Has the CAP promoted European water consumption?

A look at foreign trade

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Abstract: The concern on the effects and potential consequences of the displacements of water resources through international trade has increased in the last decades. Today, in a context of growing water needs, water scarcity is considered one of the main problems in the world. Despite large advances on its quantification and understanding, further research on the anthropogenic determinants of the exchanges of water embodied in international trade is necessary.

Our study aims to shed light on the trajectories and explaining factors of water exchanges in the European Union. In particular, we analyse how the Fischer Common Agricultural Policy Reform, which decoupled direct subsidies from production, affected European water consumption through agri-food exports. First, our methodology relies on the bottom-up approach to estimate European long-term exports of virtual water from 1995 to 2013. Second, we assess the effect of the reform on water consumption using panel data analysis in a trade gravity framework. Our main results show that the decoupling introduced by the Reform boosted extra European virtual water exports. We also observe a large heterogeneity in our sample, pointing to Mediterranean areas as the most affected by the policy reorientation. Spain, one of the most water scarce countries in the European Union, is central to explain this link.

Keywords: CAP Reform, water, trade, European Union, decoupling

1. Introduction

The importance of the agricultural sector in the European Union (EU) has declined as a consequence of the economic progress (Byerlee et al., 2011), accounting for 4.4% of the total employment in the EU-28 in 2015, and 1.3% of the value added (EUROSTAT, 2018a). Notwithstanding the decline in the relative weight of the primary sector, its economic relevance relative to the EU international trade has increased significantly. The EU has become the main exporter and importer of agricultural and food products in the world since 2010, showing external balance on these goods, mainly as a result of the important upsurge of exports (EUROSTAT, 2018b). Besides, the impact of agriculture on the environment and the natural resources is considerable and complex, comprising both positive and negative effects which take place at local, regional, national and global levels (Kampas et al., 2012). Agriculture is widespread across the EU and has caused considerable impacts on land, water, biodiversity and emissions, especially affecting freshwater ecosystems as a large part of Europe's land is dedicated to agricultural uses: 44% of total water abstracted is for agriculture, while this proportion is higher as far as Southern Europe is concerned, where the ratio reaches 70–80% (EUROSTAT, 2018a).

Agricultural uses are driven by a variety of macro elements (e.g. socioeconomic and cultural drivers), as well as local factors (Flávio et al., 2017). One of the key macro determinants are agricultural policies, crucial in the development of the primary sector. The EU Common Agricultural Policy (CAP) is a relevant external driver of European agriculture that has had a preeminent role in shaping agricultural production and its consequent environmental impacts (Coderoni and Esposti, 2018). The CAP was introduced in 1962 as a system of agricultural subsidies and other programs aiming to support farmers and improve agricultural productivity, and has undergone several changes since then. The Fischer CAP Reform is known as one of the most important CAP reforms so far, as it changed the basis of direct support (Phelps, 2007). It was applied in 2005, although was not compulsory until January 2007, and consisted of two "pillars". Based on Pillar 1, direct payments were decoupled from production via the Single Payment Scheme (SPS) [1]. The principle of decoupling was established as a

[1] The SPS affected the EU15 members plus Malta and Slovenia. The new member states, that joined from 2004 on, have been incorporated into a progressive system called Single Area Payment Scale (SAPS) (Matthews et al., 2017).

cornerstone of the CAP payments, i.e., direct aids were not related to the volume of commodity output, making subsidies to individual farmers independent of the crops grown in any particular year. To qualify for the payment entitlements, farmers were required to keep agricultural land in Good Environmental and Agricultural Condition (GAEC) and respect relevant Statutory Management Requirements, together referred to as cross-compliance (Brady et al., 2009). The former aimed to enhance environmental responsibility and link financial support to compliance with environmental standards. The second pillar concerns rural development policy. The reform promoted the extension of the Rural Development Programme, including the Agri-Environment Programme (AEP) (Stoate et al., 2009), and trying to achieve balanced territorial development as well as promote innovation and competitiveness.

Interestingly, the Fischer CAP Reform translated the growing concern on the effects of agricultural activity on the environment. The introduction of decoupling, cross compliance and the European Agricultural Fund for Rural Development was expected to have positive externalities on natural ecosystems (Coderoni and Esposti, 2018). Furthermore, the embodiment of environmental objectives in the Fischer CAP Reform do coincide with the implementation of the Water Framework Directive (WFD) that had as its main objective "*to ensure access to good quality water in sufficient quantity for all Europeans, and to ensure the good status of all water bodies across Europe*" (European-Commission, 2000, art. 4).

In this context, our paper aims to assess the role played by the Fischer CAP Reform on the trajectories of water exchanges in the EU from 1995 to 2013. More concretely, we want to analyse the impact of decoupling on the growing pressures on water resources through extra European agri-food exports. Agri-food exports were growing from 1995 to 2013, particularly from 2005 onwards, also entailing the exchanges of natural resources embodied in the goods traded (Schmitz et al., 2012). This was the case of water, a necessary input for the production and trade of agricultural products, that has been recently studied from a global perspective due to the internalization of the economies (Hoekstra and Mekonnen, 2012; Vörösmarty et al., 2015). Thus, given the increasing concern on the effects and potential consequences of the displacements of water resources through international trade, many studies have used the concept of virtual water, i.e., the volume of water necessary for the production of a commodity (Allan, 1993; Allan et al., 1997) to assess the exchanges of water resources as a result of

globalization (Antonelli et al., 2017; Carr et al., 2013; Duarte et al., 2016a; Tuninetti et al., 2016). In this work, we focus on blue virtual water: surface or groundwater evaporated during a production process (Hoekstra et al., 2011). In comparison to green water (water stored in soil as moisture), blue virtual water can be managed and therefore allocated among different uses, showing a higher opportunity cost.

To the best of our knowledge, there is scarce literature on the analysis of the environmental impacts of the Fischer CAP Reform (see Brady et al. (2009) for the effects on landscape and biodiversity, or Coderoni and Esposti (2018) for an ex-post analysis on emissions). According to Volkov and Melnikiene (2017), there is a lack of systematic approaches and instruments to assess the impact of the decoupling system to environmental sustainability. As for water, we can find mostly ex-ante studies at the farm level for the EU-15 (Giannoccaro and Berbel, 2011) and for specific countries (Scardigno and Viaggi (2007) for Mediterranean members, Dos Santos et al. (2010) for Portugal and Kampas et al. (2012) for Greece). Overall, these studies concluded that the focus of the Fischer CAP Reform on water issues was limited, and therefore important impacts in terms of water quantity and quality could be induced.

Thus, our paper contributes to the literature on the link between water impacts and the Fischer CAP Reform from different perspectives. First, it offers a macro and ex-post (based on real data) assessment of one of the main drivers of global water displacements, agricultural policy. Second, the sample considered, including 290 products and 222 countries (with 28 member states), is one of the strengths of the paper. This high level of disaggregation allows further analysis in the explanation of water exports. Third, the long-term perspective is essential to evaluate the historical changes driven by the Fischer CAP Reform in a period of trade expansion. Finally, the methodological approach, which combines a bottom-up focus with panel fixed effects regressions, allows us to exploit the longitudinal dimension of our highly disaggregated data as well as accounting for the endogeneity associated to the standard trade gravity model.

The rest of the paper is organised as follows. Section 2 explains the methods and data used. First, in section 2.1 the bottom-up calculation of our variable of interest is explained. Then, in section 2.2 we discuss the econometric specification and estimation strategy. In section 3 we present the descriptive results on the water embodied in extra

European exports and the main findings on the impact of the Fischer CAP Reform. The paper closes with the main conclusions and a discussion in Section 4.

2. Methods and data

2.1. Calculation of virtual water exports

First, we calculate the blue water embodied in extra European bilateral exports according to the method proposed by Hoekstra and Hung (2005). Given a country i in year t, the virtual water exports (VWX) to country j for each agri-food product p (VWX_{cipt}) can be obtained as:

$$VWX_{ijpt} = w_{ip} * \ x_{ijpt} \tag{1}$$

Being x_{ijpt} the volumetric quantity of product p exported by country i *to* j in year t expressed in Tonnes, and w_{ip} the product blue water footprint that measures the volume of blue water necessary to produce a tonne of each commodity in the exporting country.

We can calculate the total VWX for each pair of countries summing by products as:

$$VWX_{ijt} = \sum_p w_{ip} * \ x_{ijpt} \tag{2}$$

Bilateral trade data on agricultural and food products (x_{ijpt}) are from United Nations Statistics Division (UN, 2018) at the four-digit level of the Standard International Trade Classification, SITC, revision 3. We use annual trade data from 1995 to 2013 to be able to capture the trends on VWX before and after the Fischer CAP reform. Our sample considers 290 products and 222 countries (28 EU and 194 non-European countries[2]), accounting for approximately 85% of agricultural and food commercial exchanges in the world during these years. Finally, the product water footprints (w_{ip}) stem from Mekonnen and Hoekstra (2012, 2011).

2.2. Econometric specification and estimation strategy

As the next step, we present the trade gravity model that will be the main tool used to evaluate the impact of the Fischer CAP Reform on VWX. From the seminal work of Tinbergen (1962) the gravity equation of trade has become one of the main

[2] Note that the countries are considered as EU members after its accession date.

methodological approaches used to assess the main determinants of bilateral trade flows (Anderson, 1979; Anderson and van Wincoop, 2003; Bergstrand, 1989, 1985; Eaton and Kortum, 2002; Head and Mayer, 2014). Recently, this framework has been increasingly used to evaluate the environmental impacts generated by international trade, namely of carbon emissions (Aichele and Felbermayr, 2015; Duarte et al., 2018; Frankel and Rose, 2005) and water (Duarte et al., 2019). In this paper we use an econometric panel data model that allows studying European VWX with a temporal dimension. In this regard, the long-term perspective is essential to capture relevant historical moments affecting trade patterns and water consumption. First, the agreement on agriculture initiated in the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) in 1992, entered into force in 1995 with the beginning of the World Trade Organization (WTO). It involved specific commitments to reduce domestic support and export subsidies and therefore an intensive liberalization of agricultural trade and the extension of globalization to primary markets. In this context, the Fischer CAP Reform changed the orientation of direct aids through decoupling, trying to support income while minimizing market distortions. During these years a considerable enlargement of the European Union also happened and the WFD was implemented.

First, we estimate the effect of the policy reform using the gravity model standard in the literature. Our baseline specification is as follows:

$$VWX_{ijt} = \beta_0 + \beta_1 \mathrm{Cou}_{it} * \mathrm{inter}_{ijt} + \beta_2 \mathrm{RD}_{it} * \mathrm{inter}_{ijt} + \beta_3 \boldsymbol{X} + + u_{ijt} \qquad (3)$$

Where VWX_{ijt} are European blue VWX from *i* to *j* in year *t*. Cou_{it}, our main variable of interest, is the share of coupled aids on total direct payments (coupled plus decoupled) and reflects the main change of the Fischer CAP Reform, i.e., the transition from a coupling to a decoupling regime. We also include RD_{it}, i.e., the rural development subsidies of the Pillar 2 introduced by the reform. The data for the Cou_{it} and RD_{it} variables is drawn from the Farm Accountancy Data Network (FADN) (FADN, 2018). It is important to note that Cou_{it} and RD_{it} are interacted with inter_{ijt}, a dummy variable that takes the value 1 if the bilateral trade flow is extra European in year *t* and 0 if trade is between EU countries. $\boldsymbol{X}$ is a vector that contains the traditional variables included in trade gravity models. More concretely, we include population (POP) and Gross Domestic Product (GDP) of both commercial partners (in logarithms) by means of controlling for the scale of the countries (WorldBank, 2016). In this specification we

also use DISTANCE (in logarithms) as a proxy for trade costs. Additionally, we include dummies that control for the effect of having a common border (CONTIGUITY), a common currency (CURRENCY), a colonial past (COLONY), a common religion (RELIGION), or a common language (LANGUAGE). All these variables come from Mayer and Zignago (2011). Notably, trade agreements also influence international trade and VWX. Thus, we use dummies that take the value 1 if the importer country belongs to the World Trade Organization (WTO). Finally, we include a dummy variable that indicates whether both partners participate in the same regional trade agreement (RTA). These data were taken from Head et al. (2010) and Head and Mayer (2014). Table 1 shows the descriptive statistics of the main variables used in the analysis.

Table 1: Summary statistics of the main variables

Variable	Obs	Mean	Std. Dev.	Min	Max
COLONY	68961	0.0450835	0.2074887	0	1
CONTIGUITY	68961	0.0185612	0.1349702	0	1
COU	68961	0.4504199	0.4267269	0	1
CURRENCY	68961	0.0024942	0.0498796	0	1
DISTANCE	68961	6335.569	4065.535	160.9283	19539.48
GDP_e	68961	6.52E+11	8.60E+11	5.64E+09	3.75E+12
GDP_i	65462	2.92E+11	1.19E+12	1.10E+07	1.68E+13
LANGUAGE	68961	0.068169	0.2520375	0	1
POPULATION_e	68961	21.73222	24.43377	0.401268	82.53418
POPULATION_i	67753	35.55104	133.0132	0.009227	1357.38
RD	68961	4898.008	8616.791	0	65562
RELIGION	68199	0.1901644	0.2552771	0	1
RTA	68961	0.2723423	0.4451684	0	1
VWX	68961	4477836	4.47E+07	0	2.07E+09
WTO	68961	0.7549049	0.4301467	0	1

Source: Own elaboration

Standard gravity model regressions estimated using ordinary lest squares (OLS) imply that all observations for which there is no trade will be lost when taking logarithms, with the consequent loss of relevant information. In addition, this model also suffers from heteroskedasticity (Santos-Silva and Tenreyro, 2010, 2006). Therefore, following recent lines of discussion in economic literature (Head and Mayer, 2014; Yotov et al., 2016), we use the Poisson Pseudo-Maximum Likelihood (PPML) estimator. This approach has become standard to obtain trade gravity estimates as it is robust to heteroskedasticity and avoids the problem of zero values in bilateral trade data (Santos-Silva and Tenreyro, 2010, 2006).

Moreover, the estimated coefficients might be biased due to endogeneity issues as the traditional gravity models depicted in equation (3) do not consider either the importance of relative trade costs in determining trade flows (omitted variable bias) or the potential selection of countries into trade associate to policy reforms (selection bias). Multilateral resistant terms (MRT) capture the fact that any trade flow worldwide can be affected by changes in trade costs between any two countries. Thus, including MRT avoids generating biased estimates as a result of the omission of relevant variables (Anderson and van Wincoop, 2003; Baldwin and Taglioni, 2006). Following Baier and Bergstrand (2007) and Egger and Nelson (2011) we will include country-time fixed effects to control for MRT. On the other hand, countries likely select endogenously into trade based on observable characteristics, possible correlated with the level of trade (Baier and Bergstrand, 2004). Furthermore, the error term of the gravity model contains unobservable domestic policies that might also be related to the policy reform. In our set up, the likelihood of the Fischer CAP Reform affecting trade between the EU and other countries could be high if there exist expected welfare gains, but the potential correlation between the Fischer CAP Reform and the gravity equation error term suggests that the coefficient associated to the reform will tend to be biased. Therefore, we use bilateral pair fixed effect to correct for this source of selection bias (Baier and Bergstrand, 2007).

In this context, we aim to mitigate the aforementioned problems associated to the standard gravity model, and we further evaluate the impact of the main changes induced by the Fischer CAP Reform on extra European VWX, by using the following specification:

$$VWX_{ijt} = \beta_1 \text{Cou}_{it} * \text{inter}_{ijt} + \beta_2 \text{RD}_{it} * \text{inter}_{ijt} + \alpha_{it} + \alpha_{jt} + \delta_{ij} + u_{ijt} \quad (4)$$

Where VWX_{ijt} are European virtual water exports from *i* to *j* in year *t*. α_{it} and α_{jt} are the exporter and importer-time fixed effects introduced to control for MRT (Baier and Bergstrand, 2007; Egger and Nelson, 2010). δ_{ij} are pairwise fixed effects introduced to control for the endogeneity of policies affecting trade (Baier and Bergstrand, 2007). Egger and Nigai (2015) also show that this pair fixed effects account for bilateral trade costs better than the traditional gravity variables. Besides, the dummies controlling for MRT are perfectly collinear and therefore absorb the effect of any country-time variable as Cou_{it} and RD_{it}. Then, in order to be able to control for MRT while estimating the

effect of these exporter-time variables, Beverelli et al. (2018) and Heid et al. (2017) propose estimating the model with international and intra-national trade flows and interact the variables of interest with an indicator of international trade flows (inter_{ijt}). In our particular case, as we are interested in the main effect of the policy reform (measured using Cou_{it}) concerning extra-European VWX, we estimate the model with intra and extra European trade flows and the indicator inter_{ijt} selects only extra European exchanges.

3. Results

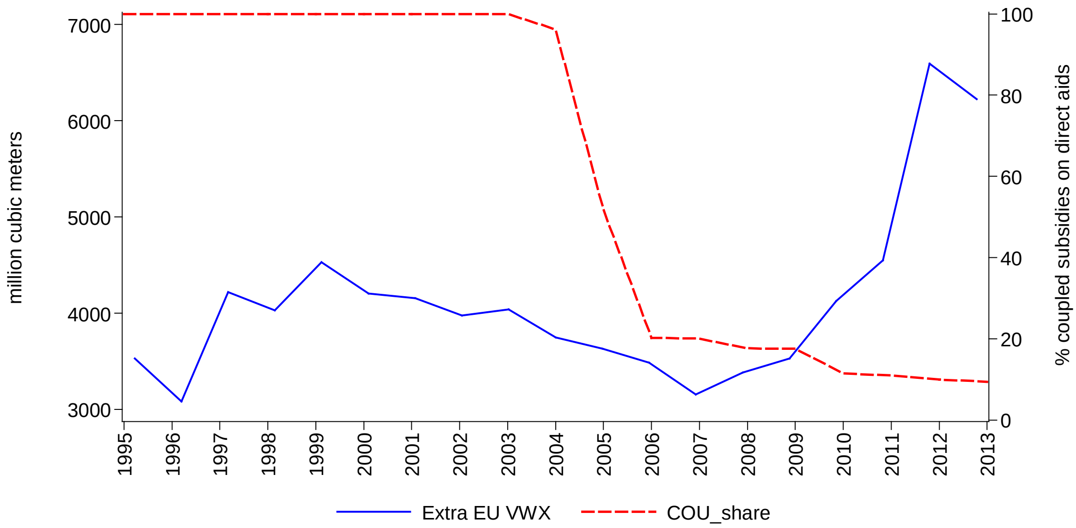
3.1. Extra European virtual water exports trends and patterns

On average, water embodied in extra European exports (solid line in Figure 1) increased at 3.1% every year between 1995 and 2013. Despite the strength of the Euro, and the enlargement of the EU that entailed a considerable rise of agricultural imports, European agri-food exports notably grew during these years, involving higher pressures on domestic water resources. Looking at Figure 1 we observe that, although with some annual fluctuations, this growth was fairly flat until 2007. In fact, extra European VWX were similar in the average period 1995-1997 compared to 2006-2008. The picture is very different from 2007. VWX boosted growing at 12% yearly during the period 2007-2013. This expansion of agri-food exports was particularly significant in a context of global economic crisis, and commercial restrictions with some of the main traditional trade partners as Ukraine and Russia (European-Commission, 2016). At this point, it is important to consider that although agri-food exports represent around 7% of total European exports (European-Commission, 2016), considering virtual water this figure reaches 22%, being especially high in some southern countries as Spain, where it accounts for more than 50% (Serrano et al., 2016).

The vast growth in VWX coincides with a significant reorientation of the CAP that crystalized with the Fischer Reform, introduced in 2005 and compulsory from January 2007 (Jaime et al., 2016; Jaraitė and Kažukauskas, 2012). As explained in the introduction, direct payments, which were conditioned to the compliance of certain environmental good practices, were decoupled from production (Pillar 1). We observe in Figure 1 how until 2003 direct aids were 100% coupled with production. From this point onwards, they fell sharply up to 50% in 2005, were about 20% in 2007 and kept

decreasing reaching 9% in 2013. During these years there was also a significant increase in rural development subsidies (Pillar 2) that were however lower compared to direct aids (either coupled o decoupled). According to the FADN data, Pillar 2 subsidies were approximately 23% of Pillar 1 aids in 2013. From an economic viewpoint, the Fischer CAP Reform increased the competitiveness of the agri-food sectors (European-Commission, 2007), reducing the distortions introduced by coupled subsidies and fostering market signals in a context of increasing globalisation (Garrido et al., 2010). After this first descriptive approximation we can say that as a consequence, the Fischer CAP Reform also seems to have triggered extra European agri-food trade, intensifying the pressures on water resources.

Figure 1: Extra European blue VWX in million cubic meters (left axis) and share (%) of coupled subsidies on direct aids (right axis)

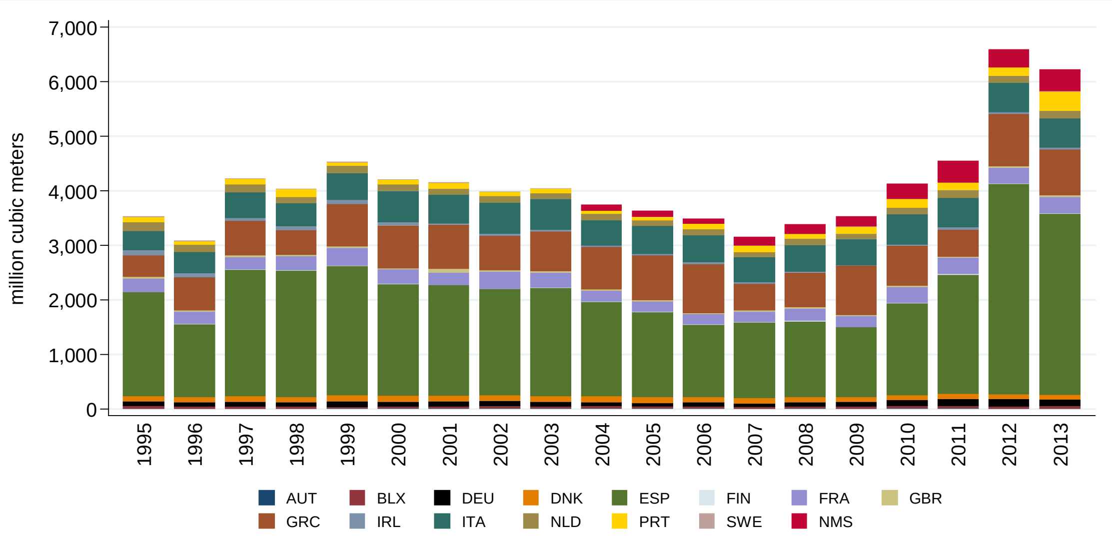


Source: own elaboration

These growing pressures on water resources were not homogeneous across countries. Figure 2 shows that Mediterranean areas (Spain, France, Greece, Italy and Portugal), which on average weighted over 86% on European blue VWX from 1995-2013, were the most affected by the expansion of agri-food exports. If the VWX kept quite stable in Mediterranean countries until 2007, it soared increasing at 11.8% between 2007 and 2013, which nearly replicates the growth found for the whole sample. As explained by Stoate et al. (2009), international markets have been increasingly demanding Mediterranean products as olive oil, and high value added crops, mostly fruits and vegetables. This entailed important agricultural transitions as the conversion of arable land into permanent crops and the intensive agricultural production of many of these

goods, oriented to foreign markets. Southern European regions have good climatic conditions to grow these agricultural products, but are also characterised as water scarce countries, being irrigation essential for this specific agricultural production. In this regard, the European Environment Agency (2018) shows that irrigation is the main pressure on water resources in the Mediterranean region reaching around 80% of the total net water use, with an irrigated area that has increased by 12% from 2002 given the growth in utilised crop areas. This increase in irrigated area related to the expansion of production, and to the requirements of international trade, has boosted the use of water resources, even in a context of technological innovations that have increased the efficiency of irrigation systems.

Figure 2: Country composition of extra European blue VWX (million cubic meters), 1995-2013.



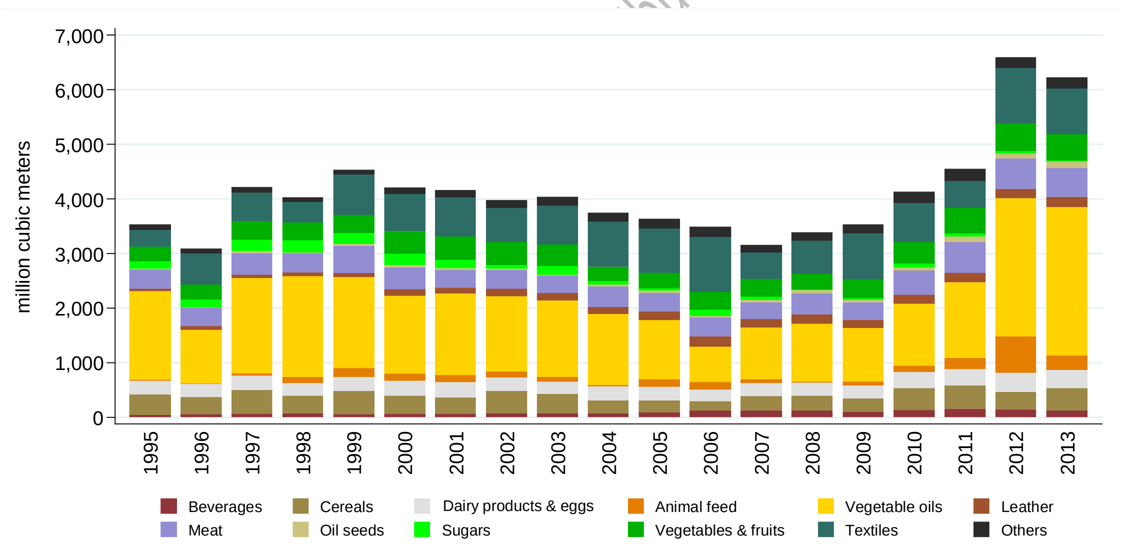
Note on country codes: AUT: Austria, BLX: Belgium and Luxembourg, DEU: Germany, DNK: Denmark, ESP: Spain, FIN: Finland, FRA: France, GBR: Great Britain, GRC: Greece, IRL: Ireland, ITA: Italy, NLD: Netherlands, PRT: Portugal, SWE: Sweden, NMS: New member states.
Source: own elaboration

Within the European Mediterranean area, the largest impact on water resources happened in Spain (see Figure 2, in green). On average, Spanish VWX were around 50% on total European VWX and represented more than 70% of the total increase in European VWX occurred from 2007. This figure is striking, especially considering that Spain is the most water scarce country in the EU, after Malta and Cyprus, with a Water Exploitation Index (WEI) of 33% in 2012 (EUROSTAT, 2018a). Spanish agri-food exports are high-value and water intensive goods like fruits, vegetables and olive oil, which are adapted to the Mediterranean climate and depend extremely on water from irrigation (Duarte et al., 2016b; Garrido et al., 2010). Irrigation in Spain represents 60% of agricultural production and 80% of farmers' exports. Despite its relevant role for the

development of the Spanish agricultural system, the economic, social and environmental sustainability of irrigation infrastructures has been questioned (Cazcarro et al., 2018, 2015). Aiming to increase its efficiency, the Spanish government implemented an ambitious plan for its modernization in the last decade. However, notwithstanding the conversion of surface into drip irrigation systems, the increase in irrigated area and some crop changes could have involved higher water consumption (Llamas et al., 2012).

Finally, the enlargement of the European Union entailed a large increase in the CAP payments. From 2004 to 2013 thirteen new member states (NMS in Figure 2) incorporated to the CAP. These countries, with a larger share of agriculture in their economic structure as compared to EU-15 areas, represented only 6.6% of the total European blue VWX on average, and triggered 9% of the growth in VWX between 2007 and 2013.

Figure 3: Product composition of extra European blue VWX (m^3)



Source: own elaboration

Moving to the agri-food products exported (Figure 3), vegetable oils, textile fibres, meat, vegetables and fruits, and cereals were on average the most significant commodity groups in blue VWX. We find that the composition changed from the mid-nineties to 2007, with decreasing shares of cereals, vegetables oils and sugars, and growing weights of textile fibres and leather. Then, from 2007 to 2013 we observe that VWX increased mainly as a result of vegetable oils exports, which accounted for 54% of the increase in total VWX. As explained in the methodology, agri-food exports are valued

considering the water used for its production (virtual water), and therefore the findings in terms of product composition of VWX can differ to those of monetary exports. In this regard, Garrido et al. (2010) show that despite wine and olive oil displaying the same monetary value of exports in Spain, the olive's virtual water is much larger than that of grapes, and therefore the VWX of olive oil could be up to 30 times larger compare to wine. Animal feed also increased its importance in blue VWX, with its weight going from 2% in 2007 to 7% in 2013. Meat, vegetables and fruits together with cereals, also drove the increase in blue VWX after the Fischer CAP Reform, although their shares remained stable. Finally, textile fibres lost weight, reaching a share similar to that of the mid-nineties.

The Fischer CAP Reform entailed a deep reorientation of the EU agricultural policy, aiming to increase the competitiveness of the sector on foreign markets and to enhance rural and environmental protection. Simultaneously, we have observed a marked growth of VWX to foreign European markets from 2007, mainly focused in Mediterranean countries that grow high-value and water-intensive products. In this context, is there any link between the Fischer CAP Reform and the increase in VWX? Did decoupling entail higher pressures on European water resources through agri-food exports? We investigate the extent to which the reform has affected these important issues in the next section.

3.2. The role of the Fischer CAP Reform as a driver of the increase in VWX

The gravity model depicted in Equation (3) aims to explain the variation in country pairs' water trade flows in terms of the countries' characteristics in the presence of the Fischer CAP Reform. Table 2 summarises the findings of the policy impact on the countries' variation in VWX. Columns (1) and (2) show the OLS and PPML estimates respectively, both without fixed effects. Estimation results indicate a positive association between the Fischer CAP Reform and VWX, suggesting that the policy has contributed to the reduction of the total water embodied in EU exports. Notice that our policy measure, Cou_{it}, is defined as the (decreasing) share of coupled subsides over total direct payments, and therefore, a positive coefficient would indicate that a reduction in the relative importance of coupled payments decreases VWX. PPML estimation improves OLS coefficients by considering all information available as well as heteroskedasticity. However, we are aware of the necessity to address other sources

of bias associated to endogeneity issues. First, as explained in the methodology, we need to consider MRT by including country-time fixed effects in order to mitigate endogeneity coming from omitted variable bias. Secondly, we need to address the bias in estimating the effect of the Fischer CAP Reform on water trade volumes, as the presence or absence of the policy is not exogenous, leading to potential selection bias. We then proceed to include the corresponding pairwise fixed effects to tackle the endogeneity of policies affecting trade.

Table 2: Estimation results of the Fischer CAP Reform

	(1)	(2)	(3)	(4)
	OLS	PPML	PPML MRT	PPML MRT Pair
Cou (coupled share)	1.586***	0.629***	-1.113***	-0.384*
	(0.0703)	(0.166)	(0.282)	(0.208)
Observations	42,321	63,280	65,041	56,125
R-squared	0.421	0.357	0.838	0.988
p-value RESET	0	0.834	0.028	0.067
Exporter-time & importer-time FE	NO	NO	YES	YES
Pair FE	NO	NO	NO	YES

Notes: Clustered errors by pair of countries in parentheses *** p<0.01, ** p<0.05, * p<0.1. Columns (1) and (2) control for population, GDP, distance, colonial past, common language, contiguity, common currency, WTO belonging, RTA and rural development subsidies.

Thus, Table 2 also shows the estimates once we have accounted for the omitted variable bias by adding country-time fixed effects (Column 3) and the policy endogeneity by also including pair fixed effects (Column 4). As a result, it turns out that now the link between the (declining) share of coupled aids and water embodied in exports is inverse, indicating that the Fischer CAP Reform triggered an increase in VWX. In our preferred specification in column (4), a 1% fall in the share of coupled aids implies a 0.4% increase in the total volume of water embodied in European exports.[3] Hence, the panel data estimations confirm the hypothesis that decoupling was a significant driver for the growing impacts on European water resources as a result of the internationalization of the agri-food sector. This result is consistent with Llamas et al. (2012) who state that the CAP affects global food trade and virtual water exchanges. It also goes in line with Scardigno and Viaggi (2007) who warn that despite the safeguard of the environment

[3] Column 4 is the preferred specification since it uses the PPML as recommended by literature on trade gravity (Head and Mayer, 2015; Yotov et al., 2016), accounts for omitted variable biased and selection effect, and the RESET test indicates that the functional form is adequate.

was one of the main objectives of the Fischer Reform, sustainable water management was not among the main goals of the CAP entailing impacts on the quantity and quality of water resources. Similarly, Kampas et al. (2012) found that decoupling may lead to higher water demand under low water prices since it induces the expansion of irrigated crops.[4] Finally, Chico and Garrido (2012) acknowledge that given the increasing link between international markets and water, the need to balance the market forces with the available local resources is becoming increasingly important.

3.3. Heterogeneous effects

We have shown that the Fischer CAP Reform changed the way that the EU supports the agricultural sector by removing progressively direct payments coupled to production. Member states had certain control concerning when the change from coupled to decoupled subsidies was implemented, being the most important requirement that there should be carried out effectively before January 2007. Thus, we now evaluate the effect of the policy considering only the time span associated to the full implementation of the reform. Moreover, comparing the results of the PPML with country-time fixed effects (Columns 3 and 4 in Table 1) to the corresponding OLS and PPML without country-time fixed effects (Columns 1 and 2 in Table 1), we observe that within country heterogeneity changes substantially the effect of the Fischer CAP Reform on VWX. This diversity of impacts on VWX across European countries can be induced by the different socio-economic and climatic conditions. Then, given the country heterogeneity and the predominance of the Mediterranean area as exporters of virtual water, we further analyse the extent to which this effect is associated to country characteristics by assessing only Mediterranean countries.

Therefore, in Table 3 we explore the role of the policy timing alongside its effect for Mediterranean countries. Column (1) shows the baseline estimation for comparative purposes[5]. In column (2) we show the estimate when we restrict our sample to the time when the reform is fully implemented. The result is striking as the magnitude of the effect is now more than 5 times as large compared to the baseline estimation. From 2007, a 1% fall in the share of coupled aids results in 2.2% increase in water embodied

[4] It is important to note that their study uses a nonlinear optimization model and only focuses on a specific region (Thessaly, Greece).

[5] It corresponds to the preferred specification in Table 2, i.e., column (4).

in extra EU exports. Then, column (3) displays the estimation associated to only Mediterranean countries. In this case, the size of the Fischer CAP Reform effect increases by 2.8 times and is now highly significant, indicating that Mediterranean countries are responsible for most of the policy effect. In particular, a 1% fall in the share of coupled aids implies now a 1.08% increase in VWX for Mediterranean countries. We repeat this exercise considering only Mediterranean countries from 2007 in column (4) and we observe how the estimate further increases. From 2007, a 1% fall in the share of coupled aids implies a 2.88% increase in VWX for Mediterranean countries. As Stoate et al. (2009) warned, the effect of decoupling seems to have very different impacts, particularly associated to regions already characterised by being intensive in agriculture. These differences across regions tend to escalate along with international trade and competition as the (increasing) production of the most valuable crops is region specific, leading to potentially damaging effects on water resources (Chico and Garrido, 2012).

Table 3: Heterogeneous effects of the Fischer CAP Reform considering the timing of policy implementation and only Mediterranean countries.

	(1) PPML MRT Pair	(2) From 2007	(3) MED	(4) MED from 2007
Coupled share	-0.384* (0.208)	-2.200*** (0.779)	-1.081*** (0.340)	-2.884*** (1.066)
Observations	56,125	24,356	15,297	5,605
R-squared	0.988	0.993	0.990	0.994
p-value RESET	0.067	0.07	0.002	0.93
Exporter-time & importer-time FE	YES	YES	YES	YES
Pair FE	YES	YES	YES	YES

Notes: Clustered errors by pair of countries in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Finally, Table 4 shows the corresponding estimates when Spain is excluded from the sample. On average, Spain accounted for approximately 50% of all water used for extra European exports. As we have seen in section 3.1., more than 70% of the increase in water used for exports from 2007 to 2013 happened in Spain (see Figure 2). Therefore, this exercise aims to highlight the importance of a single country, Spain, driving the results on VWX even after considering the full implementation of the Fischer CAP Reform. Again, column (1) shows the baseline results for comparison, and columns (2)-(3) show the corresponding estimates once Spain has been removed from the sample. It

is certainly clear from the results that the effects of the policy reform are completely mediated by Spain. The estimate associated to the full period under consideration has turned positive and lost all statistical significance. Besides, looking at column (3) in Table 4 where the policy is evaluated after it has been fully implemented, we observe that there still exists a negative link between the share of coupled aids and VWX, almost of the same magnitude as the result found in our baseline specification, but it is not significant. We interpret this result as a clear indication that most of the scale and composition changes originated as a result of the policy reform took place in Spain.

Table 4: Heterogeneous effects of the Fischer CAP Reform without Spain

	(1) PPML MRT Pair	(2) Without Spain	(3) Without Spain from 2007
Coupled share	-0.384* (0.208)	0.130 (0.147)	-0.490 (0.358)
Observations	56,125	53,348	23,172
R-squared	0.988	0.987	0.993
p-value RESET	0.067	0.094	0.000
Exporter-time & importer-time FE	YES	YES	YES
Pair FE	YES	YES	YES

Notes: Clustered errors by pair of countries in parentheses *** p<0.01, ** p<0.05, * p<0.1.

In this regard, Ruiz et al. (2011), suggest that the reform involved the redistribution of land in Spain, being the profitability of crops an important criterion for this change. Similarly, Garrido and Varela-Ortega (2008) found gradual and steady variations in the composition of irrigated land in Spain since the Fischer CAP Reform. For example, they observed that between 2004 and 2006 the irrigated area decreased for maize, legumes, rice, sugar beet and cotton, products that benefited from subsidies before the reform but that experienced an important decoupling. On the contrary, the irrigated surface increased for vineyards and olive trees, which most than doubled between 1995 and 2008 (Chico and Garrido, 2012). Then, the irrigated area for these crops kept growing smoothly in absolute terms. However, between 2008 and 2013 the ratio of irrigated on total surface moved from 29.2% to 35.4% in the case of vineyards and from 25.7% to 28.6% for olive trees (MAPA, 2013, 2008). This trend is quite significant, given the importance of vineyards and olive trees in 2013, which occupied 21% and 10% of total crop area, respectively (MAPA, 2013). Therefore, the Fischer CAP Reform reduced the incentives of producing certain water-intensive crops. However, the policy reform

intensified the spatial concentration of irrigated production and exports in some regional specific crops –mainly Andalusia for olive trees and vegetables and Castile La Mancha for wine–, a trend that has historical origins (Cazcarro et al., forthcoming). These main changes in crop production alongside with the specialization and improvement of the Spanish terms of trade in specific agricultural irrigated products (olive oil, wine, vegetables and fruits) have increased the consumption of blue water resources in Spain (Chico and Garrido, 2012), offering support for the results observed in Table 4.

4. Conclusions

In this paper we focus on the analysis of the impact of the Fischer CAP Reform on extra EU VWX. In particular, we are interested in the variation in country pairs' water trade flows as a result of the decoupling of direct aids introduced by this important agricultural and farming reform. In this regard, our methodology relies on a bottom-up approach which allows us to estimate European VWX using highly disaggregated data during the period from 1995 to 2013. We evaluate the impact of the policy reform using panel fixed regressions to address different forms of endogeneity associated to the standard trade gravity model.

Our main results, once we have considered the presence of omitted variable bias and endogeneity of policies, indicate that the Fischer CAP Reform notably contributed to the increment of the total water embodied in extra EU exports. Besides, the fact that VWX increase substantially under the policy reform by country characteristics suggests the determinant role of specific EU countries, i.e., Mediterranean areas. The consideration of this heterogenous effect is very important, especially when the economies of these countries are characterised as having a larger weight of agriculture in their GDP compared to their EU counterparts. Moreover, the agricultural sector of these Mediterranean countries is heavily oriented to international markets and based on high valued added agri-food products, which are mostly irrigated and therefore highly intensive in the consumption of blue water. We have also seen that one country, Spain, is essential to understand the effect of decoupling on European VWX, posing serious questions on the water sustainability of the CAP during the last years.

From the policy-making viewpoint, the findings of this work seem rather paradoxical. On the one hand, the Fischer CAP Reform, seeking for the improvement of the sectoral

competitiveness, but also, at least theoretically, for environmental protection, was triggering a higher consumption of water resources in the most arid areas of the EU. On the other hand, the results indicate that the CAP has diverged from the WFD objectives, neglecting the opportunities highlighted by Heinz (2008) and leading to an insufficient integration of water management in the CAP (ECA, 2014). Thus, our results call for a real harmonization of agricultural and water policies to further enhance agricultural sustainability in line with the coordination demanded by Gómez-Limón et al. (2002). This has been also highlighted in one of the last European Commission reports stating that *"any new CAP should reflect higher ambition and focus more on results as regards resource efficiency, environmental care and climate action"* (European Commission, 2017).

Finally, the results in this paper draw future research lines. First, it would be interesting to develop this analysis in a regional/local context, which would allow deepening into the heterogeneities seen at the country level and to evaluate the most affected areas –in terms of water resources- by the policy reform and its induced effects. Second, the impact of the CAP changes could also be assessed for different products, particularly focusing on water-intensive goods oriented to foreign markets. Finally, a natural extension of this study would be to evaluate the effect of the reform not only focusing on trade data, but on the total production using a different methodological framework.

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Supplementary material

List of products (SITC rev. 3 codes)

00111	01681	044	05453	05751	05995	07512	21112	26511	42161
00119	0174	0449	05454	05752	05996	07513	21113	26512	42169
00121	0175	0451	05455	0576	06111	07521	2112	26513	42171
00122	0176	0452	05456	05774	06112	07522	2114	26521	42179
00131	02211	0453	05457	05775	06121	07523	2116	26529	4218
00139	02212	04591	05459	05776	06129	07524	2117	26541	42211
00141	02213	04592	05461	05777	06151	07525	22211	26549	42219
00149	02221	04593	05469	05778	06159	07526	22212	26551	42221
00151	02222	04599	0547	05779	06192	07527	2222	26559	42229
00152	02223	0461	05481	05791	06193	07529	2223	26571	42231
01111	02224	0462	05483	05792	06194	08131	2224	26579	42239
01112	02231	04711	05484	05793	06195	08132	2225	26581	42241
01121	02232	04719	05485	05794	06196	08133	22261	26589	42249
01122	02241	04721	05487	05795	06199	08134	22262	26851	4225
01211	02249	04722	05488	05796	07111	08135	2227	29192	42299
01212	0241	04729	05489	05797	07112	08136	2231	29194	59211
01213	0242	04813	05612	05798	0712	08137	2232	29294	59212
01221	0243	04814	05619	05799	0721	08138	2234	41131	59213
01222	02491	04815	05641	05821	0722	11211	2235	42111	59214
0124	02499	0482	05642	05822	07231	11213	2237	42119	59217
01251	0251	0541	05646	05831	07232	11215	2239	42121	6113
01252	02521	05421	05647	05832	0724	11217	2631	42129	61141
01253	02522	05422	05711	0591	0725	1122	2632	42131	61142
01254	0411	05423	05712	0592	0731	1123	26331	42139	61151
01255	0421	05424	05721	0593	07411	11242	26332	42141	61152
01256	0422	05425	05722	05991	07412	1211	26339	42142	61161
01611	04231	0544	05729	05992	07413	1212	2634	42149	61162
01612	04232	05451	0573	05993	07414	1213	2641	42151	61171
01619	0430	05452	0574	05994	07511	21111	2649	42159	65133

List of EU countries

Country	**Year of accession**
Austria	1995
Belgium	1957
Bulgaria	2007
Croatia	2013
Cyprus	2004
Czechia	2004
Denmark	1973
Estonia	2004
Finland	1995
France	1957
Germany	1957
Greece	1981
Hungary	2004
Ireland	1973
Italy	1957
Latvia	2004
Lithuania	2004
Luxembourg	1957
Malta	2004
Netherlands	1957
Poland	2004
Portugal	1986
Romania	2007
Slovakia	2004
Slovenia	2004
Spain	1986
Sweden	1995
United Kingdom	1993

List of non-EU countries

Afghanistan	Benin	China, Hong Kong SAR	FS Micronesia	Haiti	Libya	Nepal	Rep. of Moldova	South Sudan	USA
Albania	Bermuda	China, Macao SAR	Faeroe Isds	Honduras	Madagascar	Neth. Antilles	Russian Federation	Sri Lanka	Uganda
Algeria	Bhutan	Colombia	Falkland Isds	Iceland	Malawi	New Caledonia	Rwanda	State of Palestine	Ukraine
American Samoa	Bolivia	Comoros	Fiji	India	Malaysia	New Zealand	Reunion	Sudan	United Arab Emirates
Andorra	Bonaire	Congo	Fmr Sudan	Indonesia	Maldives	Nicaragua	Saint Kitts and Nevis	Suriname	United Rep. of Tanzania
Angola	Bosnia Herz.	Cook Isds	French Guiana	Iran	Mali	Niger	Saint Lucia	Swaziland	Uruguay
Anguilla	Botswana	Costa Rica	French Polynesia	Iraq	Marshall Isds	Nigeria	Saint Pierre and Miquelon	Switzerland	Uzbekistan
Antarctica	Brazil	Cuba	Gabon	Israel	Martinique	Niue	Saint Vincent and the Grenadines	Syria	Vanuatu
Antigua and Barbuda	Brunei	Cote d'Ivoire	Gambia	Jamaica	Mauritania	Norfolk Isds	Samoa	TFYR of Macedonia	Venezuela
Argentina	Burkina Faso	Dem. People's Rep of Korea	Georgia	Japan	Mauritius	Norway	Sao Tome and Principe	Tajikistan	Viet Nam
Armenia	Burundi	Dem. Rep. of the Congo	Ghana	Jordan	Mayotte	Oman	Saudi Arabia	Thailand	Wallis and Futuna Isds
Aruba	Cabo Verde	Djibouti	Gibraltar	Kazakhstan	Mexico	Pakistan	Senegal	Timor-Leste	Yemen
Australia	Cambodia	Dominica	Greenland	Kenya	Mongolia	Palau	Serbia	Togo	Zambia
Azerbaijan	Cameroon	Dominican Rep.	Grenada	Kiribati	Montenegro	Panama	Serbia and Montenegro	Tokelau	Zimbabwe
Bahamas	Canada	Ecuador	Guadeloupe	Kuwait	Montserrat	Papua New Guinea	Seychelles	Tonga	
Bahrain	Cayman Isds	Egypt	Guam	Kyrgyzstan	Morocco	Paraguay	Sierra Leone	Trinidad and Tobago	
Bangladesh	Cent. African Rep.	El Salvador	Guatemala	Lao.	Mozambique	Peru	Singapore	Tunisia	
Barbados	Chad	Equatorial Guinea	Guinea	Lebanon	Myanmar	Philippines	Solomon Isds	Turkey	
Belarus	Chile	Eritrea	Guinea-Bissau	Lesotho	Namibia	Qatar	Somalia	Turkmenistan	
Belize	China	Ethiopia	Guyana	Liberia	Nauru	Rep. of Korea	South Africa	Tuvalu	