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THE EFFECT OF GLOBALIZATION ON WATER CONSUMPTION: A CASE STUDY OF SPANISH VIRTUAL WATER TRADE, 1849-1935

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Abstract: This paper aims to analyse the impact on water consumption of the trade expansion of the first globalization era. To that end, we choose the case of Spain, a semi-arid country with significant cyclical water shortages that excelled as an exporter of agricultural and food products in the period of study. More specifically, we are interested in answering the following questions: What was the volume of water embodied in agricultural and food products exports, how did this variable evolve over time, what factors drove this evolution and what was the volume of water incorporated in imports of these products?. In short, we want to know the impact on water resources of Spain's entry into agriculture and food markets. To explore these issues, we will use the concepts of virtual water and virtual water trade. First, we examine virtual water trade flows in the long run. Further, we attempt to disentangle certain major drivers underlying these trajectories. In order to establish the role played by trade in the final net balance of water, a Structural Decomposition Analysis (SDA) is applied. Finally, an analysis of the implications of the increase in virtual water trade on water resources is carried out.

Keywords: Virtual water trade, environmental history, agricultural trade, water history

Resumen: El objetivo de este trabajo es analizar el impacto sobre el consume de agua de la expansión comercial de la primera globalización. Para ello hemos elegido como caso de estudio España, un país semi-árido con una significativa escasez cíclica de agua, que destacó como un gran exportador de productos agrarios y alimentos en el periodo que estudiamos. Más específicamente estamos interesados en contestar las siguientes preguntas: ¿Cuál fue el volumen de agua incorporada en las exportaciones de productos agrarios y alimentos?¿Cómo evolucionaron a lo largo del tiempo? ¿Qué factores impulsaron esta evolución? ¿Cuál fue el volumen de agua incorporada en las importaciones de este tipo de productos? En suma, queremos averiguar el impacto sobre los recursos hídricos de la creciente participación de España en los mercados internacionales agrarios. Para resolver estas cuestiones, usaremos los conceptos de agua virtual y comercio de agua virtual. Primero estudiaremos los flujos de comercio virtual de agua en el largo plazo. Más adelante, trataremos de saber cuáles han sido los principales factores impulsores de esta evolución. Para averiguar el papel jugado por el comercio en el balance neto de agua, aplicaremos un Análisis de Descomposición Estructural. Finalmente, analizaremos las implicaciones del incremento en el comercio virtual de agua sobre los recursos hídricos.

Palabras clave: Comercio virtual de agua, historia ambiental, comercio agrario, historia del agua

1. Introduction

Those countries that experienced intensive economic growth during the Industrial Revolution profoundly modified their relationship to the environment. On the one hand, the increase in the availability of energy from fossil fuels played a crucial role in the success of the Industrial Revolution itself, both in England and in other nations (Wrigley, 1988; Stern, 2011; Stern and Kander, 2012). On the other, the changes in the use of energy and in its sources have profoundly influenced the economies of the developed countries in the last two centuries (Kander and Lindmark, 2004; Rubio, 2005; Gales et al., 2007). Furthermore, the industrial economies have, throughout the last two hundred years, caused serious damage to their natural environments, whether by modifying them greatly or by generating serious problems of pollution (McNeill, 2000; Krausmann et al., 2008; Stern and Kaufmann, 1996; Stern, 2005). The analysis of the impact of the processes of industrialization on the use of raw materials has also merited special attention (Iriarte and Ayuda, 2008 and 2012). In this regard, Krausmann et al. (2009) show that global raw materials use increased eight-fold during the last century.

The changing uses of energy and of raw materials have been closely studied from a long-term perspective, while water, another key resource for human subsistence and economic development, has received much less attention. The use of water has increased considerably in the last two centuries - and especially in the 20th century - driven by population growth but also, very significantly, by rising per capita income (Duarte et al., 2011 and 2013). The consumption of water has increased principally as a consequence of formidable growth in agricultural production, leading to not only the use of more land but also the need to undertake significant water projects for the extension of irrigation in arid or semi-arid regions (Federico, 2005). The openness of economies and the extension of agricultural trade has been one of the main drivers of this process.

In this general framework, our paper aims to provide insights on the role that international trade expansion and the process of economic globalization has played in increasing global pressures on water resources. To that end, we make use of the concepts of virtual water footprints and virtual water trade. While water itself is a not a significant commodity in international trade; exchanges of agricultural commodities are related to large volumes of upstream water use (Hoekstra et al., 2011; Mekonnen and Hoekstra, 2011, 2012).

First conceived by Allan (1997, 1999), virtual water has been defined as the volume of water required for the production of a commodity (Zimmer and Renault, 2003; Merret, 003; Hoekstra and Hung, 2005; Yang et al., 2007). Thus, we can refer to virtual water trade as the volume of water contained in products exchanged internationally. In other words, for a specific country, virtual water exports refer to domestic water effectively consumed to produce the goods sold abroad, while virtual water imports refers to all the water consumed in the countries of origin to produce the imported goods.

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Hoekstra and Hung (2005) showed that international virtual water flows related to trade in crop products were 695 billion cubic meters (Gm³), on average, in the period 1995-1999, equivalent to 13% of all the water used for crop production.

From the economic and environmental points of view, virtual water trade and its components (virtual water exports and imports) are of great interest and provide different perspectives on the economic growth of countries and its implications for local and global resources. As we will see, the evolution of virtual water exports tell us about the pressure on domestic resources from the processes of open trade. Moreover, virtual water imports represent water that the economy, in its process of economic growth, has not needed to consume. As a result of these flows, there exists a virtual water balance, showing the export and import characteristics of the particular country, but also a specific impact and pressure on domestic resources.

Against this background, our study examines virtual water trade flows over time, their composition, and the underlying economic factors. As a case study, we have chosen the period 1849-1935 and Spain, which was an important exporter of agricultural products in the period analysed.

From 1849 to 1935, the exchange of agricultural raw materials and food was of enormous importance in world trade (Lewis, 1952). Trade in agricultural products and food increased worldwide between 1850 and 1902 at an average annual rate of 3.7%, and between 1903 and 1938 at a much slower pace, 1.4%, as a result of the impact of the First World War, the collapse of the first globalization produced by the crisis of 1929, and the measures taken by various countries in its wake (Aparicio et al., 2009: 54). In a semi-arid country like Spain, the main factor restricting agriculture was the irregularity and the low average amount of rainfall, resulting in frequent water shortages during key periods for crop development (González de Molina, 2001).

For this country and period, we are interested in answering the following questions: What was the volume of water embodied in agricultural and food exports and imports, how did this variable evolve over time, and what factors lay behind such evolution?, what was the relative contribution of foreign trade to the increase in embodied water as a result of agricultural production? (We deal with both green and blue water[1].)

We relate the data to the historical context and establish the role played by trade composition and the increasing volume of trade in the final net balance of water. So far, no other study has analysed such flows of virtual water from a long-term perspective.

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[1]Green water refers to the volume of rainwater (stored in soil as moisture) evaporated during a production process; blue water is the volume of surface or groundwater evaporated as a result of the production of a commodity (Hoekstra and Chapagain, 2008). Blue water can be reallocated to agricultural, industrial, or urban use; by contrast, green water cannot be easily reallocated (Yang and et al., 2007). Accordingly, blue water has greater opportunity costs (Hoekstra, 2010).

The article is organised as follows. Section 2 provides a stylized view of the evolution of Spanish foreign trade in agricultural products during the first wave of globalization and the first years of its collapse. Section 3 reviews the methodology and the data used. Section 4 presents the main results of our analysis and is divided into two subsections. Section 4.1 focus on the main trends and composition of virtual water trade flows, and Section 4.2 performs a decomposition analysis of virtual water exports and imports. Finally, Section 5 closes the paper with a discussion of the results and our conclusions.

2. Spain in the international markets for agricultural products: some stylized facts

From the middle of the 19th century, the institutional changes promoted by the liberal governments were complete, making possible the development of a market economy. The deregulation of trade from 1869 onwards and the growth in agricultural exports, taking advantage of demand from the more developed European countries, increased the degree of integration of Spain in international markets.

Between 1850 and 1935, food and other agricultural products accounted for between 60% and 75% of total Spanish exports, and only the boom in mining exports, which took place between 1890 and 1920, caused this percentage to fall to approximately 50%.

Between 1850 and 1891, Spanish agricultural exports were concentrated on Mediterranean products, in which it had a clear competitive advantage. The growth of demand for wine by France, as a result of the phylloxera plague that devastated French vineyards, provided an authentic export boom for Spain. Between 1870 and 1890, wine represented 53% of Spanish agricultural exports; add nuts and olive oil and this sector's share of total exports reached two thirds (Pinilla, 1995). The growth of exports was rapid between 1850 and 1890, as exports by volume increased at an average annual rate of 3.2%, thus more than tripling in four decades (Gallego and Pinilla, 1996: 396). Those products were principally cultivated on rain-fed land, although part was also cultivated on irrigated land, all of which created a moderate pressure on the need for water for agricultural uses. In a semi-arid country such as Spain, these crops were very well adapted to their natural environment and climate.

However, in the final decade of the 19th century, the expansion of these exports was sharply halted. In the case of the star product, table wine, the end in 1891 of the wine-trade agreement with France, and the French choice to import wine from Algeria, with a more favourable tariff treatment, ended the golden age of Spanish wine exports (Pinilla and Ayuda, 2002). Alternative markets did not make up for the loss of the French, and also contracted, due to lower levels of wine consumption, protectionist policies in Argentina and Uruguay, and prohibition in the US (Pinilla and Ayuda, 2008; Pinilla and Serrano, 2008). Exports of olive oil also ran into serious difficulties, due to the employment of other, cheaper oils for industrial use, and to the low level of consumption in non-Mediterranean countries (Ramón, 2000).

However, from 1890 to 1930, Spanish agricultural exports continued to grow, although at a slower rate (1.3% annually). The most important factor from the end of the 19th century was the growth of Mediterranean horticultural products as the principal items in Spanish agricultural exports. Before 1890, these constituted no more than 15% of exports, but now became the most important element – at the turn of the century they represented 25% of Spanish agricultural exports, and by 1930 were approximately 50%. The volume of exports of fresh fruit, the most important in this group, was 63 times greater in the 1930s than it had been in the 1850s (Pinilla and Ayuda, 2010). Between 1900 and 1935, Spain had more than one third of the world exports of Mediterranean horticultural products (Pinilla and Ayuda, 2009). For oranges alone, the Spanish share ranged between 50 and 60% of world exports.

On the imports side, Spanish trade policy evolved from a high degree of protectionism against the entry of agricultural products, in force from 1820 onwards, to a significant liberalisation, beginning in 1869. Subsequently, approximately half of imports were products characteristic of tropical zones, not cultivated in Spain, such as sugar, cotton, coffee, cocoa and tobacco. From 1891 onwards, and principally as a consequence of the agricultural crisis at the turn of the century, there took place a protectionist turn, which in the case of agricultural products tended to be selective. Especially protected were certain products to facilitate the development of agro-industry in Spain, such as wheat, which in this case can be seen as an income policy aimed at protecting those farmers who were severely affected by falling prices as a consequence of foreign competition (Gallego, 2001 and 2003).

The Spanish agri-food trade expansion described above had its counterpart in the need for water to produce the trade goods, at a time when additional potential pressures on domestic resources were prevented through imports. These virtual water flows can be calculated and analysed on the basis of the methodology and data described in the following section.

3. Methodology and Data

3.1. Methodological aspects

Our starting point is the calculation of virtual water trade flows in agri-food products, following the approach developed by Hoekstra and Hung (2005).

For a country c (Spain in our case), in year t, the virtual water flow (m³/year) associated with exports can be obtained as the sum of the virtual water content in each of its p exported products, i.e.,

$$VWX(c,t) = \sum_p d_p^c(c,p,t) * x_p^c(c,p,t) \qquad (1)$$

Where x_p^c denotes the physical quantity of product p exported and d_p^c denotes the specific demand of water for each product (physical water intensity) in the exporting country. We will distinguish between green and blue virtual water flows, depending on whether d_p^c represents green or blue water content.

Similarly, the virtual water content of the imports for country c can be calculated as the sum of the virtual water content of the p imported goods coming from the different z countries of origin of imports.

$$VWM(c,t) = \sum_p d_p^Z(z,p,t) * m_p^Z(z,p,t) \qquad (2)$$

with d_p^Z being the physical water intensity (m3/Tm) in country z for product p, and m_p^Z the imports (Tm) of product p coming from country z. As consequence, the virtual water trade balance for a country can be defined as:

$$VWB(c,t) = VWX(c,t) - VWM(c,t) \qquad (3)$$

These physical water flows and their evolution can be seen regarded from the perspective of their relationship to economic growth and, more specifically, to the evolution of the agricultural and food trade.

The expressions above are calculated for blue and green water. Once we have obtained the virtual water flows and balances, we proceed with the analysis of the underlying economic drivers. This consists of two steps. First, virtual water exports and imports are expressed in terms of economic trade flows, more specifically comparing the contributions of size, product, and country of origin to the changes observed in the economic and water flows. Second, in order to analytically study trends in virtual water flows and disentangle the forces contributing to this trend, a form of Structural Decomposition Analysis (SDA) is applied.

From the expressions above, water exports and water imports can be expressed, in general terms, as dependent on three kinds of factor: water intensities, trade composition, and trade scale. More specifically, Spanish virtual water exports can be expressed as:

$$VWX(c,t) = \sum_p w_{cpt} \cdot \left(\frac{e_{cpt}}{e_{ct}}\right) e_{ct} \qquad (4)$$

This can be expressed in matrix form as:

$$VWX(c,t) = w_{ct}^{'} \hat{E}_{ct} e_{ct} \qquad (5)$$

where w'_{ct} is a vector including the virtual water content of each product in Spain, measured in m³/peseta; that is to say, the water intensity , $\hat{E}_{ct}$ is a diagonal matrix of the share of each product in total Spanish exports in period t, and e_{ct} is a scalar containing the total value of the Spanish exports in year t (in pesetas)

The decomposition of virtual water imports can be expressed as follows:

$$VWM(c,t) = \sum_{p,z} w_{cpzt} \cdot \frac{m_{cpzt}}{m_{cpt}} \cdot \frac{m_{cpt}}{m_{ct}} m_{ct} \ (6)$$

or, in matrix form,

$$VWM(c,t) = w'_{czt} M_{czt} \widehat{M}_{ct} m_{ct} \qquad\qquad (7)$$

in which w'_{czt} is a vector of the virtual water content for each product in the country of origin z measured in m³/peseta; i.e., the water intensity, M_{czt} is a matrix with information about the share that each country z represents in Spanish imports of each product, $\widehat{M}_{ct}$ is a diagonal matrix of the share of each product in total Spanish imports, and m_{ct} is a scalar representing the total value of Spanish imports in year t (in pesetas)

Changes in the trade components would imply changes in the volume of virtual water exports and imports and, consequently, changes in the country's water balance. From the empirical point of view, two assumptions must be introduced due to the lack of information for the period analysed. Firstly, water intensities per product are assumed to be constant over time. This is a strong assumption, since water intensities depend on geographical and physical conditions that could have changed from the middle of the last century until today. We examine the potential uncertainty associated with this assumption in Appendix 1, analysing the evolution of the main climatic characteristics in Spain over time. This analysis, in the absence of other information, gives us some confidence that no significant bias in the results has been introduced. Second, when dealing with historical trade data, we find one or more significant commercial partners for each product. Thus, when working with imports, we have chosen the specific water coefficient of the country with the largest volume in Spanish imports; otherwise, in those cases where several countries show a noteworthy weight in Spanish imports, we have computed a simple average of water coefficients in each of these nations.

Applying the former assumptions yields:

$$VWX(c,t) = w'_c \hat{E}_{ct} e_{ct} \qquad\qquad (8)$$

$$VWM(c,t) = w'_{cz} \widehat{M}_{ct} m_{ct} \qquad\qquad (9)$$

SDA has been applied to equations (8) and (9), to synthesize the driving forces responsible for virtual water exports and virtual water imports, respectively. This approach attempts to separate a time trend of an aggregated variable into a group of driving forces that can act as accelerators or retardants (Dietzenbacher and Los 1998; Hoekstra and van der Berg 2002; Lenzen et al. 2001).

Generally speaking, considering a variable y depending on n explicative factors $y=f(x_1,\dots x_n)$, additive structural decomposition can be obtained through its total differential.

$$dy = \frac{\partial y}{\partial x_1}dx_1 + \frac{\partial y}{\partial x_2}dx_2 + \cdots + \frac{\partial y}{\partial x_n}dx_n \qquad (10)$$

On the basis of a multiplicative relationship, that is $y=x_1\dots x_n$, expression (10) holds:

$$dy = (x_2 x_3 \dots x_n)dx_1 + \cdots + (x_1 x_2 x_3 \dots x_{n-1})dx_n = \sum_{i=1}^{n}\left(\prod_{j=1} x_j\, dx_j\right) \ (11)$$

In a discrete schema, when we attempt to measure the changes in the dependent variable between two periods, $t-1$ and t, we can solve the expression by way of exact decompositions, which lead to the well-known problem of the non-uniqueness of the SDA solution. In our case, if decomposition is based on two factors, we obtain the following 2 exact decompositions. In practice, the average of these two decompositions has been considered to calculate the contribution of the different factors. Thus, the two polar decompositions of (8) can be written as follows:

$$\Delta VWX(c) = w_c'\left[\Delta\hat{E}_c e_{ct} + \hat{E}_{ct-1}\Delta e_c\right] \qquad (12)$$

$$\Delta VWX(c) = w_c'\left[\Delta\hat{E}_c e_{ct-1} + \hat{E}_{ct}\Delta e_c\right] \qquad (13)$$

Furthermore, based on (7) we obtain its two exact decompositions, which yields:

$$\Delta VWM(c) = w_{cz}'\left[\Delta\hat{M}_c m_{ct} + \hat{M}_{ct-1}\Delta m_c\right] \qquad (14)$$

$$\Delta VWM(c) = w_{cz}'\left[\Delta\hat{M}_c m_{ct-1} + \hat{M}_{ct}\Delta m_c\right] \qquad (15)$$

Taking the average of (12) and (13) we obtain (16):

$$\Delta VWX(c) = w_c'\left[\frac{\Delta\hat{E}_c e_{ct} + \Delta\hat{E}_c e_{ct-1}}{2} + \frac{\hat{E}_{ct-1}\Delta e_c + \hat{E}_{ct}\Delta e_c}{2}\right]$$

Proceeding the same way with (14) and (15) gives equation (17)

$$\Delta VWM(c) = w_c' \left[\frac{\Delta \widehat{M}_c m_{ct} + \Delta \widehat{M}_c m_{ct-1}}{2} + \frac{\widehat{M}_{ct-1} \Delta m_c + \widehat{M}_{ct} \Delta m_c}{2} \right]$$

As a result, trends in virtual water flows can be explained by:

- Scale effect: links changes in virtual water flows to changes in the volume of trade and can be expressed by (18) for exports and (19) for imports:

$$SE_e = w_c' \left[\frac{\widehat{E}_{ct-1} \Delta e_c + \widehat{E}_{ct} \Delta e_c}{2} \right]$$

$$SE_m = w_{cz}' \left[\frac{\widehat{M}_{ct-1} \Delta m_c + \widehat{M}_{ct} \Delta m_c}{2} \right]$$

- Composition effect: explains changes in water virtual flows depending on changes in the share of products in trade. It is given by (20) for exports and (21) for imports

$$CE_e = w_c' \left[\frac{\Delta \widehat{E}_c e_{ct} + \Delta \widehat{E}_c e_{ct-1}}{2} \right]$$

$$CE_m = w_{cz}' \left[\frac{\Delta \widehat{M}_c m_{ct} + \Delta \widehat{M}_c m_{ct-1}}{2} \right]$$

3.2. Data

Spanish data for agri-food trade during the period 1849-1935 come from the Foreign Trade Statistics of Spain (1849-1935). Use has been made of the data for trade by volume, extracted by Gallego and Pinilla (1996), for all agricultural products and food in those years. We work with a sample of 148 products for exports and 118 products for imports, over the years 1849 to 1935. This sample accounts, on average, for approximately 90% of total Spanish agricultural trade. Crops used as livestock feed are not considered, to avoid double accounting. When applying the structural decomposition analysis, data on trade value measured in constant pesetas are needed, and we obtain the price of each product in a certain year (1910) from the Foreign Trade Statistics of Spain (1849-1935). Then, this price will be applied to the traded quantity of each product in each year, obtaining trade value in constant prices.

Data for specific water demands for crops, or derived crop products (by individual countries), have been taken from Mekonnen and Hoekstra (2011), while water coefficients for farm animals and

animal products come from Mekonnen and Hoekstra (2012), being average coefficients for the period 1996-2005. These coefficients compute water volumes per physical unit of production.

4. Results

In order to better organize the results, this section is divided into two subsections: the analysis of virtual water trade flows (section 4.1) and the quantification of the factors that entail changes in virtual water trade (section 4.2).

4.1. Analysis of virtual water trade flows

On the whole, virtual water exports and virtual water imports display a rising pattern throughout the period 1849-1935 (Figure 1), green water being much larger than blue water in both (80% for exports and 90% for imports on average).

Insert Figure 1

Virtual water exports grew at an annual average rate of 1.9%, from around 500 Hm3/year in 1850 to more than 3,000 Hm3/year before the Spanish Civil War. Nevertheless, this growth was not homogeneous over the period considered. Looking at Figure 1, a growing trend in virtual water exports is found, with an annual growth of 2.9% until 1903, and a smooth deceleration from then on, increasing at 1.9% annually. However, virtual water exports clearly plunge from 1929 onwards, decreasing at 4.1% annually, as the consequence of the contraction of trade caused by the Great Depression. Virtual water imports also display a rising trajectory that seems to be particularly flat during the first two decades, while the Spanish economy was tightly closed to the entry of goods from abroad; but from then on this trajectory tended to rise at an annual rate of 2.3% until 1929. From then, virtual water imports decreased by 1.2% annually, a less intense fall that the one seen for Spanish exports.

Figure 2 shows blue virtual water flows, both exports and imports, expanded at a similar pace until 1905. However, whereas virtual water imports grew by 0.5% from 1905 to 1935, virtual water exports rose sharply, at 2.8% annually, until 1929, when they plunged by 5.9% annually.

Insert Figure 2

Insert Figure 3

Spain appears as a net exporter of blue water from 1862, with the exception of two particular years, 1894 and 1906. In this case, the trend is evident: Spanish blue virtual water exports tend to increase throughout the period, chiefly from 1906 to 1930. The largest net exports of blue water are found from 1916 to 1931. These data reflect the strong growth of exports of Mediterranean horticultural products that took place from the end of the 19th century onwards.

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The green water balance (figure 3) followed nearly the same path as the global one, since it notably contributes to total virtual water. That is to say, Spanish net imports of green virtual water continued to grow until 1906, but this trend reversed from then on.

Insert Table 1

A view of the evolution of virtual water trade by agri-food products is summarised in Tables 1, and 2, which respectively present the average share of virtual green and blue water exports and imports of agricultural and food products, and their growth rates, for the 16 groups which comprise it.

Looking at Table 1, it can be observed that, throughout the period, three groups of products constituted approximately 60% of the exports of virtual green water: olive oil, wine, and fruit and vegetables. Until 1891, the importance of wine grew, and following the end of the golden era of exports to France declined continually. In parallel, fruits and vegetables occupied a key position, initially as a consequence of the great importance of nut exports, and from 1891 onwards due to the strong growth of fresh fruits and vegetables. Olive oil was always important but after 1914, following an improvement in the refining of oil that gave low quality oil a mild taste adequate for food consumption, its weight increased still further (Zambrana, 1985). Finally, two types of products that were initially important, cereals and live animals, declined sharply, once the exports of wheat to Cuba disappeared following the Spanish-American War and the last colonies were lost; the exports of cattle to Great Britain also fell drastically.

In the case of virtual blue water, fruit and fresh vegetables were always the most important products in this group. Initially, products such as nuts, raisins, and table grapes were the most important within this group, but from the final decades of the 19th century onwards, it was above all fresh fruits and vegetables that were predominant. This group consists of 46 products, so it is worth searching for its most representative items. During the first decades, hazelnuts, almonds, and raisins were the most significant products, but from 1880 onwards oranges became the most important, with percentages of around 25% of total virtual water exports of fruits and vegetables. The importance of exports of olive oil and wine explains the significant contribution of the product groups included in virtual blue water exports[2]. The last important group is that of cereals, initially, as a consequence of the importance of the above-mentioned exports of wheat to Cuba, and from the end of the 19th century, due to the growth of exports of rice, a crop with high blue water content.

Insert Table 2

Table 2 shows average shares of Spanish virtual water imports. In this case, the compositional change seems to be less sharp than that seen for exports. In the first place, coffee and cocoa were

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[2] These crops can be grown under arid conditions pretty well, but traditionally occupied important areas of irrigation, to ensure high and reliable yields.

the main drivers of Spanish virtual green water imports. The other plantation product, sugar, notably decreased its contribution to virtual green water imports over the period of study. The high tariffs placed on sugar from abroad, following the loss of Cuba and Puerto Rico in 1898, made imports marginal. Textile fibres also made an important contribution to green water imports, with cotton, an essential raw material for the growing textile industry, being the most representative fibre. Virtual green water imports due to cereals were quite variable. The oscillations of tariff policies regarding wheat, which were prohibitionist between 1820 and 1869, subsequently liberal, and protectionist after 1891 (although there were significant imports in years of poor national production), form part of the explanation (Gallego, 2003 and 2004). Furthermore, it must be taken into account that considerable imports of maize took place following the First World War, to feed livestock. In the case of virtual blue water imports, cotton - almost alone - accounts for approximately two thirds of such imports throughout the period. Without the key role of cotton, imports of this type of virtual water products would have been drastically reduced.

4.2. Decomposition analysis of virtual water trade flows

After identifying virtual water trade trends and composition patterns, we proceed to quantify the forces that could have driven the increase in virtual water flows in the long term. Following the Structural Decomposition Analysis (SDA) approach, virtual water flows are decomposed into two components, showing the effects of trade growth and composition changes. The results are presented in Tables 3 and 4.

First, we examine the average contribution of the effects from 1850 to 1930. Then we study the four different sub-periods into which we have divided our sample, corresponding to four singular stages of historical Spanish trade flows (1850-1869, 1870-1890, 1891-1914 and 1915-1930). Due to the high volatility of trade data, we take a three-year average of each reference period, and subsequently we apply SDA.

Insert table 3

As shown above, virtual water exports (table 3) rose by 3,097 Hm^3 from 1849 to 1930, the growth in volume of Spanish trade was responsible for 78% of this increase; only 22% was due to changes in the composition of trade towards products with a higher content of virtual water.

Exports of virtual blue water grew by 668 Hm^3 during these years; however, the share of the composition effect is slightly higher, reaching 23.5%, indicating that despite Spanish agricultural exports moving towards intensive products, especially Mediterranean horticultural products, with a higher content of blue water, the scale effect was dominant. An examination of the different sub-periods shows that the scale effect was in fact negative in the period from 1891-1914. Although the volume of trade fell, blue virtual water exports increased because of the re-orientation of Spanish

exports towards water intensive products. Subsequently, the strong export boom in Mediterranean horticultural products meant that the scale effect was more important once more, although the composition effect again made an important contribution. In the case of virtual green water exports, the scale effect was more important.

On the other hand, virtual water imports (table 3) showed an increase of 1,873 Hm³ during the period 1849-1930. Changes in both blue and green virtual water imports were determined by the vast growth of Spanish purchases of agricultural and food products from the rest of the world. Thus, as we highlighted in Section 4.1., on average the composition effect had a negligible effect on virtual water imports over these years.

5. Understanding virtual water trade

From our perspective, the most important challenge is to examine the consequences of the evolution of foreign trade in virtual water. The expansion of exports and the substitution of certain imports due to protectionist policies involved various requirements in the supply of blue water to the different crops. At the same time, agricultural imports saved as much green water as blue. Although from Spain's perspective the type of water incorporated in imports is not important, it is interesting to keep in mind that those imports meant less water requirements and in a semi-arid country like Spain, they could have reduced the need to increase irrigation is reduced.

In a hypothetical country with an unlimited supply of irrigation water at zero cost, we could say that the evolution of the need for blue water would have no economic consequences, beyond those produced by foreign trade itself, upon national income. However, the obtaining of water for irrigation requires heavy capital investments and the results of these investments may on occasion be uncertain. In addition, the increase in irrigation has had a deep impact on the natural environment.

The balance of green water is also of a certain interest and the use of this water is not completely independent of that of blue water. Although it can be considered that exports of green water do not have significant consequences in terms of consumption (the argument being that substituting exports of crops for 'natural vegetation' could produce even greater consumption of green water and therefore less availability of blue water[3]), the consequences will depend on the specifics of the land use (Fader et al., 2011).

Insert table 4

The first question to be answered is to what extent the expansion of irrigation in Spain was

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[3]This probably occurred, for example, in the Ebro basin in the second half of the 20th century, since the growing needs of new vegetation, as a consequence of the decline in agriculture and forestry in some areas, due to depopulation processes, had allowed a sort of 'sponge' to develop, absorbing a considerable part of the rainfall and affecting the volume of water available in water courses (Bielsa et al., 2011),

conditioned by the foreign sector. The answer lies in estimating what part of the growth in blue water use by Spanish agriculture between 1860 and 1930 was due to the foreign sector. As can be seen in table 4, the virtual exports of blue water represented an elevated percentage of water built into Spanish agricultural production (from a minimum of 8.7% in 1860 to a maximum of 21.9% in 1930). As we have seen in previous sections, virtual imports of blue water were lower than exports, beginning in the mid-1860s. The increase in agricultural production between these two dates was substantial, and consequently the need for blue water increased by approximately 2,701 cubic hectometres (64% of this increase took place during the twentieth century (see table 4)). Throughout these years, approximately 28% of this increase was a direct consequence of the increase in exports of agricultural products and food (see appendix 2 for more detail on production data sources).If we keep in mind the savings of blue water from imports, the result is that the net balance in virtual blue water in the Spanish foreign trade of agricultural products and food meant a 21% increase in the need for blue water in agriculture between 1860 and 1930 (a 23% increase between 1860 and 1900, and 19.9% between 1900 and 1930). It is reasonable to conclude, therefore, that the growing incorporation of Spain in international markets as a major exporter of Mediterranean products, substantially increased the pressure on water resources, and the necessity to expand irrigation. This increase was a very important topic in public and political debate during that period, and had a significant effect on agricultural production (Pinilla, 2005). It also meant that, from the end of the 19th century, there was a growing intervention by the public sector to increase the amount of irrigated land, which required increased public and private investment.[4].

A fundamental difference is that the percentage represented by virtual exports and imports incorporated in total agricultural production in the case of green water, was much less than that of blue water. The impact of foreign trade was therefore less. In addition, the net balance of green water derived from foreign trade does not show a clear trend. Graphic 2 shows that exports and imports grew in parallel, and alternated positive and negative balances. In the large increase of green water in Spanish agricultural production, foreign trade had a modest contribution that was less than 7% in the period between 1860-1939.

6. Conclusions

The volume of water embodied in agricultural products exchanged through international trade experienced a great increase from 1849 to 1935, a period of intense development in the Spanish foreign sector. Despite the sensitivity of trade to global historical events, such as the Great Depression of 1929 and the successive political changes in Spain, exports and imports tended to grow vigorously during these years. In spite of standing out as a net exporter of blue water resources, Spain appears to have been a net importer of green virtual water, although this pattern is

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[4]The investment in hydro-infrastructure of all kinds (not only for irrigation) increased by approximately a factor of 10 between 1860 and 1930 (Herranz, 2004: 129-132).

not very clear and quite variable. The increase in the volume of exports was an essential factor of the growing trend observed for virtual water flows; however, compositional change towards growing exports of Mediterranean horticultural products, highly intensive in water, also meant a significant rise of both green and blue virtual water exports. The rise of imports was triggered by the scale effect, since cereals, cotton, coffee, and cocoa were always dominant, and compositional change does not appear to lead to greater increases in virtual water imports.

These facts involved noteworthy impacts on domestic water resources. It is true that a certain volume of water (green and blue) could be saved through the increase in imports; nevertheless, it seems quite clear that the expansion of exports, together with a notable substitution of imports during protectionist periods, entailed growing demand for water. Thus, from 1860 to 1930, about 21% of the rise of water requirements was due to the increase in exports, with exports of blue water representing 16.5% of production-embodied water on average. The contribution of trade development on green water was less significant. Accordingly, the expansion of the Spanish foreign sector during the first globalization had a significant impact on domestic agricultural production systems, and consequently strong pressure on water, an essential input for the development of this strategic industry. In this framework, irrigation played a key role, since without its broad development during these years, this expansion of trade would not have been possible.

Acknowledgements

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Figure 1: Total virtual water flows (1849-1935) Hm³/year.
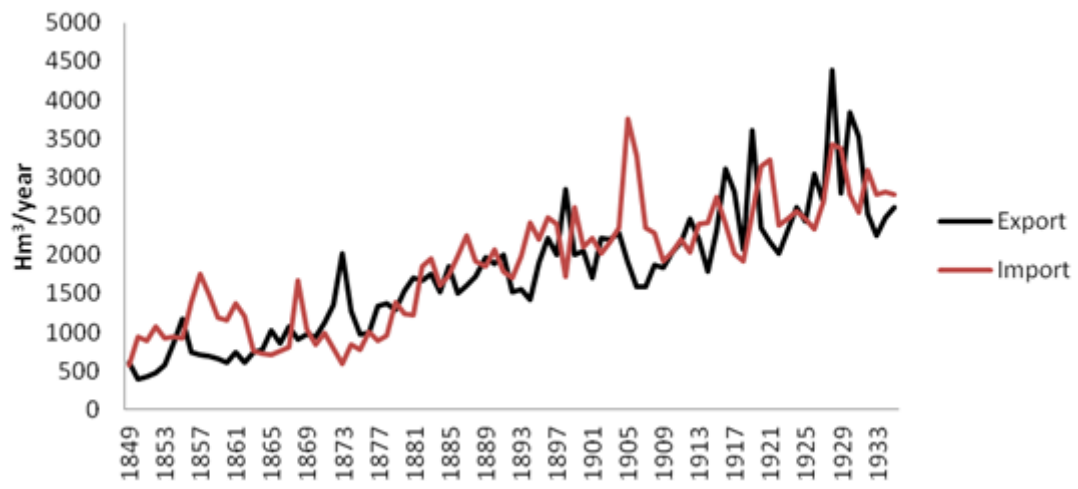
Source: own elaboration based on foreign trade Statics of Spain extracted by Gallego and Pinilla (1996). Sum of green and blue water flows.

Figure 2: Blue virtual water flows (1849-1935) Hm³/year.
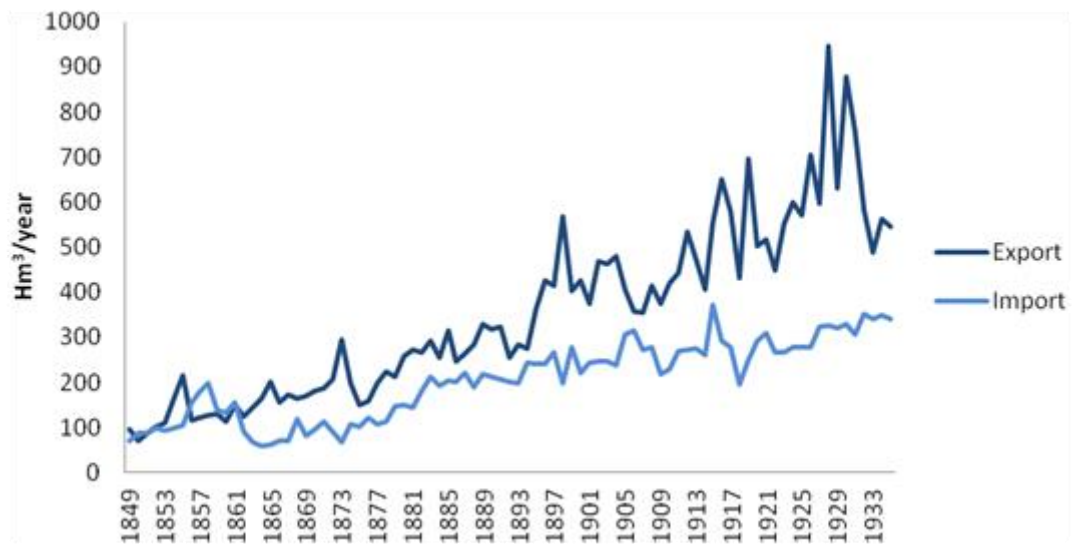
Source: own elaboration based on foreign trade Statics of Spain extracted by Gallego and Pinilla (1996).

Figure3: Green virtual water flows (1849-1935) Hm^3/year.

Source: own elaboration based on foreign trade Statics of Spain extracted by Gallego and Pinilla (1996).

Table 1: Green and blue virtual water exports by group of products (average share %)

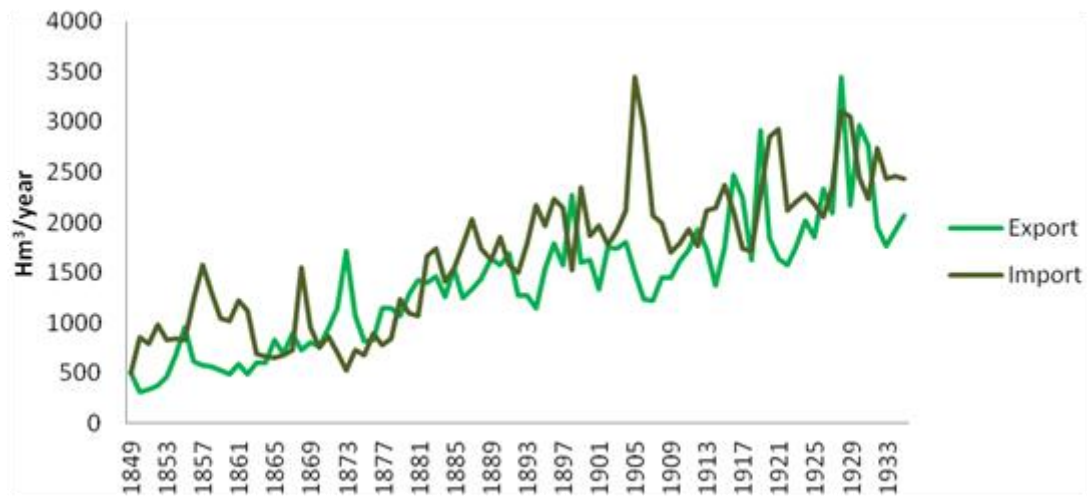|	1850-1870	1871-1890	1891-1914	1915-1929	1930-1935	1850-1870	1871-1890	1891-1914	1915-1929	1930-1935
					Green VWX					Blue VWX
00. Live animals	8.4	11.7	17.6	2.5	2.5	5.8	9.2	18.1	2.3	2.4
04. Cereals and preparations	14.7	8.6	2.3	3.3	3.0	22.7	5.9	5.7	13.9	13.3
22. Oilseeds	0.1	0.0	0.1	1.0	1.0	0.3	0.0	0.3	2.4	2.4
26. Textile fibres	0.0	0.0	0.1	0.1	0.1	0.4	0.3	0.4	1.0	0.8
TOTAL BULK PRODUCTS	23.2	20.4	20.1	6.8	6.6	29.1	15.4	24.4	19.7	18.9
06. Sugar	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.1	0.2	0.2
07.Coffee, tea, cocoa, and spices	3.3	0.6	0.5	1.3	1.2	1.7	2.3	2.5	2.2	2.2
TOTAL PLANTATION PRODUCTS	3.4	0.6	0.5	1.3	1.2	1.9	2.3	2.7	2.5	2.4
01. Meat	0.5	0.1	0.2	0.4	0.4	0.3	0.1	0.1	0.2	0.2
02. Dairy products and eggs	0.2	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0
05. Fruits and vegetables	30.6	24.5	34.1	38.0	37.8	30.5	27.6	35.5	36.4	36.6
08. Animal feed	1.7	1.6	0.5	0.2	0.2	0.3	0.4	0.1	0.0	0.0
11. Beverages	17.5	34.5	21.6	16.2	16.4	13.7	31.7	16.1	10.4	10.5
12. Tobacco	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
21. Leather and hides	0.5	1.2	1.9	3.0	3.8	0.3	1.1	1.6	1.8	2.5
41. Animal fats	0.3	0.5	0.5	0.6	0.6	0.2	0.4	0.3	0.3	0.3
42. Vegetable oils	22.1	16.5	20.6	33.3	33.2	23.5	20.8	19.2	28.7	28.7
TOTAL HIGH VALUE PRODUCTS	73.4	79.1	79.4	91.9	92.2	69.0	82.3	73.0	77.9	78.7
TOTAL	8.4	11.7	17.6	2.5	2.5	5.8	9.2	18.1	2.3	2.4

Source: own elaboration based on foreign trade Statics of Spain extracted by Gallego and Pinilla (1996).

Table2: Green and blue virtual water imports by group of products (average share %)

	1850-1870	1871-1890	1891-1914	1915-1929	1930-1935	1850-1870	1871-1890	1891-1914	1915-1929	1930-1935
					Green VWM					Blue VWM
00. Live animals	13.8	11.6	19.5	4.3	4.5	*7.3*	*7.5*	*10.8*	*2.2*	*2.3*
04. Cereals and preparations	8.7	20.2	25.8	24.3	22.3	6.8	13.4	11.2	8.2	7.6
22. Oilseeds	0	0	0	4.3	5	0	0	0	2.2	2.6
26. Textile fibres	17.2	18.6	20	19.9	19.3	64	58.5	62.5	61.1	59.9
TOTAL BULK PRODUCTS	39.7	50.4	65.3	52.8	51.1	78.1	79.4	84.6	73.8	72.4
06. Sugar	12	10.3	2.3	2.3	2.3	15.8	11.3	2.6	2.9	2.9
07.Coffee, tea, cocoa, and spices	42.9	27.1	21.5	33.4	34.3	4.6	4.6	6.5	12.1	12.5
TOTAL PLANTATION PRODUCTS	54.9	37.4	23.8	35.7	36.6	20.4	16	9.1	15	15.4
01. Meat	0.1	1.2	0.5	0.6	0.6	0.1	1.2	0.6	0.6	0.6
02. Dairy products and eggs	0.1	0.6	1.2	2.7	3.2	0.2	0.8	1.9	5.3	6.1
05. Fruits and vegetables	1.1	2.4	2.4	2.9	3.2	0.4	0.5	0.6	3.2	3.4
08. Animal feed	0	0.3	0.7	1	1.1	0	0.2	0.4	0.7	0.7
11. Beverages	0.4	1.5	0.1	0	0	0	0.1	0	0	0
12. Tobacco	2.8	3.5	2.5	2.5	2.6	0	0	0	0	0
21. Leather and hides	0	0.2	0.3	0.3	0.3	0	0.1	0.1	0.1	0.1
41. Animal fats	0.7	1.8	2.8	1.3	1.3	0.7	1.6	2.6	1.3	1.3
42. Vegetable oils	0.1	0.5	0.3	0.1	0.1	0	0.1	0.1	0	0
TOTAL HIGH VALUE PRODUCTS	5.4	12.2	10.9	11.5	12.3	1.4	4.6	6.3	11.2	12.2
TOTAL	13.8	11.6	19.5	4.3	4.5	*7.3*	*7.5*	*10.8*	*2.2*	*2.3*

Source: own elaboration based on foreign trade Statics of Spain extracted by Gallego and Pinilla (1996).

Table 3: Decomposition analysis of virtual water exports and imports

	Effects	1850-1869	1870-1890	1891-1914	1915-1930	1849-1930
Green VWX	**composition (%)**	46.3	-41.5	362.4	34.0	21.7
	scale (%)	53.7	141.5	-262.4	66.0	78.3
	Δ VWX (Hm3)	429.5	922.5	70.1	1,006.9	2,428.9
Blue VWX	**composition (%)**	39.1	-100.1	120.6	3.6	23.5
	scale (%)	60.9	200.1	-20.6	96.4	76.5
	Δ VWX (Hm3)	93.6	141.9	230.6	201.7	667.7
Total VWX	**composition (%)**	45.0	-49.3	176.9	29.0	22.1
	scale (%)	55.0	149.3	-76.9	71.0	77.9
	Δ VWX (Hm3)	523.0	1,064.4	300.7	1,208.6	3,096.7
Green VWM	**composition (%)**	531.6	-19.9	28.0	-23.2	-30.1
	scale (%)	-431.6	119.9	72.0	123.2	130.1
	Δ VWM (Hm3)	-42.17	859.2	974.6	-140.2	1,651.4
Blue VWM	**composition (%)**	-264.6	-14.5	41.9	64.0	-14.4
	scale (%)	364.6	114.5	58.1	36.0	114.4
	Δ VWM (Hm3)	5.86	114.6	166.7	-65.4	221.8
Total VWM	**composition (%)**	660.2	-19.3	30.1	4.6	-28.2
	scale (%)	-560.2	119.3	69.9	95.4	128.2
	Δ VWM (Hm3)	-36.3	973.9	1,141.2	-205.6	1,873.2

Source: own elaboration based on foreign trade Statics of Spain extracted by Gallego and Pinilla (1996).

Table 4: Comparison of blue water embodied in exports and production (Hm^3)

	EWP	VWX	VWM	External Balance	VWX/ EWP	VWM/ EWP	Ext.Bal./ EWP
Green water							
1860	14,710	494	1,017	-523	3.4	6.9	-3.6
1900	20,608	1,631	1,871	-241	7.9	9.1	-1.2
1930	30,187	2,965	2,449	515	9.8	8.1	1.7
Blue water							
1860	1,299	113	133	-20	8.7	10.2	-1.5
1900	2,276	427	222	205	18.7	9.7	9.0
1930	4,000	878	330	548	21.9	8.3	13.7
	Δ EWP	ΔVWX	ΔVWM	ΔExternal Balance	ΔVWX/Δ EWP	ΔVWM/Δ EWP	ΔExt.Bal./Δ EWP
Green water							
1860-1900	5,898	1,136	855	282	19.3	14.5	4.8
1900-1930	9,579	1,334	578	756	13.9	6.0	7.9
1860-1930	15,477	2,470	1,433	1,038	16	9.3	6.7
Blue water							
1860-1900	977	314	88	225	32.1	9.1	23.0
1900-1930	1,724	451	109	342	26.2	6.3	19.9
1860-1930	2,701	765	197	567	28.3	7.3	21.0

Source: own elaboration based on foreign trade Statics of Spain extracted by Gallego and Pinilla (1996) and agricultural production data (see appendix 2).

EWP: Embodied water in production, VWX: Virtual water exports, VWM: Virtual water imports, External Balance: VWX-VWM

Appendix 1: Uncertainty

A final consideration should be about the necessary caution in the interpretation of our results. One of the main drawbacks of this study lies in the assumption of water demand coefficients being constant for the period studied. The data, taken from Mekonnen and Hoekstra (2011a, 2011b), provide information about the average volume of water required per crop, from 1996 to 2005. Although the main focus of this paper is to examine long term trends in virtual water, an analysis of the impact of the assumption that water coefficients at the end of the 20th century can be applicable to the 19th century, is now in order.

As we previously said, Mekonnen and Hoekstra (2011a, 2011b) obtain water demand coefficients following Allen et al. (1998), who consider that evapotranspiration (crop water use) under non-optimal conditions depends on climatic parameters, crop characteristics and management, and environmental conditions. Whereas crop parameters are assumed to be static (Allen et al., 1998), climatic variables and management practices have clearly changed over time. For that reason, in the following we will examine temporal series for some of the variables for which long-term data can be found.

First, if we look at figure 4, displaying data on average precipitations in Spain, from Carreras (2005), it is possible to say that precipitation seems to be, generally, quite stable from 1852 to today. However, due to the strong variability of this data, there is currently no clear evidence about trends in precipitations (Barriendos and Rodrigo, 2005; Pauling et al., 2006).

**Figure 4: Average annual precipitations in Spain (mm).**
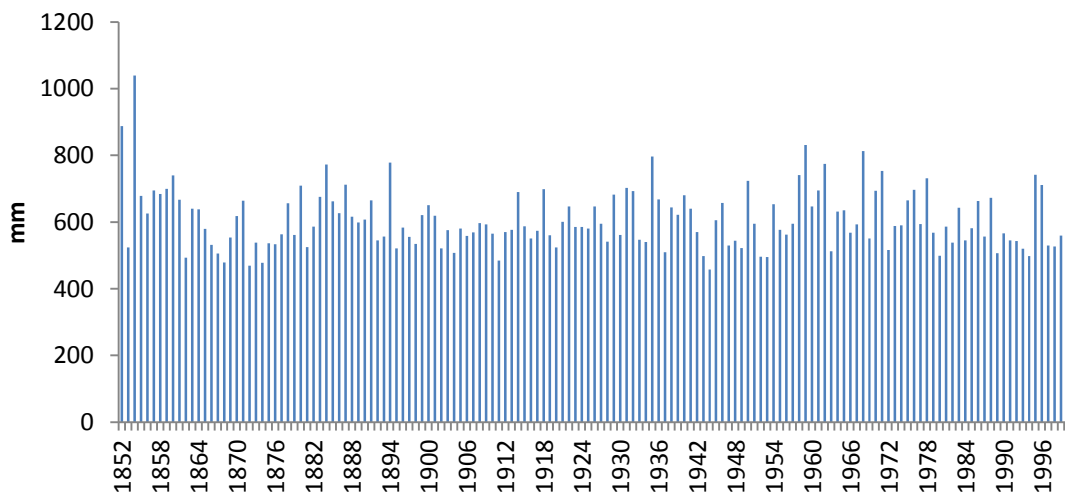
Source: own elaboration from Carreras (2005).

On the contrary, most researchers of climate history appear to agree about the rise in global temperatures (Guiot et al., 2010; Brunet et al., 2006), as illustrated in Figure 5 showing the

trajectory followed by adjusted annual variations (1850–2003) of daily maximum and minimum temperature records.

Figure 5: Adjusted annual variations (1850–2003) of daily maximum and minimum temperature records in Spain.
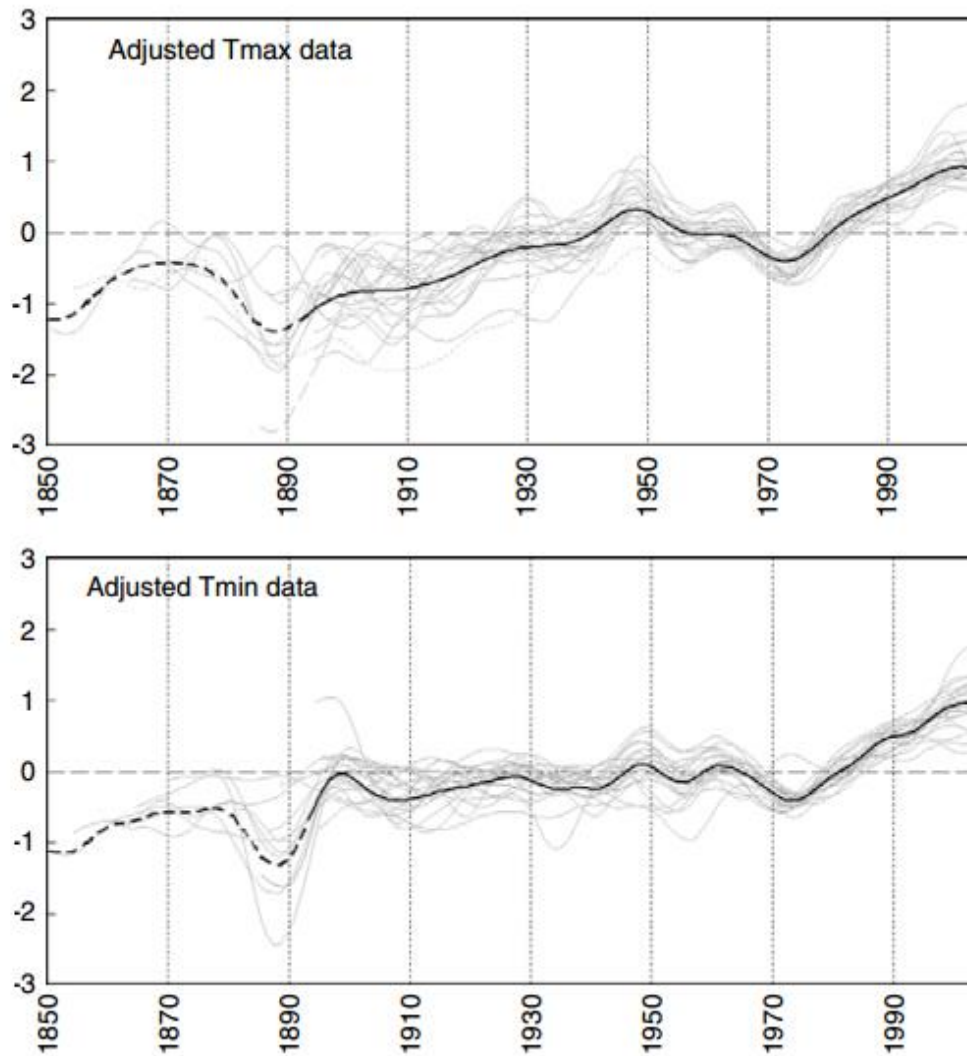
Source: Brunet et al. (2006)

According to Allen (1998), management and environmental conditions such as soil salinity, land fertility, application of fertilizers, hard or impenetrable soil horizons, control of diseases and pests, and soil management all have a direct influence on crop development affecting evapotranspiration. In this regard, figure 6 depicts the evolution of the consumption of fertilizer that experienced a clear growth from the beginning of the twentieth century.

Figure 6: Total consumption of fertilizers in Spain (Tm).
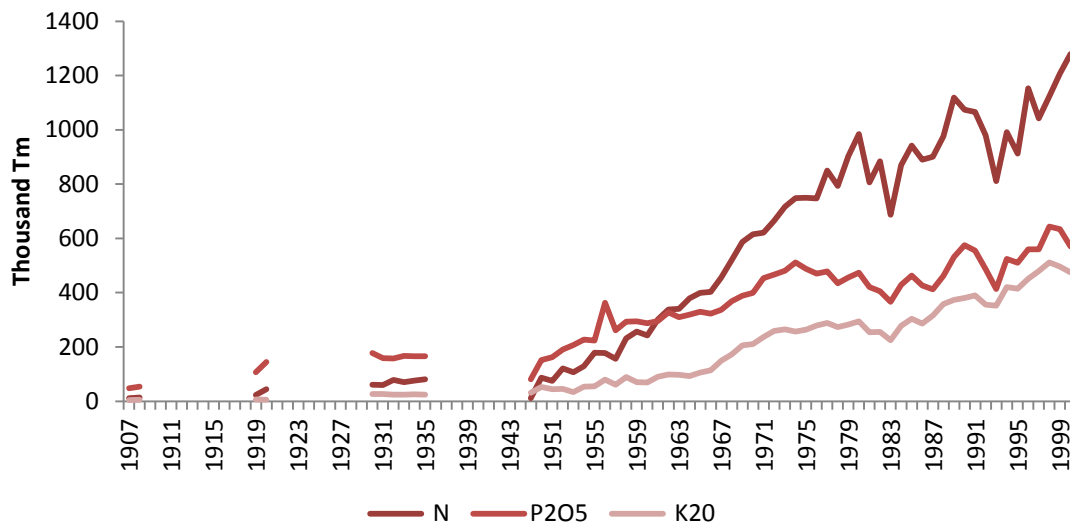
Source: own elaboration from Barciela et al. (2005)

We can find many variables affecting crop water use in different ways, but it is impossible to find a long-term series that helps us to determine their global effect on evapotranspiration throughout the period of study.

For that reason, facing the impossibility of proceeding with an accurate reconstruction of crop water requirements, we looked for an alternative time series dataset for long-term evapotranspiration in Spain. In the 20th century, we find historical data about real and potential evapotranspiration for the period 1940-2010. According to MAGRAMA (2013),potential evapotranspiration(ETP), highly dependent on temperature, is the evapotranspiration produced with soil moisture and vegetation under optimal conditions. Its mean reaches 1,041 mm, showing its highest values in the south of Spain, the Ebro Valley, and the Canary Islands. Moreover, real evapotranspiration (ETR) is that which actually takes place under existing conditions. In Spain, it reaches an average of 453.65 mm, notably below ETP because optimal soil humidity conditions are not fulfilled. Since ETR is the actual volume of water required by crops, we carry out an econometric analysis of this time series to determine whether keeping its magnitude fixed in time could be justified. As a first step, we will look at the time series graph that seems to have no tendency and fluctuates around its mean, that is, at first sight it seems to be stationary in the mean.

Figure 7: Real Evapotranspiration in Spain (mm).
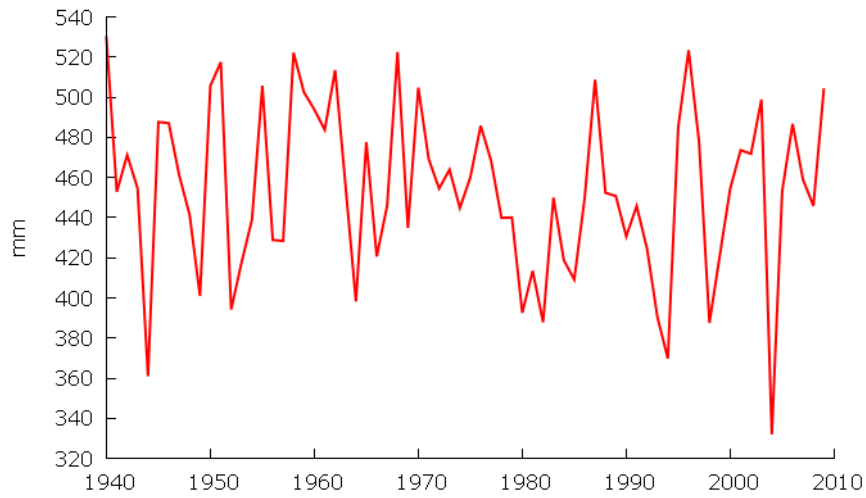
It is also necessary to carry out a range-mean analysis to check whether the series is stationary in variance. We find that the slope of the range with respect to the mean equals -0.27, with a p-value of the test p=0.77, which leads to the non-rejection of the null hypothesis of the slope=0, concluding that the series is also stationary in variance. Moreover, if we look at the correlogram of real evapotranspiration, it again points to a stationary series. Finally, to have strong evidence towards the stationary character of real evapotranspiration we carry out the KPSS test, which yields a statistic of 0.074, not rejecting the null hypothesis of stationary at the 1% significance level.

Figure 8: ETR correlogram

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.104	0.104	0.7836	0.376
		2	-0.175	-0.187	3.0464	0.218
		3	-0.038	0.003	3.1548	0.368
		4	-0.003	-0.033	3.1556	0.532
		5	0.134	0.138	4.5517	0.473
		6	-0.128	-0.179	5.8320	0.442
		7	-0.105	-0.016	6.7078	0.460
		8	0.150	0.124	8.5479	0.382
		9	0.069	0.018	8.9452	0.442
		10	0.110	0.130	9.9559	0.444
		11	-0.007	0.009	9.9602	0.534
		12	0.037	0.101	10.080	0.609
		13	0.033	-0.044	10.175	0.680
		14	-0.043	0.019	10.339	0.737
		15	0.058	0.069	10.645	0.777
		16	-0.042	-0.057	10.806	0.821
		17	0.032	0.072	10.905	0.861
		18	0.005	-0.059	10.908	0.898
		19	-0.012	0.034	10.922	0.926
		20	0.023	-0.061	10.975	0.947
		21	-0.067	-0.043	11.442	0.953
		22	-0.004	-0.013	11.443	0.968
		23	-0.058	-0.114	11.805	0.973
		24	-0.148	-0.126	14.192	0.942

Source: Own elaboration

In sum, real evapotranspiration appears to be stationary in the long term, providing us with some level of confidence in the hypothesis of constant water crop coefficients during the period studied.

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Appendix 2: Sources for the calculation of agricultural production, 1860-1930

In section 5 we examined the impact that the development of the foreign sector had on the use of water. To that end, it was necessary to have data on Spanish agricultural production for 1860, 1900, and 1930. On the whole, Spanish agricultural production data from official statistics come from Estadísticas Históricas de la Producción Agraria Española, 1859-1935 (GEHR, 1991). To reduce data volatility, we took triennial production averages whenever possible. Crops for livestock feed are not considered, to avoid double accounting.

Since Estadísticas Históricas de la Producción Agraria Española, 1859-1935 do not provide data for most products in 1860, we used alternative sources. Specifically, data for physical production of wheat, rye, barley, oats, corn, rice, chickpeas, broad beans, beans, potatoes, sweet potatoes, wine, olive oil, flax, hemp, almonds, chestnuts, oranges, lemons, raisins, figs, and olives have been taken from Bringas (2013), whose information is based on Navarro Faulo (1882). Data on sugar cane and sugar beet production were taken from Martín Rodriguez (1994).The remaining agricultural products were obtained assuming that per capita production in 1860 and 1900 were the same. Thus, Spanish production minus exports in 1900 was divided by population in that year, obtaining per capita production not exported. Subsequently, we multiply the former coefficient with the number of inhabitants in 1860 and, provided we have the information, we add exports in 1860 from foreign trade statistics of Spain. The next step involves estimating livestock production. Data on numbers of animals were taken from GEHR (1991), which collects data from the Censo de Ganadería (Livestock Census) of 1865. From that point, we have estimated meat production, keeping in mind the age and sex of different livestock species, the average life of the animals before slaughter, and the meat obtained from each animal, adult and young. To calculate the coefficients of conversion we have used the livestock census of 1932 and the data for animals in the slaughterhouse of Zaragoza between 1870 and 1935 (Pinilla, 1995b). We have taken the data for milk from Hernández Adell (2012). The problem with production data of crops in 1860 stems from a deep underestimation, as Bringas (2013) points out. Nevertheless the livestock production data appear

correct or, at worst, somewhat overestimated. In order to verify the quality of the data, we have compared the differences in the monetary value of production in our calculations from 1860, and from 1900. The result is disproportionate growth if we compare it with the growth of gross agricultural value added between 1860 and 1900 of Prados de la Escosura (2003). To correct our estimate from 1860, and following the main analyses (GEHR, 1978; 1979 and Bringas, 2013) we supposed that there exists a serious problem of underestimation in crop production of 1860, while data for animal production was correct. To correct this problem, we have re-scaled crop production to the corresponding value assuming that the data from Prados de la Escosura is good.

For those goods for which we have no information for 1900, we have assumed that their production followed a similar pattern to the nearest similar crop with available data. The following table provides information about the crops for which we have no data, the coefficients used, and the reference product or group of products used to obtain it. The main source is also given.

Table 5: Products with no data in 1900 and crops used to estimate their production

Data unavailable for	Similar crop
Grapes	production of wine
Raisins	production of wine
Olives	production of olive oil
Source: GEHR (1987)	
Sweet potatoes	potatoes
Walnuts	almonds
Dates	Figs
Source: GEHR (1991)	
Tomatoes	horticultural products
Peppers	horticultural products
Artichokes	horticultural products
Asparagus	horticultural products
Green beans	horticultural products
Melons	horticultural products
Water melons	horticultural products
Anise	horticultural products
Source:GEHR (1983), Gallego (1986), Pinilla (1992)	

For livestock production data in 1900 we have obtained the number of animals of each species from the livestock census of 1910. Later, to estimate meat production we have proceeded in a similar way to 1860. Data for milk is from Hernández Adell (2012), and the numbers for eggs are from the official data of 1908.

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