policies and land abandonment is complex.

Finally, it is worth noting that Brady et al. (2017[183]) document concerns raised by some observers in the EU context that decoupled direct payments will result in "passively farmed land",[51] which will increase costs for productive farmers wanting to expand. However, using an agent-based model calibrated to a case study region in Sweden, the authors find that passively farmed land does not pose a problem for expanding active farmers, and can have benefits in terms of actively managing land to maintain a minimum level of environmental condition rather than allowing land to be abandoned.

The overall conclusion that can be drawn from the literature is that agricultural and agri-environmental policies generally result in land abandonment either because they are aiming to *undo* negative impacts of past policies or because they are aiming to achieve a specific environmental goal in another area of interest, *without* adequately taking landuse change consequences into consideration and without including mechanisms to either (actively) promote re-wilding or regeneration, transition to other managed landuse such as forestry, or to preserve some minimal level of land management. Examples of the former include decoupling reforms, one aim of which is to reduce intensification incentives. Examples of the latter are the

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[50] Beilin et al. (2014, p.67) define sub-categories of these mechanisms as follows:

- *Pressures*: Market driven changes in economic conditions for farming; Expansion of forest land owned by companies/state; Diminishing level of public and commercial service; Relative decline of working opportunities; Relative decline of infrastructural accessibility; Increased nature conservation regulations; Feeling of continuing remoteness.
- *Frictions*: Cohesiveness and the farming identity among land owners; Official funding and subsidies for land management; State campaigns for rural development; Tourism and secondary home owners; Appreciation of natural and cultural values.
- *Attractors*: Physical conditions for cultivating; Physical conditions for livestock keeping.

[51] The authors define *passively farmed land* as agricultural land "not used for production, but is maintained to meet the land management obligation for collecting Common Agricultural Policy (CAP) direct payments" (p. 640).

now-ceased CAP set-aside provisions and provision of policy incentives for farmers to exit irrigation. While further research is needed to establish the most cost-effective policy options for managing land where agricultural activity is declining or ceasing,[52] researchers generally agree that positive policy approaches are needed, which either view land abandonment as an opportunity for habitat restoration and species re-introduction (e.g. (Merckx and Pereira, 2015[39]; Queiroz et al., 2014[180]), or which incentivise farmers to maintain landscapes and produce environmental goods (the "ecosystem services" approach) (MacDonald et al., 2000[179]). Taking into account the potential for both positive environmental impacts and negative environmental and socio-economic impacts of contraction of agricultural land, the reviewed literature suggests that in addition to carefully considering how agricultural policies affect land abandonment trends, policymakers may also need to be more pro-active about managing land use transitions resulting from specific policies or from policy change. This may require new approaches to agricultural policies, and potentially new approaches outside the sphere of agriculture – for example, forestry or conservation area policies.

3.4. Dynamic impacts of removing agricultural support: evidence from Australian and New Zealand experiences

Several OECD countries, notably Australia and New Zealand, have within the last 30 years undertaken substantial policy reforms to almost entirely eliminate support to agriculture.[53] This reform history allows examination of the dynamic impacts of removing support on both productivity and sustainability.

Vitalis (2007[184]) studies the environmental and economic impacts of the elimination of agricultural support in New Zealand in the mid-1980s. The key pillars of the reform were the removal of market price support (in the form of minimum price floors for wool, beef, sheep meat and dairy products, withdrawing tax concessions for farmers, and reducing coupled support based on inputs such as support for irrigation and fertiliser). Removal of support to agriculture was one part of the overall reform package, which also included floating the New Zealand dollar and liberalising tariffs. Economic rather than environmental concerns spurred these reforms.

The author reports that observed economic impacts of this reform were profound, particularly for New Zealand's livestock industries: the sheep flock declined by over 40%, whereas dairy cattle more than doubled (although the number of herds declined, indicating consolidation), dairy production has risen by around 75%, and deer herds went from negligible in 1983-84 to around 2 million in 2004-05. Wine and horticultural production and exports also grew substantially after the reforms. Agricultural productivity growth has also been substantially higher in the post-reform period, and although sheep numbers have declined, export revenues for sheep products has sharply increased. Morrison Paul, Johnston and Frengley (2000[185]) also study the efficiency impacts of regulatory reform on sheep and beef farming in New Zealand, using data from 1981-82 and 1991-92. The authors agree with Vitalis that the primary economic impact of the reforms was to induce (in relation to beef and sheep farming) changes in output composition, with increased production of beef and deer relative to wool and lamb. The authors found no evidence that the reforms stimulated improvements in technical efficiency of livestock farmers (dairy was not considered). In fact, their analysis suggests that the rapid reform process may have initially driven down efficiency due to farmers' financial stress limiting their ability to adapt to new regulatory and market

[52] For example, Nogués-Bravo et al. (2016[197]) comment that "rewilding is the new Pandora's box in conservation" and that much more work is needed to design effective rewilding programmes.

[53] As of 2017, Australia and New Zealand are the only OECD countries whose support to agriculture, as measured by the OECD Producer Support Estimate (PSE) constitutes less than 2% of gross farm receipts (GFR). Chile also has very low levels of support, at 2.4% of GFR in 2017. (OECD, 2018[52])

settings. Owing to the time period of their data, this study does not consider the longer-term impacts of reform on industry productivity, and therefore provides no comparison (on this point) for the results found by Vitalis.

Observed environmental impacts of this reform package were both positive and negative. On the positive side, Vitalis (2007[184]) observes that removal of support payments for land development removed incentives to bring new land into production, and incentivised a switch to forestry on marginal land. Removal of payments based on inputs (subsidised fertilisers) resulted in a long-term decline of fertiliser use, although the author notes that "as a consequence of the Government's decision to give advance notice of and a transition period for the elimination of fertiliser supports, application of superphosphates rose sharply in 1984 and 1985 and declined just as dramatically thereafter" (p. 32[184]).

On the negative side, the most significant environmental impact was a rise in water pollution attributable to the increased size of the dairy herd. Greenhouse gas emissions from agriculture also rose modestly over the period 1990 to 2001, and land under irrigation has increased (although the author notes the difficulty in determining causality due to absence of data). However, agricultural water abstractions rose at a slower rate than when support for irrigation was available.

Barnett and Pauling (2005[186]) also study the environmental impacts of New Zealand's deregulatory reforms as implemented for the dairy industry, focussing their attention on the major environmental impact of dairy farming: polluting water resources (i.e. water quality impairment). The authors note that both point source (dairy factories) and non-point sources (dairy farms) were affected by the reforms. On the point source side, the number of New Zealand dairy factories decreased from around 200 to 30 by 1997, with an accompanying improvement in pollution control technology. On the non-point side, the total effect of the reforms was to decrease the total number of livestock units in New Zealand by 7% (between 1985 and 1997), with a corresponding decrease in the area of pasture (and an increase in farm-forestry activities). However, the overall decline in livestock numbers masks a significant shift towards dairy cattle from sheep, and cows have an excreta load around 30 times that of sheep: therefore, the overall result of the reform was an estimated 85% increase in excreta entering the environment (based on OECD data circa 1998). Water quality degradation associated with the dairy industry remains an ongoing challenge for New Zealand.

Sheng and Jackson (2016[58]) study the impacts of Australian dairy industry deregulation on productivity growth, using farm level data from 1979 to 2003. Implemented in 2000, the reform consisted of abolishing Statutory Marketing Authorities (SMAs) and a Domestic Market Support (DMS) scheme which together regulated the marketing of milk between Australian states and subsidised the export of manufacturing milk. The authors find that deregulation allowed for the reallocation of resources between dairy farms using a year-round production system to those using a seasonal production system, and a consequent increase in average industry total factor productivity (TFP) growth. Noting that a different study showed that average technical efficiency *declined* in the post-reform period, the authors explain that technical efficiency explains only part of the changes in TFP. They conclude that the impact of deregulation was via causing structural change in the industry, rather than via improving technical efficiency. Kompas and Che (2006[22]) and Kompas and Che (2004[187]), also studying productivity growth in the Australian dairy industry, found that deregulation in combination with persistent drought saw the number of Australian dairy farms halve in the past two decades to 2006, but milk production per farm rose by 78%since 1991-92. Thus, these studies find a clear positive link between deregulation (removal of market price support) and productivity.

The environmental impacts of dairy market deregulation are less clear. While the OECD's agri-environmental indicator database shows that nitrogen balances (in per hectare terms) had been trending downward since 2002, but have risen again in recent years (OECD, n.d.[188]), Smith, Western and Hannah (2013[189]) observe that pastoral-based dairying has intensified significantly over the past two decades (to

2013). The authors find strong links between intensification of milk production and increasing concentrations of nitrogen and phosphorous in streams from 1990 to 2000, but that environmental impacts appear to become more decoupled after 2000, the year of the deregulation reforms. The authors are able to attribute this decoupling effect to changes in farming systems (discarding alternative explanations of hydrological changes and erosional change), although they are unable to clearly specify which system changes have had the greatest effect, or the extent to which changes to farming systems are caused by the policy reform. The authors also note that the industry has adopted best management practices to improve water quality, which (at least in the one catchment studied) offset the effects of increased agricultural production. Further research is required to determine whether potential negative environmental impacts resulting from deregulation-induced intensification has been mitigated by changing industry practices.

4. Improving the evidence base

The previous sections have presented evidence that the impact of agricultural support on farms' economic and environmental performance differs according to the nature of the payment. However, many studies which estimate efficiency impacts do not contain much information about the payment type, analyse aggregated categories such as "coupled payments" or "total subsidies" which amalgamate a number of different payment types, or use terms such as "direct payments" whose meaning is not necessarily clear and could change over time. There is a need for more work which isolates the individual impact of specific policy instruments. Similarly, there is a need to distinguish between policies with accompanying mandatory conditions and those without, as well as the type of condition—this is particularly crucial in relation to environmental conditions. The OECD (2016[41]) has previously noted that the OECD PSE categorisation has some limitations when being used for evaluating agri-environmental policies;[54] one particular improvement would be to include a higher level of detail about the nature of constraints (e.g. for an input constraint, the type of input being constrained and the level of the constraint), particularly to be able to distinguish between payments based on inputs which are environmentally helpful versus those which are harmful.

In some cases, the ability to undertake policy-relevant analysis is limited by the data upon which analyses are based (e.g. see Dudu and Kristkova (2017[190]) for discussion of data limitations in the EU context). A significant case in point is the EU's Farm Accountancy Data Network (FADN) database.[55] Many of the studies included in the Annexes, which form the basis for this literature review, relied on FADN data. This database, while providing information on a variety of support categories, does not provide detail on whether constraints are applied, and it is not clear exactly what type of payments are included in some aggregate classes—e.g. the category "environmental subsidies". Moreover, notwithstanding the recent FLINT initiative[56] to extend the coverage of FADN on environmental variables, this database does not include

[54] OECD (2016, p. 189[41]) states: "the [PSE] indicator database in its current version does not lend itself to modelling agri-environmental policies. These policies are characterized by an "input constraint" label, indicating whether the input constraint is voluntary, and whether it has an environmental objective. However, these same policies can be classified under categories B through to F depending on the implementation criteria for provision. Even if the modeller knows that a programme is agri-environmental, the input constraint label provides no information on the type of input being constrained and on the level of constraint. Consequently, the analyst cannot distinguish between a policy limiting the stocking rate on pasture and one limiting fertiliser use."

[55] See http://ec.europa.eu/agriculture/rica/, accessed August 2018.

[56] See http://www.flint-fp7.eu/Results.html, accessed August 2018.

much detail on farm environmental performance. Thus, studies based on this database are necessarily limited in the level of policy granularity they are able to achieve and in their ability to link policy impacts to economic and environmental outcomes.

OECD is also undertaking a number of studies which, on the one hand, isolate the impacts of specific policies and make clear the impact of elements such as mandatory constraints, and, on the other, simultaneously evaluate both economic and environmental impacts. One current example is Henderson and Lankoski (2019[37]), which provides evidence on environmental impacts as well as changes to farm profitability for a range of agricultural support instruments, classified using the OECD PSE categories and labels.

Further, there is a need for more studies to consider both economic and environmental impacts at once, in order to gain more evidence on the potential for complementarities or trade-offs between productivity and sustainability objectives. While a piecemeal approach to gathering evidence across many different studies (as has been done here) yields useful insights, theoretical and empirical approaches differ so greatly across studies that it can be difficult to “link up” environmental results from one study with economic results from another to have a holistic assessment.

Another aspect to consider is the empirical methods used to evaluate policy impacts. The Annexes supporting this review provide detail on empirical methods used: most common among these are regression, scenario modelling and stochastic frontier approaches (for technical efficiency analyses). This literature review has not attempted to assess the merits of different empirical methods and has not undertaken a statistical meta-analysis of the empirical results reported on in the tables and figures in this report, or in the accompanying annexes. One area for further research is to review the merits of the various methods used to assess this research, particularly where there are multiple environmental impacts.

Beyond the *ex ante* and *ex post* approaches covered in this literature review, Colen et al. (2016[191]) note that the use of economic experiments could also provide assistance to evidence-based policy making (that article is written in the context of the European Union Common Agricultural Policy). Another approach, an example of which is provided in a forthcoming OECD report (OECD, forthcoming[192]), is using Qualitative Comparative Analysis (QCA) to analyse complex relationships between government policies and productivity and sustainability performance.

The OECD supports countries’ efforts to improve agricultural and agri-environmental data collection and accessibility, for example through the OECD Farm Level Analysis Network[57] and in working together with countries to develop and publish agri-environmental indicators[58] which are relevant for policy analysis and comparable across countries. However, more work is needed to improve the granularity and coverage of data for policy-relevant research, and to improve access to existing government-held datasets (OECD, 2019[193]). Further, more engagement between policymakers and researchers is needed to ensure academic studies yield results that are directly relevant to policy-making.

[57] See https://www.oecd.org/agriculture/farm-level-analysis-network/, accessed August 2018.

[58] See http://www.oecd.org/tad/sustainable-agriculture/agri-environmentalindicators.htm, accessed August 2018.

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Annex A. Literature review search procedure

The review was conducted by first constructing an overall conceptual approach, which is implemented via the structure of this report. This approach consists of:

- Identifying the theoretical pathways via which agricultural policies may impact on productivity and sustainability performance in agriculture—Section 1.
- Using the OECD's PSE classification of agricultural support, presenting evidence from 130 empirical studies on the impacts of different kinds of agricultural support on productivity (and the related concept of technical efficiency) and sustainability performance in agriculture—Section 2.
- Presenting evidence on how impacts vary dynamically and spatially—Section 3.
- Identifying gaps in the evidence base, with recommendations on directions for future research—Section 4.
- Bringing together key findings into a coherent narrative for policy-makers—Executive Summary.

Having defined this structure, for each Chapter the review was approached by conducting online searches of OECD publications (OECD iLibrary) and the peer-reviewed literature via Google Scholar and other databases such as EconLit. Bibliographies in key papers were also searched to identify further papers of interest. In addition, certain grey literature (for example, policy evaluations published by governments) were also used. This review covers English-language publications only (including English translations of studies undertaken in other languages, where publicly available). OECD member countries were also invited to supply relevant studies from their countries.

Literature on theoretical impacts of agricultural policies

For Section 1 and introductory paragraphs of subsections within Section 2 (which present the economic theory about policy impacts), the literature search started with identifying relevant OECD publications, based on Secretariat expertise. References lists within these OECD publications were also searched to identify further papers containing theoretical discussions. Following this, economic theory presented within empirical papers (see next section) was identified. Finally, these sections draw in part from a consultant literature review commissioned by the OECD, conducted by Alban Thomas, Toulouse School of Economics.

Literature containing empirical evidence

This review provides a non-statistical (i.e. non-econometric) meta-analysis of studies examining the impacts of different kinds of agricultural payments on productivity and technical efficiency at the farm level, together with environmental impacts.[59] Collection of data for this part of the analysis follows Minviel and

[59] Environmental impact information is much more heterogeneous than data on technical efficiency or productivity, and could relate to pressure indicators (e.g. nutrient or greenhouse gas emissions, land use change) or environmental outcomes (e.g. habitat, biodiversity, water quality).

Latruffe (2017[3]), who undertook an extensive survey and statistical meta-analysis of the literature examining the effects of public support on farm technical efficiency, using data up to 2014. Beginning with the supplementary online appendix provided by these authors (containing 172 observations on *technical efficiency* impacts of agricultural support payments), this review augments Minviel and Latruffe's earlier study by:

- Gathering an additional 110 observations from 14 *ex post* studies (mostly studies which were published after Minviel and Latruffe), for a total of 282 observations on technical efficiency impacts from 79 studies.
- Collecting data from *ex post* studies examining the impact of agricultural support payments on farm-level *productivity* (usually total factor productivity (TFP) — 84 observations from 5 studies.
- Collecting data from *ex post* studies examining the *environmental impacts* of agricultural support payments—142 observations from 24 studies.
- Collecting data from *ex ante* policy simulations which study the potential environmental impacts and economic outcomes (e.g. employment, agriculture gross margins, agricultural income) from different policy reform scenarios, which allow consideration of the potential impacts of 'policy packages', complementing evidence on the individual impacts of specific kinds of agricultural support payments—418 results from 18 studies.

Whereas Minviel and Latruffe undertake a statistical meta-analysis, the current paper reports a range of cross-tabulations from the dataset, together with discussion on key findings from this literature. A full statistical meta-analysis is beyond the scope of the current work. Nevertheless, the data provided in the annexes to this paper (Annexes B to E) provide the data that could underpin a new meta-analysis, updating and expanding on the work of Minviel and Latruffe.

The search procedure was as follows:

- For *technical efficiency* impacts: first, the papers cited in Minviel and Latruffe's supplementary appendix ('supplementary appendix') were located. The Secretariat reviewed these papers to (i) verify the information presented in the complementary appendix; (ii) extract discussions on theoretical impacts or empirical findings; and (iii) extract further potentially useful references from the bibliographies of these reports. Then, the literature was searched using online search engines (primarily Google Scholar, but also EconLit, JSTOR, Ebscohost). Key search terms used were "technical efficiency" plus a variety of terms referring to agricultural support policies, such as "agricultural support", "agricultural subsidies", "agricultural payments", "PSE", etc. Additionally, search terms included names of key agricultural policies (e.g. "CAP", "Farm Bill", "Conservation Reserve Program") or phrases referring to specific categories of policies as relevant for undertaking the review using the OECD PSE classification (e.g. "market price support", "quota", "cross-compliance", "subsidised crop insurance", "direct payments", "coupled payments", "decoupled payments", etc.). Once it was identified that the majority of papers related to the EU or North American context, these searches were repeated with the names of non-EU, non-OECD countries included in the search terms; however, this additional search yielded limited additional material.
- For *productivity* impacts, the literature was searched using online search engines (primarily Google Scholar, but also EconLit, JSTOR, Ebscohost). Key search terms used for policies were as above. Key search terms relating to productivity were "productivity", "total factor productivity", "TFP".
- For *environmental* impacts, key past OECD work was identified using Secretariat expertise. Then, the literature was searched using online search engines (primarily Google Scholar, but also EconLit, JSTOR, Ebscohost). Key search terms used for policies were as above, with additional terms relating to environmental aspects of policies such as "agri-environmental scheme", "conservation", "greening" and "natural resource management". Key search terms relating to

environmental impacts included “nutrient balance”, “water quality”, “biodiversity”, “greenhouse gas emissions”.

In total, this search yielded upwards of 300 publications, the majority of which were peer-reviewed English language journal articles. The Secretariat reviewed the abstracts, tables and conclusions sections of these papers to screen them for relevance for the theoretical and empirical sections of the review. Around 265 publications were included in the review, either directly cited or included in the Annexes B to E.

Empirical findings were extracted from papers and included into a Microsoft Excel database. Tables and charts included in the paper were prepared using pivot table analysis on this dataset. Information was recorded on the following fields, following Minviel and Latruffe:

- Author(s) name(s)
- Publication date
- Time period (i.e. time period which survey data was gathered)
- Country
- Region (if applicable)
- Agriculture sector—farm sectors were aggregated into broader categories using the groupings identified in Table A A.1.
- Sample size
- Policy type—if possible, the policy type was classified using the OECD PSE classification, using Secretariat expert judgement. Policies were aggregated into broader categories using the groupings identified in Table A A.2.
- Payment proxy—if possible, the payment proxies were aggregated into broader categories using the groupings identified in Table A A.3.
- Effect estimate—extracted from tables in the reviewed paper.
- Effect direction—significant negative, zero or not statistically significant, significant positive.
- Effect on what (i.e. dependent variable)—if possible, the dependent variables were aggregated into broader categories using the groupings identified in Table A A.4.
- Empirical method used
- Data source
- Whether paper was included in Minviel and Latruffe’s supplementary appendix (Y/N).

Table A A.1. Sector groupings

Sector	Sector group
Alfalfa; Cereals; Cereals, oilseeds and protein seeds; Crop; Grain crops; Grain farms; Winter wheat; Indica rice; Cotton Mixed crops; Other crops; Tobacco; Wheat; Rice	Crops
Dairy; Dairy (organic)	Dairy
Farms; Representative farm	Farms (no sector breakdown)
Fruits; Horticulture	Fruit & Horticulture
Beef cattle; Cattle finishing; Cattle rearing; Cattle, suckler; Cattle other; Cow-calf operations; Pig; Sheep; Livestock; Poultry; Sheep and goats; Sheep, goats	Livestock (non-dariy)
Crop, livestock; Crop, dairy, livestock; Mixed farming	Mixed crop-livestock

Table A A.2. Policy groupings

Policy	Policy group
Agri-environmental payment; Environmental subsidies; Organic subsidies	Agri-environmental payments
Coupled payments; Crop subsidies; Livestock subsidies; Other crop subsidies; Other cattle subsidies; Sheep & goats subsidies; Other livestock subsidies; Output subsidies	Coupled payments
CAP Greening requirements	Cross compliance
Decoupled payments; Single Farm Payment; Single Area Payment	Decoupled payments
Input and investment subsidies	Input and investment payments
Input subsidies; Operational subsidies; Subsidies for seeds and pesticides purchase	Input and operational payments
Crop insurance; Crop insurance participation and premium subsidies; subsidised insurance; revenue insurance (purchased); whole-farm income insurance	Subsidised crop insurance
Investment programmes; Investment subsidies; Operational and investment subsidies	Investment payments
LFA subsidies	LFA payments
Other subsidies	Other
Policy reform	Policy reform
Rural development subsidies	Rural development payment
Set-aside payment	Set-aside payment
Public agricultural subsidies; Total operational subsidies; Total subsidies	Total payments

Table A A.3. Payment proxy groupings

Payment proxy	Payment proxy group
Scenario modelling	Scenario modelling
ratio to total farm income; ratio to farm revenues; ratio to farm output value; ratio to gross margin; ratio to farm income; ratio to output value; ratio to total net farm income	Dependence on payments
Payment per hectare; Payment per animal; payment per farm; payment per livestock unit; average payment per region;	Payment per physical unit
Payment ratio (payment of type x to total support payments)	Payment ratio
Dummy (=1 for post-policy reform period)	Policy reform dummy

Table A A.4. Dependent variable groupings

Effect on what?	Effects group
Biodiversity; Biodiversity - Area weighted mean species richness of vascular plants; Biodiversity - number of species; Habitat richness; Habitat evenness; Habitat rarity	Biodiversity
Climate change adaptation	Climate Change (CC) Adaptation
Mitigation; Carbon storage in soil; Soil Organic Carbon (SOC)	Climate Change (CC) Mitigation
Crop acreage; Crop production; Arable land; Cereals; Oil & protein; Indus. Crops; Fodder; Arable land; Land allocated to crops; Total grain area	Crop area or production
No. crops	Crop diversification
Agricultural income; Taxpayer savings; Agriculture gross margin; Agricultural employment; Agriculture gross margin; Consumer surplus; Agricultural sector output; GDP; Employment; Farm income per hectare; Producer surplus; Milk production; Beef production; Gross margin; Gross value added plus subsidies	Economic impacts
Fertiliser and chemical use; Fertiliser use; N per acre; P per acre; Potassium per acre; Herbicide treatments per acre; Insecticide treatments per acre; Pesticide expenditure per corn acre; Pesticide expenditures; Pesticides Nitrogen; Phosphate; Potash; Fertiliser expenditure; Crop protection expenditure; Fertiliser and chemical expenditure; N synthetic fertiliser quantities (total); P synthetic fertiliser quantities (total); Total fertiliser use; Fertiliser expenditures; Pesticide expenditures; Soil erosion; Fertiliser usage	Fertiliser and chemical use
GHG emissions; Methane emissions; GHG; C02-equivalents; CH4 total emissions; CH4 emissions (total); N2O emissions (total); Global warming potential	GHG emissions
Set-aside; Agricultural land set-aside; Share of grassland; Total set-aside area; Share of grassland	Grassland or set-aside
Agricultural land abandonment	Land abandonment
Land allocation; Land use; Pasture; Beef cattle; Dairy; Pigs; Poultry; Other animals; Pasture; Fallow; Livestock; Grassland; Fallow land; Meadows and pasture; Extensive arable land; Intensive arable land; Agricultural land set in GAEC; Forest; Livestock units; Water; Settlement and others	Landuse / Production
Livestock units per hectare; Cattle livestock density	Livestock intensity
N surplus; Ammonia emissions; Atmospheric N deposition on land from agriculture (tonnes N/yr); N leaching of domestic marine waters from agriculture (tonnes N/year); Nitrate from manure; Nitrate from mineral fertilisers; Nitrogen surplus; N_20; Nutrient surplus—Nitrogen; Nutrient surplus—Phosphorus; Water pollution index; Total nitrogen loss N runoff; N percolation; P surplus; Ammonium output; N atmospheric deposition; Gross Nitrogen Balance per hectare; P atmospheric deposition; Gross Phosphorous Balance per hectare; N_2O atmospheric deposition; N leaching	Nutrient loadings
Organic farming on arable land	Organic farming
Soil erosion; Wind erosion; Loss of Soil Organic Carbon (SOC); Wind erosion; Water erosion	Soil degradation
Winter soil cover	Soil improvement
Total Factor Productivity (TFP); Productivity; Technical efficiency; Log-productivity of intermediate consumption	Technical efficiency or TFP
UAA; Farm UAA	Utilisable Agricultural Area
Wetland drainage	Wetland drainage