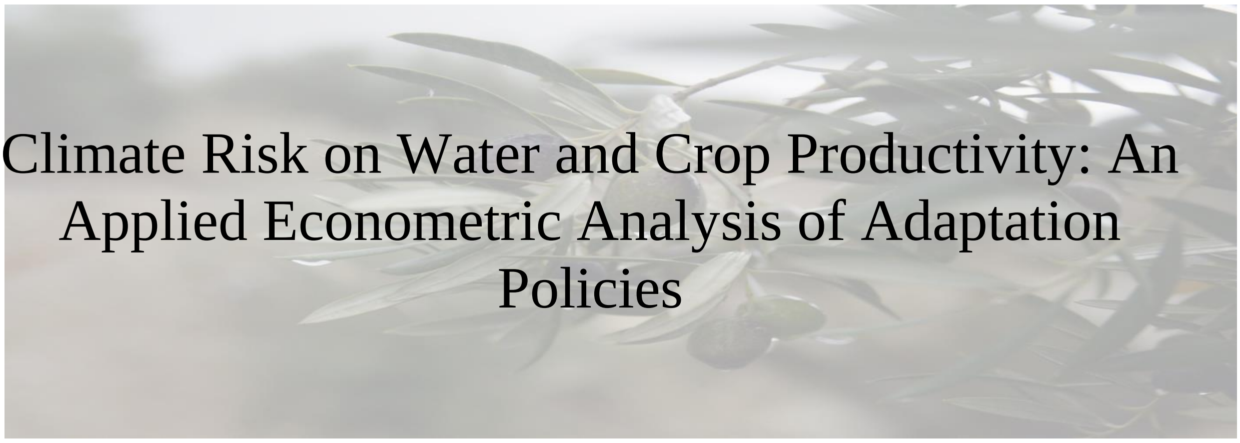

Climate Risk on Water and Crop Productivity: An Applied Econometric Analysis of Adaptation Policies

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Climate Risk on Water and Crop Productivity: An Applied Econometric Analysis of Adaptation Policies

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RESUMEN

La agricultura es el principal usuario de los recursos naturales y ambientales, además de que aún define a la sociedad en muchas áreas del planeta, conservando la vitalidad rural. El riesgo climático y el aumento de la población mundial generan grandes presiones en la agricultura así como en los recursos hídricos necesarios para mantener la producción de alimentos. A nivel europeo, la agricultura representa casi la mitad del comercio mundial de alimentos y está muy influenciada por las políticas nacionales, europeas y globales. Dentro de Europa, de acuerdo con diversos escenarios de clima y población, la región Mediterránea será una de las más afectadas por el cambio climático. Dado esto, es necesario evaluar tanto las medidas de política ambiental como aquellas que impulsan la competitividad, teniendo en cuenta los trade-offs existentes entre ambas. La evidencia sugiere que la información sobre las condiciones climáticas y socio-económicas futuras es crucial en el desarrollo y mejora de políticas de adaptación y mitigación fundamentales a nivel europeo y local, así mismo, también es necesario observar cómo cambios exógenos como las reformas de política impactan a la actividad agrícola.

El objetivo general de este estudio es analizar y caracterizar las relaciones clima, agua y producción agraria tanto a corto como a largo plazo, tomando en cuenta variables de gestión y políticas de adaptación, como los diversos tipos de subsidios y las dotaciones de regadío. Específicamente, esta investigación se centra en tres preguntas clave: (i) ¿Cuáles son las implicaciones del riesgo hidrológico y de las políticas de agua en la producción agrícola Mediterránea? (ii) ¿Cuál es el impacto de cambios en los derechos de riego sobre la competitividad y distribución social de los cultivos? (iii) ¿Cómo afecta la nueva gama de subsidios a la productividad a través de la eficiencia técnica? ¿Generan convergencia? Para contestar a estas preguntas, se hará uso de funciones de producción agrícola, las cuales serán analizadas a través de diferentes metodologías. Dado lo anterior, esta tesis está organizada en cinco capítulos, que se describen a continuación. En el **Capítulo 1** se presenta una introducción general donde se muestran los retos actuales de la agricultura europea, en un contexto de cambio climático, aumento poblacional y escasez de agua. Así mismo, se plantea la metodología que se desarrollará a lo largo de la tesis para analizar tanto a corto como a

largo plazo los cambios en la productividad, competitividad y distribución social de la producción agrícola, tomando en cuenta las especificaciones de la Directiva Marco del Agua (DMA) y las recientes reformas de la Política Agraria Común (PAC).

En el **Capítulo 2** se observan los efectos a corto plazo de políticas ambientales hipotéticas, tomando en cuenta el contexto de la Directiva Marco del Agua, así como otras variables socio-económicas y de clima, sobre el rendimiento agrícola. Se estiman funciones de producción estadística, vinculando los factores biofísicos y socioeconómicos mediante la introducción de variables ambientales, hidrológicas, tecnológicas, geográficas y económicas para caracterizar el rendimiento de los principales cultivos mediterráneos en la cuenca del Ebro. Los resultados proporcionan información sobre el mejor cultivo para minimizar el riesgo, así como de su impacto en el valor agregado agrícola. Posteriormente, estos modelos se utilizan para probar una política simulada evaluando algunos escenarios de política basados en ajustes del área de regadío, los cuales pueden ser válidos en un contexto de creciente escasez del agua. Es decir, observaremos cómo una reducción en las tierras de regadío puede resultar en pérdidas moderadas o significativas de la productividad de los cultivos. Esta respuesta es específica a cada cultivo y puede servir para priorizar estrategias de adaptación. De acuerdo a estos resultados, podría decirse que las políticas de reducción de área de regadío podrían ser una solución no dramática para la producción, sin embargo es necesario tener en cuenta las consecuencias a largo plazo sobre la competitividad y la distribución social en la agricultura.

Después, en el **Capítulo 3** con una visión de más largo plazo y considerando el efecto de las dos políticas europeas principales, se evalúa el efecto de cambios en los derechos de regadío, como un instrumento de política de agua, sobre la eficiencia y la distribución social de los rendimientos de algunos cultivos seleccionados en la cuenca del Ebro en España. Este análisis consta de dos componentes, primero se estiman funciones de producción de frontera estocástica para cada cultivo, usando datos históricos, para después calcular la eficiencia técnica. En un segundo paso, se usa una descomposición del coeficiente de Gini para estimar el impacto que tienen los cambios en el área de regadío sobre la desigualdad del rendimiento en cada sitio. En ambos casos se estimaron los efectos marginales. Los resultados obtenidos aquí, muestran que en el largo plazo la superficie regada tiene un efecto estabilizador sobre la distribución de los rendimientos del trigo y del viñedo, ya que favorece a las regiones más pobres, pero además favorece el aumento de la eficiencia técnica en ambos cultivos.

En el **Capítulo 4**, se analizan el efecto de los subsidios agrícolas en la productividad agraria en varios países de Europa, tomando en cuenta las recientes modificaciones a la Política Agraria Común. Es decir, en esta parte se estudia los efectos de los subsidios como inputs “facilitadores” en la productividad agrícola a través de la elasticidad input-output y de la eficiencia técnica, así como su efecto en los patrones de convergencia en la eficiencia entre algunos países europeos. Centrándonos en los efectos de los subsidios acoplados y desacoplados así como en los subsidios ambientales y de áreas menos favorecidas, se realizó un análisis de frontera estocástica tomando en cuenta la endogeneidad de estos instrumentos de política para después estimar la eficiencia técnica por país, así como la beta- y la sigma-convergencia entre las diferentes regiones europeas. Los resultados muestran que los subsidios tienen un impacto negativo en la función de producción pues generan desincentivos que afectan la competitividad, sin embargo los diferentes tipos de subsidios afectan de diferente manera a la eficiencia técnica en todos los países del estudio. También se encontró evidencia de un proceso de convergencia en la eficiencia.

Finalmente, en el **Capítulo 5** se presentan las conclusiones generales de esta tesis, donde se resumen y contrastan los principales resultados encontrados en los diferentes capítulos de este estudio. Estos resultados confirman la necesidad de estudios que ayuden a profundizar en la revisión de los planes de gestión de cuenca hidrológicas con el fin de hacer frente a las especificaciones de la Directiva Marco del Agua, así como de las políticas nacionales, teniendo en cuenta las recientes reformas de la Política Agraria Común; todo esto, bajo un contexto del cambio climático. Así mismo, se presentan las posibles extensiones y las limitaciones de esta investigación.

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Capítulo 1. Introducción general

En Europa y en el mundo, la agricultura es el principal usuario de los recursos naturales y ambientales como la tierra y el agua, además de que aún define a la sociedad en muchas áreas del continente conservando la vitalidad rural, por lo tanto es uno de los sectores más vulnerables en la economía de la región (Ciscar, et al., 2011; Schlickenrieder, et al., 2011). A nivel mundial y europeo, el agua en la agricultura representa el 70% del agua disponible y la agro-silvicultura abarca el 78% del territorio de la Comunidad Europea, en donde el área agrícola usada representa aproximadamente 178 millones de hectáreas. El riesgo climático y el aumento de la población mundial generan grandes presiones en la agricultura así como en los recursos hídricos necesarios para mantener la producción de alimentos en muchas regiones de Europa (Iglesias, et al., 2012a). También, es probable que la presión impuesta por el cambio climático, en la agricultura y el agua, aumente las disparidades regionales existentes en las áreas rurales de Europa y de otras partes del mundo (IPCC, 2007; EEA, 2008; Stern, et al., 2006).

Es evidente que los efectos del cambio climático sobre la agricultura están caracterizados por cambios en la productividad de los cultivos. Los escenarios existentes sobre los impactos del cambio climático proyectan diferentes resultados, sin embargo todos son consistentes en la distribución espacial de dichos efectos a nivel global y europeo (Iglesias, et al., 2012). El cambio climático tendrá un efecto beneficioso en la región Boreal (Finlandia y Suecia) pues tenderá a incrementar el rendimiento medio de los cultivos y a reducir la variabilidad en la productividad. Sin embargo, en las regiones Atlántica Central (UK), Atlántica Sur (Aleamania), Mediterránea-Norte (Francia y Portugal), Mediterránea-Sur (Grecia, Italia y España) los efectos serán menos beneficiosos y por lo tanto es necesario que las políticas de adaptación se centren en una mejor gestión basada en un incremento de la productividad media y una disminución de la variabilidad agrícola. Por último, las regiones Alpina y Continental (Hungary) muestran las mayores discrepancias respecto a las otras regiones, por ejemplo en la región Continental se proyecta un aumento en el rendimiento medio sin embargo es importante priorizar el riesgo a través de una reducción en la variabilidad de la productividad (González-Zeas et al., 2013). Medidas de política serán evaluadas para los países antes mencionados, con el propósito de tener un espectro amplio basado en las diferentes zonas agroclimáticas de Europa.

De acuerdo con diversos escenarios de clima y población, la región Mediterránea será una de las más afectadas, teniendo como consecuencia un aumento en los conflictos por el agua entre los diversos sectores productivos, así como cambios en la competitividad y distribución social de los rendimientos agrícolas. Dentro de esta región, en España, centraremos nuestro estudio en la Cuenca del Ebro, que se encuentra en el noreste de la Península Ibérica en la región mediterránea. El clima en esta cuenca es principalmente continental mediterráneo, con veranos muy cálidos y secos e inviernos fríos y húmedos, así como primaveras y otoños cortos e inestables. En la parte central de la cuenca, el clima es semiárido y en la esquina noroeste es oceánico. Por consiguiente, existe una gran heterogeneidad en la temperatura. Aunque en la actualidad, no existen restricciones explícitas sobre la superficie de regadío en esta cuenca, sí existen grandes conflictos socioeconómicos, dada la posibilidad planteada por las autoridades de trasvasar agua a otras cuencas con grandes presiones hídricas dentro de dicho país. Así mismo, este estudio se enfocará en los cultivos más importantes de la zona, en términos de área agrícola o de su importancia en la región. La evaluación del riesgo hidrológico y de las implicaciones de política de agua en la producción agrícola en la cuenca del Ebro, es fundamental para hacer frente a las políticas ambientales impuestas. Por otro lado, la gestión óptima del agua ayuda a reducir la vulnerabilidad en la agricultura, pero es altamente dependiente de la calidad de los sistemas de alerta temprana. Un tema de especial interés es saber si algunos cultivos son técnicamente más eficientes en algunos lugares que otros.

La agricultura europea representa casi la mitad del comercio mundial de alimentos y está muy influenciada por las políticas europeas y globales (Smith, 2009). Además, es evidente que tanto a nivel global como europeo existen *trade-offs* entre las políticas ambientales y aquellas que impulsan la competitividad. Por lo tanto, es necesario realizar un análisis del impacto de las políticas actuales así como políticas hipotéticas tomando en cuenta variables socioeconómicas y biofísicas. Es decir, un análisis del impacto de las reformas a la Política Agraria Común (PAC) así como de la Directiva Marco del Agua (DMA) es fundamental para entender la compleja conexión que existe entre las políticas agrícolas y ambientales en la agricultura europea, haciendo énfasis la agricultura de regadío. Por lo tanto, en este estudio nos centraremos en estas dos grandes políticas europeas (PAC y DMA), y en el caso de España se tomará en cuenta políticas nacionales como el Plan Nacional de Regadíos (2001), aunque de manera muy marginal.

En la actualidad existe gran preocupación acerca de la efectividad de la actual Política Agrícola Común, ya que la UE ha propuesto cambios importantes en apoyo a la agricultura como el desacoplamiento de las ayudas de la producción (1er pilar), y el refuerzo del desarrollo rural (2º pilar), tratando de adaptarse a las presiones internas y externas sobre el sector agrícola Europeo. Sin embargo, es necesario tener en cuenta los requerimientos ambientales impuestos por la DMA, los cuales pueden tener implicaciones de largo plazo afectando la competitividad de los agricultores y generando incrementos en las disparidades rurales.

La agricultura es subsidiada de alguna u otra forma en la mayoría de los países. En Europa, la Política Agraria Común (PAC), introducida en 1962, tiene un rol fundamental en la protección y soporte de los agricultores, donde los subsidios agrícolas y pesqueros representaron más del 40% del presupuesto europeo en 2010. En los últimos 20 años, la PAC ha estado en constante evolución a través de varias reformas cruciales en el esquema de subsidios. En 1992 con la reforma MacSharry se introdujo el sistema de pagos directos, el cual fue extendido por la reforma llamada Agenda 2000. Esta última reforma convirtió al desarrollo rural en el segundo pilar de la PAC, trayendo consigo algunas medidas estructurales como los subsidios LFA (Áreas menos favorecidas -Least Favored Areas) y los subsidios ambientales generándose así una política integrada a favor del desarrollo de una agricultura sostenible así como de áreas rurales dinámicas en toda Europa. La reforma Fischler (2003) la cual se hizo efectiva desde 2005, desacopló la mayoría de las ayudas directas y las transfirió a un nuevo esquema de pago único (SPS – Single Payment Scheme) a través del llamado mecanismo de modulación. El desacoplamiento de los pagos fue reforzado con la aprobación del Chequeo de Salud de 2008. El propósito de estas dos últimas reformas es lograr la complementariedad de los dos pilares de la PAC y así lograr que el sector agrícola esté más orientado al mercado, favoreciendo el desarrollo rural. Actualmente se encuentra en discusión la estrategia Europa 2020, la cual propone, entre otros temas, un techo a los subsidios para las granjas individuales o la dedicación de un 30% de cualquier ayuda para el mantenimiento de pastizales y la preservación de las reservas ecológicas.

De acuerdo con documentos publicados por la Unión Europea, el desacoplamiento de los subsidios es una medida que no ha producido cambios dramáticos en la estructura de producción dentro de la UE, logrando que los agricultores puedan producir lo que el mercado demanda de una forma más sostenible. Numerosos estudios han tratado a los subsidios como variables exógenas, sin embargo esto puede dar lugar a sesgos en las estimaciones, debido a la presencia de la heterogeneidad inobservada. Los subsidios no se distribuyen aleatoriamente y los agricultores pueden manipular las subvenciones recibidas, entonces es importante tener en cuenta la endogeneidad de esta variable. En este estudio, nosotros seguimos el criterio de que los subsidios deberían ser tratados como “inputs facilitadores" en lugar de “inputs tradicionales", dado que no son necesarios para la producción y tampoco se puede producir ningún output por sí mismo, sin embargo sí afectan a la productividad a través de diversos canales. Adicionalmente, un análisis de convergencia es requerido para determinar si las diferencias regionales en Europa están siendo reducidas por el actual esquema de subsidios. Tampoco se debe olvidar la valoración de las consecuencias para el desarrollo regional y el empleo rural, tomando en cuenta la conservación de los paisajes rurales, la biodiversidad y la protección al medio ambiente.

La pregunta clave en este punto, es saber cómo afecta la nueva gama de subsidios a la productividad a través de la eficiencia técnica y de otros mecanismos. Se puede esperar, a priori, efectos tanto positivos como negativos de las subvenciones en la eficiencia técnica a través del efecto ingreso. Esto significa que los subsidios podrían aumentar la eficiencia técnica sólo si proveen a los agricultores los medios necesarios para mantener la tecnología adecuada y actualizada o para hacer inversiones que aumenten la eficiencia de la empresa. Sin embargo, los subsidios podrían disminuir la eficiencia técnica si este ingreso extra hace que los agricultores estén menos motivados y por lo tanto muestren un bajo rendimiento.

El análisis del impacto de los subsidios es importante, pero no se debe olvidar el efecto de las políticas ambientales como la DMA en la productividad agrícola. Como parte del Artículo 130R del Tratado de la Unión (el cual empoderó a Bruselas para proteger al medio ambiente), la Comisión y el Parlamento Europeo iniciaron en 1995 el proceso para el desarrollo de una Política Común de Agua. A pesar de las barreras de inicio y de los problemas presentados por el Artículo 9, se espera que en el corto plazo y de acuerdo al calendario de implementación de la Directiva Marco del Agua (DMA), los miembros de la UE cumplan con los objetivos medioambientales. Centrándonos en la parte económica, la DMA introduce dos principios clave: (i) Se solicita a los consumidores de agua, como las industrias, los agricultores y las familias, pagar los costes de los servicios relacionados con el agua que reciben. Es decir, los

Estados miembros deben tratar de recuperar todos los costes de servicios por el agua, incluyendo los costes medioambientales, de acuerdo con el principio “del que contamina paga”. (ii) La Directiva exige a los Estados miembros que incluyan un análisis económico en la evaluación de los recursos hídricos y examinen tanto la rentabilidad como los costes y los beneficios de las diversas opciones en el proceso de toma de decisiones. Por lo tanto, será necesaria una evaluación económica de las actividades de gestión del agua.

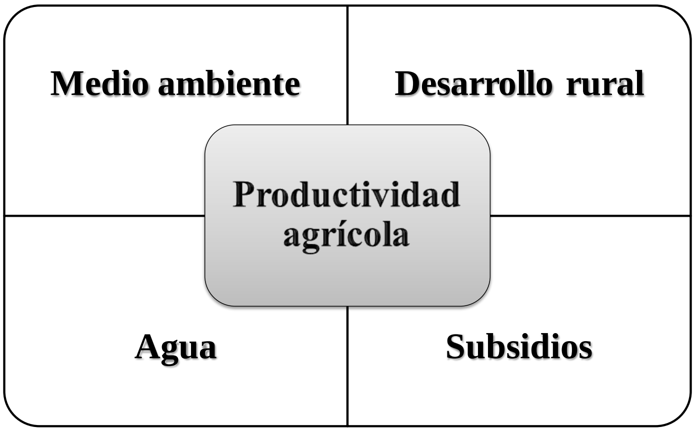
Por otro lado, las políticas de mitigación y adaptación son de gran importancia dado que ambas representan un factor clave para paliar los futuros efectos del cambio climático en la producción de alimentos. Diferentes propuestas de políticas ambientales basadas en regulaciones de la gestión del agua han sido evaluadas. Algunos autores sugieren que un incremento en los precios del agua obligaría a los agricultores a cambiar los patrones de cultivo en dirección de aquellos de mayor valor agregado o de aquellos que son menos intensivos en el uso del agua, algunos de los cuales son fuertemente subvencionados por la PAC, en lugar de aquellos cultivos de regadío intensivos en mano de obra (Gómez-Limón, et al., 2002; Berbel and Gómez-Limón, 2000). Sin embargo, es importante tener en cuenta que algunos cultivos están relacionados a los paisajes rurales y a las costumbres de la región, por lo que algunas veces es importante mantenerlos. Por otro lado, otros investigadores mencionan que la revisión de las concesiones actuales de las áreas de regadío puede ser un instrumento de política potencial para cumplir los requisitos legales de la DMA (Atwi y Arrojo, 2007; Quiroga, et al, 2011). En este trabajo nos centraremos en el efecto de un cambio en las dotaciones de regadío. Un pequeño cambio en las dotaciones de regadío (por ejemplo, los derechos sobre el área de regadío) o en general de las políticas agrícolas y ambientales puede tener impactos ambientales, económicos e hidrológicos significativos.

La agricultura de regadío tiene gran importancia en diversos países de Europa como en la región Mediterránea, sin embargo en algunos países de Europa del Este, como es el caso de Hungría, cerca del 98% del área agrícola no se riega. Es evidente que el regadío aumenta el rendimiento agrícola pero tiene diversos impactos ambientales, sobre todo si se considera que muchos de los sistemas de riego son ineficientes. Sin embargo, el regadío puede ayudar a mantener el nivel de vida de la población en zonas poco favorecidas y más sensibles al cambio climático así como disminuir la desertificación de las zonas más áridas. Por lo tanto se requiere ir más allá del análisis microeconómico clásico y realizar estudios de más largo plazo, para poder tener en cuenta el impacto social del regadío así como su contribución al empleo en las regiones más marginadas y en general su contribución al desarrollo rural. En pocas palabras es necesario tomar en cuenta la distribución social del agua basada en el valor social, en oposición a los derechos del agua tradicionales relacionados a la propiedad de la tierra.

Dado lo anterior, es innegable que un mejor entendimiento de la incertidumbre asociada a las diferentes presiones del cambio climático sobre la producción agrícola y del uso de los recursos naturales puede orientar mejor la adaptación de las políticas agrícolas y ambientales en Europa. En este estudio se intenta hacer una caracterización de las relaciones clima, agua y producción agraria así como de la gestión y de las políticas de adaptación, tomando como variables de gestión a diversos tipos de subsidios o la cantidad de tierra de regadío. En un primer análisis, se observarán los efectos a corto plazo de políticas ambientales hipotéticas, tomando en cuenta el contexto de la Directiva Marco del Agua y otras variables de clima y socioeconómicas, sobre el rendimiento agrícola. Después, con una visión de más largo plazo, se analizará el efecto de las dotaciones de regadío en la eficiencia técnica de los cultivos y en la equidad social, considerando el efecto de las dos políticas europeas principales. Finalmente, se analizará el efecto de los subsidios agrícolas en la productividad agraria en varios países de Europa, tomando en cuenta las recientes modificaciones a la Política Agraria Común. En la Figura 1, se muestran los elementos estudiados en esta tesis.

Para el logro de las actividades antes mencionadas se hará uso de funciones de producción agrícola. La estimación de funciones de producción agrícola siempre ha sido controversial y cada enfoque tiene fortalezas y limitaciones. En este estudio se utilizará la función de producción Cobb-Douglas ampliada con o sin progreso técnico neutral. Esta función de producción fue elegida dada su simplicidad y validez (Zellner et al., 1966, Giannakas et al., 2003) y su amplia aceptación en la literatura de la economía agrícola (Lobell et al., 2005, 2006; Quiroga et al., 2011). Es importante, mencionar que también se tomó en cuenta la función de producción translogarítmica, sin embargo en el caso de nuestros datos presentó problemas de colinearidad y de grados de libertad, los cuales son característicos de esta función.

Figura 1. Relaciones clima, agua y políticas de adaptación en la producción agraria



La Figura 2 muestra los temas claves, la metodología propuesta y la estructura de esta investigación. A groso modo, estas funciones de producción agrícola serán analizadas a través de diferentes métodos de estimación con el fin de responder a las preguntas planteadas en el estudio. En la primera parte se estimaran funciones de producción estadística, vinculando los factores biofísicos y socioeconómicos mediante la introducción de variables ambientales, hidrológicas, tecnológicas, geográficas y económicas para caracterizar el rendimiento de los principales cultivos mediterráneos en la cuenca del Ebro. Los resultados proporcionarán información sobre el mejor cultivo para minimizar el riesgo, así como de su impacto en el valor agregado agrícola. Posteriormente, estos modelos se utilizarán para probar una política simulada evaluando algunos escenarios de política basados en ajustes del área de regadío, los cuales pueden ser válidos en un contexto de creciente escasez del agua. Es decir, observaremos cómo una reducción en las tierras de regadío puede resultar en pérdidas moderadas o significativas de la productividad de los cultivos. Esta respuesta es específica a cada cultivo y puede servir para priorizar estrategias de adaptación.

Figura 2. Temas clave y metodología propuesta

Pregunta	**Métodos**
¿Cuáles son las implicaciones del riesgo hidrológico y de las políticas de agua en la producción agrícola Mediterránea?	Funciones de producción estadística; Funciones de distribución cumulativa basadas en simulaciones de Montecarlo; Escenarios de política de agua sobre el rendimiento agrícola
¿Cuál es el impacto de cambios en los derechos de riego sobre la competitividad y distribución social de los cultivos?	Función de producción (FP) de frontera estocástica con efectos de ineficiencia técnica por cultivos; Impacto de los diferentes inputs en la desigual del rendimiento a través de una descomposición del coeficiente de GINI; Estimación de efectos marginales
¿Cómo afecta la nueva gama de subsidios a la productividad a través de la eficiencia técnica? ¿Generan convergencia?	FP de frontera estocástica con efectos de ineficiencia técnica por países, considerando la endogeneidad de los subsidios a la producción (inputs facilitadores); (i) Regresión crecimiento-nivel inicial o velocidad de ajuste (catching-up process). (ii) Reducción de la dispersión de la eficiencia técnica en el tiempo

En la segunda parte, se evaluará el efecto de cambios en los derechos de regadío, como un instrumento de política de agua, sobre la eficiencia y la distribución social de los rendimientos de algunos cultivos seleccionados en la cuenca del Ebro en España. Este análisis constará de dos componentes, primero se estimarán funciones de producción de frontera estocástica para cada cultivo, usando datos históricos, para después calcular la eficiencia técnica. En un segundo paso, se usará una descomposición del coeficiente de Gini para estimar el impacto que tienen los cambios en el área de regadío sobre la desigualdad del rendimiento en cada sitio. En ambos casos se estimarán los efectos marginales. Por último, en la tercera parte se estudiarán los efectos de los subsidios como inputs facilitadores en la productividad agraria a través de la eficiencia técnica, así como su efecto en los patrones de convergencia en la eficiencia entre algunos países europeos. Centrándonos en los efectos de los subsidios acoplados y desacoplados así como en los subsidios ambientales y de áreas menos favorecidas, se realizará un análisis de frontera estocástica tomando en cuenta la endogeneidad de estos instrumentos de política para después estimar la eficiencia técnica por país, así como la beta- y la sigma-convergencia entre las diferentes regiones europeas.

La evidencia sugiere que la información sobre las condiciones climáticas y socio-económicas futuras es crucial en el desarrollo y mejora de políticas de adaptación y mitigación fundamentales a nivel europeo y local, así mismo, también es necesario observar cómo cambios exógenos como las reformas de política impactan a la actividad agrícola (Iglesias, et al., 2012b). En otras palabras, los últimos avances científicos han permitido el desarrollo de mejores proyecciones climáticas, sin embargo es necesario que éstas se traduzcan en estrategias de adaptación efectivas (Schlickenrieder, et al., 2011). Concretamente, la agricultura Europea ha tenido que enfrentar muchos retos como las presiones climáticas e hídricas, así como las reformas a las políticas agrícolas y el reforzamiento de las políticas ambientales. Por lo tanto, este tipo de estudios puede ayudar a la formulación de políticas públicas futuras, pues generan información confiable y profunda tanto a nivel país como para una región específica.

Limitaciones a nuestro enfoque pueden surgir de la simplicidad de los modelos estadísticos usados así como de la calidad de los datos observados. Así mismo no se tomó en cuenta de manera directa las medidas de política nacionales ni regionales, las cuales tienen una importancia clave en los cambios de la productividad y en la distribución social. Tampoco se consideró la calidad y la degradación de la tierra.

Chapter 1. General Introduction

In Europe and worldwide, agriculture is the largest user of natural and environmental resources such as land and water, and still defines society in many areas of the continent maintaining rural vitality therefore is one of the most vulnerable sectors in the economy of the region (Ciscar, et al., 2011; Schlickenrieder, et al., 2011). Both globally as at European level, water in agriculture accounts for 70% of the available water and agro-forestry covers 78% of the territory of the European Community, where the agricultural area used is about 178 million ha. Climate risk and increasing world population generate large pressures on agriculture and water resources, which are necessary to maintain food production in many regions of Europe (Iglesias et al., 2012a). Also, it is likely that the pressure imposed by climate change on agriculture and water could increase regional disparities in rural areas of Europe and around the world (IPCC, 2007; EEA, 2008; Stern, et al., 2006).

Clearly, the effects of climate change on agriculture are characterized by changes in crop productivity. The existing scenarios on projected climate change impacts show different results, but all are consistent in the spatial distribution of these effects at both global and European level (Iglesias et al., 2012). Climate change will have a beneficial effect in the Boreal region (Finland and Sweden), throughout increases in the average crop yield and reductions in the variability in productivity. However, in the Atlantic Central (UK), Atlantic South (Aleamania), Mediterranean North (France and Portugal), Mediterranean South (Greece, Italy and Spain) regions, the effects will be less beneficial, therefore there is necessary that the adaptation policies focus on a better management based on an increase in average productivity and on a decrease in agricultural variability. Finally, Alpine and Continental regions (Hungary) show the greatest discrepancies respect to the other regions, for example in the Continental region is projected an increase in the average yield, however it is important to prioritize the risk through a reduction in the variability of productivity (Zeas Gonzalez et al., 2013). Policy measures will be evaluated for the above countries, in order to have a broad-based spectrum of the different climatic zones of Europe.

According to diverse future scenarios of climate and population, the Mediterranean region will be one of the most affected, having as consequences an increase in conflicts for water among the different productive sectors, as well as changes in competitiveness and social distribution of agricultural yields. Inside this region, in Spain, we will focus our study in the Ebro Basin, located in the northeast of the Iberian Peninsula. The climate in this basin is mostly Continental-Mediterranean, with hot-dry summers and cool-wet winters and short-unstable springs and autumns. In the middle part of the basin, the climate is Semi-Arid and in the northwest corner is Oceanic. Consequently, there is great heterogeneity in temperature. Although at present time, there are no explicit restrictions on the irrigated area in the basin, there exist large socioeconomic conflicts; given the possibility afforded by the authorities to transfer water to other basins with high water pressures in Spain. Furthermore, in this study will focus on the most important crops in the area, in terms of agricultural area or of its importance in the region. The assessment of hydrological risk and policy implications of water in agricultural production in the Ebro basin is essential to deal with environmental policies imposed. Furthermore, the optimal management of the water helps to reduce vulnerability in agriculture, but is highly dependent on the quality of early warning systems. One issue of particular interest is whether some crops are technically more efficient in some places than in others.

European agriculture accounts for almost half of global food trade and is heavily influenced by European and global policies (Smith, 2009). It is further evident that there are trade-offs between environmental policies and those that promote competitiveness, both at global and European level. Therefore, it is necessary to analyze the impact of current and hypothetical policies considering socioeconomic and biophysical variables. That is, an analysis of the impact of reforms to the Common Agricultural Policy (CAP) and the Water Framework Directive (WFD) is fundamental to understanding the complex connection between agricultural and environmental policies in European primary sector, making emphasis on irrigated agriculture. Therefore, in this study we focus on these two major European policies (CAP and WFD), and in the case of Spain will take into account national policies as the National Irrigation Plan (2001), although in a very marginal way.

At the present time, there is great concern about the effectiveness of the current Common Agricultural Policy since the EU has proposed major changes in agricultural support as the decoupling of subsidies from production (1st pillar), and the strengthening of rural development (2nd pillar), trying to face internal and external pressures on the European agricultural sector. However, it is necessary to take into account the environmental requirements imposed by the WFD, which may have long-term implications affecting the competitiveness of farmers and increasing rural disparities.

Agriculture is subsidized in some way in most of the countries. In Europe, the Common Agricultural Policy (CAP), introduced in 1962, has a fundamental role in the protection and support of farmers, where agricultural and fisheries subsidies accounted for over 40% of the EU budget in 2010. In the last 20 years, the CAP has been in constant evolution through several key reforms in the scheme of subsidies. In 1992 MacSharry reform introduced direct payments system, which was extended by the Agenda 2000 reform. In this last reform, rural development became the second pillar of the CAP, bringing some structural measures as environmental subsidies and LFA subsidies (Least Favored Areas), thus creating an integrated policy to promote development of a sustainable agriculture as well as dynamic rural areas across Europe. Fischler Reform (2003), which became effective in 2005, introduced the decoupling of the majority of direct payments and transferred to a new single payment scheme (SPS - Single Payment Scheme) through a mechanism of modulation. The decoupling of payments was reinforced by the adoption of the Health Check in 2008. The purpose of these last two reforms is to achieve complementarity of the two pillars of the CAP, and thus ensure that the agricultural sector is more market-oriented, favoring rural development. Currently is under discussion the Europe 2020 strategy, which proposes among other issues, a cap on subsidies for individual farms and the dedication of 30% of any support to maintain pastures and to preserve ecological reserves.

According to documents published by the European Union, the decoupling of subsidies is a measure that has not produced dramatic changes in the structure of production within the EU, achieving that farmers can produce what the market demands in a more sustainable way. Several studies have treated to subsidies as exogenous variables; however this may lead to bias in the estimates, given the presence of unobserved heterogeneity. Subsidies are not distributed randomly and farmers can manipulate the subsidies received, then it is important to keep in mind the endogeneity of this variable. Here, we follow the point of view that subsidies should be treated as "facilitating inputs" rather than "traditional inputs", since they are not needed for production and cannot produce any output by itself, but they affect productivity through different channels. Additionally, a convergence analysis is required to determine whether regional differences in Europe are being reduced by the current scheme of subsidies. Nor should we forget the assessment of the consequences for regional development and rural employment, taking into account the conservation of rural landscapes, biodiversity and environmental protection.

The key question at this point is to know how the new variety of subsidies affects to productivity through technical efficiency and other mechanisms. One can expect, a priori, both positive and negative effects of subsidies on technical efficiency through the income effect. This means that subsidies could increase technical efficiency only if provide to farmers the necessary means to maintain an adequate and updated technology or to make investments that increase the efficiency of the firm. However, subsidies could reduce technical efficiency if this extra income makes farmers less motivated and therefore show a low yield.

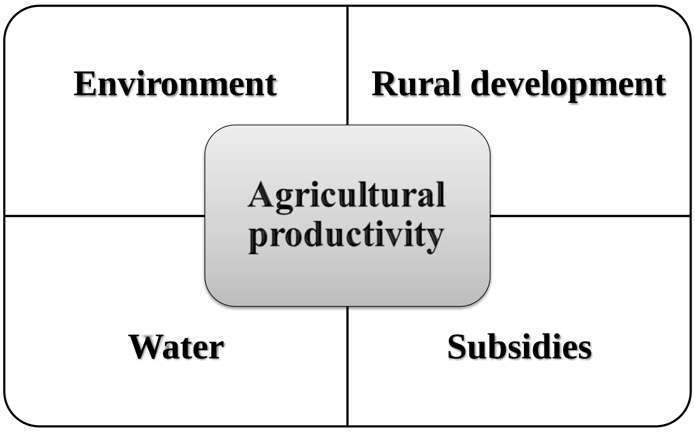
Analysis of the impact of subsidies is important, but we must not forget the effect of environmental policies as the WFD on agricultural productivity. As part of Article 130R of the European Union Treaty, which empowered Brussels in order to protect the environment, the European Commission and the Parliament began in 1995, the process for developing a Common Water Policy. Despite starting barriers and problems presented by Article 9, in the short term, according to the WFD timetable for implementation, the EU Member States must comply with the environmental objectives. Focusing on the economic side, the WFD introduces two key principles: (i) It solicits to water consumers, as industries, farmers and households, to pay the costs of water related services they receive. In other words, Member States should try to recover the full costs of water services, including environmental costs, according to the "the polluter pays principle". (ii) The Directive calls on Member States to include economic analysis in the assessment of water resources (in example, characterization), and examine profitability as the costs and benefits of diverse options in the decision-making process. So, it is necessary an economic evaluation of water management activities.

Moreover, mitigation and adaptation policies are important because both represent a key factor to alleviate the future effects of climate change on food production. Different environmental policy proposals based on regulations of water management have been evaluated. Some authors suggest that an increase in water prices would force farmers to change cropping patterns towards those with higher added value or those that are less intensive in the use of water, some of which are heavily subsidized by CAP, rather than those irrigated crops that are labor intensive (Gómez-Limón, et al., 2002; Berbel and Gómez-Limón, 2000). However, some crops are linked to rural landscapes and customs, so that sometimes it is important to keep them. On the other hand, other scholars mentioned that the review of current concessions of irrigated areas can be a potential policy instrument to meet the legal requirements of the WFD (Atwi and Arrojo, 2007; Quiroga, et al, 2011). In this research we focus on the effect of changes in irrigation dutties. A small change in irrigation dutties (i.e. rights in irrigated area) or in general in agricultural and environmental policies can have environmental, economic and hydrological significant impacts.

Irrigated agriculture has great importance in several countries in Europe as in the Mediterranean region; however in some Eastern European countries, such as Hungary, about 98% of the agricultural area is not irrigated. It is clear that irrigation increases crop yield but have different environmental impacts, especially considering that many irrigation systems are inefficient. However, irrigation can help to maintain the standard of living of the population in less favored areas and more sensitive to climate change as well as reduce desertification of arid areas. So we need to look beyond the classic microeconomic analysis and carry out studies of longer term, in order to take into account the social impact of irrigation and its contribution to employment in disadvantaged regions and in general its contribution to rural development. In few words, it is necessary to take into account the social distribution of water based on the social value, as opposed to traditional water rights related to land ownership.

Given the above is undeniable that a better understanding of the uncertainty associated with the different pressures of climate change on agricultural production and of the use of natural resources can better orient the adaptation of agricultural and environmental policies in Europe. This study attempts to characterize the relationships between climate, water and agricultural production as well as management and adaptation policies, taking in account as management variables the different types of subsidies or the amount of irrigated land. In a first analysis, we observe the short-term effects of hypothetical environmental policies, taking in mind the context of the Water Framework Directive and other climate and socioeconomic variables, on crop yield. Then, with a longer-term view, we analyze the effect of irrigation duties in the technical efficiency and social equity of crop, considering the effect of the two main European policies. Finally, we analyze the effect of subsidies on agricultural productivity in several European countries, taking in mind the recent changes to the Common Agricultural Policy. In Figure 1 are shown the elements studied in this thesis.

Figure 1. Relations climate, water and adaptation policies in agricultural production



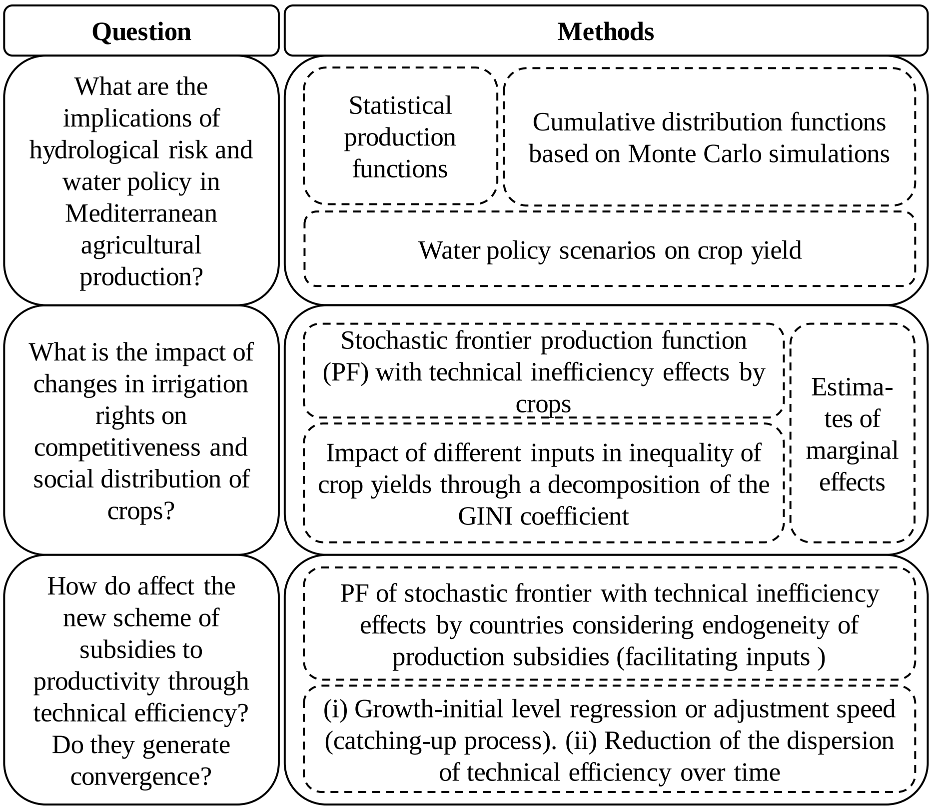
To achieve the above mentioned activities, we will make use of agricultural production functions. The estimation of agricultural production functions has always been controversial, and each approach has strengths and limitations. In this study we use an extended Cobb-Douglas, with or without neutral technical progress. This production function was selected because of its simplicity and validity (Zellner et al., 1966, Giannakas et al., 2003) and its wide acceptance in the agricultural economics literature (Lobell et al., 2005, 2006; Quiroga et al., 2011). It is important to mention that we also took into account the Translog production function, however in the case of our data, this king of function presented problems of collinearity and degrees of freedom, which are a characteristic of it.

Figure 2 shows the key issues as well as the proposed methodology and structure of this research. Broadly speaking, these functions of agricultural production will be analyzed through different estimation methods in order to answer the questions raised in the study. In the first part, we will estimate statistical production functions, linking biophysical and socioeconomic factors, through the introduction of environmental, hydrological, technological, geographical and economic variables to characterize the yield of the main Mediterranean crops in the Ebro basin. The results will provide information about the best crop to minimize risk as well as its impact on agricultural value added. Later, these models will be used to test a simulated policy, evaluating some policy scenarios based on adjustments of irrigated area, which may be valid in the context of increasing water scarcity. In other words, we will observe how a reduction in irrigated area could result in moderate or significant losses of crop productivity. This response is specific to each crop and can be used to prioritize adaptation strategies.

In the second part, we will evaluate the effect of changes in irrigation rights as an instrument of water policy over the efficiency and the social distribution of selected crop yields in the Ebro basin in Spain. This analysis will consist of two components, first production functions of stochastic frontier will be estimated for each crop, using historical data, and then calculate the technical efficiency. In a second step, we use a decomposition of the Gini coefficient to estimate the impact of changes in irrigated area on inequality of crop yields in each site. In both cases the marginal effects will be estimated. Finally, in the third part we will study the effects of subsidies as facilitating inputs in agricultural productivity and through technical efficiency as well as its effect on convergence patterns in efficiency between some European countries. Focusing on the effects of coupled and decoupled subsidies as well as environmental subsidies and less favored areas, we will apply a stochastic frontier analysis, taking into account the endogeneity of these policy instruments, then we will estimate the technical efficiency by country as well as beta-and sigma-convergence between European regions.

Evidence suggests that information about future climatic and socio-economic conditions is crucial in the development and improvement of fundamental adaptation and mitigation policies at European and local level, so it is also necessary to observe how exogenous changes as policy reforms impact the agricultural activity (Iglesias et al., 2012b). In other words, the latest scientific advances have allowed the development of better climate projections, however there is needed that these projections can be translated into effective adaptation strategies (Schlickenrieder, et al., 2011). Specifically, European agriculture has faced many challenges such as climate and water pressures as well as agricultural policy reforms and the strengthening of environmental policies. Therefore, this kind of studies can help future public policy, because they generate reliable and deep information at both country and regional level.

Figure 2. Key issues and methodology



Limitations to our approach arise from the simplicity of the statistical models used as well as the quality of the observed data. Also was not taken into account, in an explicit way, the national and regional policy measures, which have a key importance over changes in productivity and social distribution. Neither was considered the quality and degradation of land.

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Chapter 2. Crop yields response to water pressures in the Ebro basin in Spain: risk and water policy implications[1]

Abstract

The increasing pressure on water systems in the Mediterranean enhances existing water conflicts and threatens water supply for agriculture. In this context, one of the main priorities for agricultural research and public policy is the adaptation of crop yields to water pressures. This paper focuses on the evaluation of hydrological risk and water policy implications for food production. Our methodological approach includes four steps. For the first step, we estimate the impacts of rainfall and irrigation water on crop yields. However, this study is not limited to general crop production functions since it also considers the linkages between those economic and biophysical aspects which may have an important effect on crop productivity. We use statistical models of yield response to address how hydrological variables affect the yield of the main Mediterranean crops in the Ebro river basin. In the second step, this study takes into consideration the effects of those interactions and analyzes gross value added sensitivity to crop production changes. We then use Montecarlo simulations to characterize crop yield risk to water variability. Finally we evaluate some policy scenarios with irrigated area adjustments that could cope in a context of increased water scarcity. A substantial decrease in irrigated land, of up to 30% of total, results in only moderate losses of crop productivity. The response is crop and region-specific and may serve to prioritise adaptation strategies.

Keywords: *Crop productivity, water production function, water policy, Montecarlo simulations.*

[1] Paper published in Hydrology and Earth System Sciences, 15: 505-518. 2011. Previous versions of this paper were presented in: (i) XXXV Simposio de la Asociación Española de Economía (SAEe 2010). Madrid, España. 16-18 dic-2010. (ii) STAHY 2010: International workshop "Advances in Statistical Hydrology". Taormina, Italia. 23-25 may-2010.

1 Introduction

Water conflicts in the Mediterranean have been extensively reported, and many of the studies have analysed the costs for governments to maintain or even increase water supply (Smith, 2002). In the past, studies have focused on the supply side through cost-benefit analyses. However, with the new water-related problems, such as climate change, droughts and floods, focus on the demand side is needed. For this kind of analysis physical, political and socioeconomic components must be integrated for an optimal management of activities to increase the basin's output. It is crucial for the Mediterranean region, where irrigation represents as much as 90% of total water consumption (Gómez-Limón and Riesgo, 2004), to measure the risks associated with climate variability in agriculture and to implement water demand policies that promote an efficient allocation and use of resources in the region's farms.

According to the OECD, agriculture is the major user of water in most countries, since about 70% of total available water is used for irrigation. It also faces the enormous challenge of producing almost 50% more food by 2030 and doubling production by 2050. This will likely need to be achieved with less water, mainly because of growing pressures from urbanisation, industrialisation and climate change (OECD, 2010). Agriculture is also the main user of other environmental and natural resources and therefore has an important role to play in global ecosystem sustainability. Therefore, small changes in agricultural water use (in planting, crop management or crop production) can have significant economic and hydrological impacts.

In Spain, irrigated agriculture accounts for 80% of national consumption of water (Gómez-Limón and Riesgo, 2004) and only 40% of the land area is suitable for cultivation (Iglesias et al., 2000). This paper focuses on the Ebro basin, where agriculture can reach up to 90% or more of water consumption. In fact, more than 354,245 ha of irrigated land are projected to be added according to the National Irrigation Plan (2001) for the nine regions in the Ebro basin. This represents an increase of 2,110 hm3/year of water demand and an expected increase of 44% in the irrigated area, raising the total mean to 1,128,653 hectares. This increase imposes significant additional pressure on aquatic ecosystems and has serious environmental implications, such as the maintenance of environmental flows and water quality in rivers. Although some efforts are being made to make the irrigation systems more efficient, trying to reduce water consumption for agriculture, such a huge increase on irrigated land is not likely to occur in a climate change context since more and more severe drought events are expected to happen. In addition, it will be difficult to make this incompatible with the water framework directive environmental restrictions. So we have considered three policy scenarios where irrigated area is reduced.

The Ebro Basin is located in the Northeast of the Iberian Peninsula with a total area of 85,362 km2. This watershed is the largest in Spain, accounting for 17.3% of the total national area. It is made up of 347 major rivers, including the Ebro River, which drains the basin. It rises in the Cantabrian Mountains and ends in the Mediterranean and has a total length of 910 km and 12,000 km of main river network (CHEBRO, 2009). The climate in the Ebro basin is primarily Continental Mediterranean, with hot, dry summers, cold, wet winters and short, unstable autumns and springs. In the middle of the basin, the climate is semi-arid and in the northwest corner it is oceanic. Consequently, there is a wide heterogeneity in temperature. In 2007, for example, Tarragona, in the Ebro delta—that is part of the Mediterranean agroclimatic area-- reached a maximum temperature of 43 °C, while, Burgos, in the northern Spanish plateau—that is part of the Continental agroclimatic area—got to a minimum of -22 °C. Our methodological approach deals with these differences since links bio-physical and socio-economic factors.

In this paper, we focus on the evaluation of hydrological risk and water policy implications for agricultural production in the Ebro basin in Spain. We link bio-physical and socio-economic factors by the introduction of environmental, hydrological, technological, geographical and economic variables to characterize crop yield for the main Mediterranean crops in this basin. The results provide information about the best crop to minimise risk. Later, these models are used to address a simulated policy to assess some policy scenarios with irrigated area adjustments that could cope in a context of increased water shortage. We observe how a reduction in irrigated land results in moderate or significant losses of crop productivity. The response is crop specific and may serve to prioritise adaptation strategies.
The article is organized as follows: The second section provides general and detailed information on the methodological steps. The third section describes the results of the estimates crop-water production functions for 8 main crops in the basin. This section shows

also the estimates of agricultural added value function, Montecarlo risk analysis and virtual policy scenarios. The final section presents the conclusions of the paper.

2 Methods

2.1 Steps on methodology

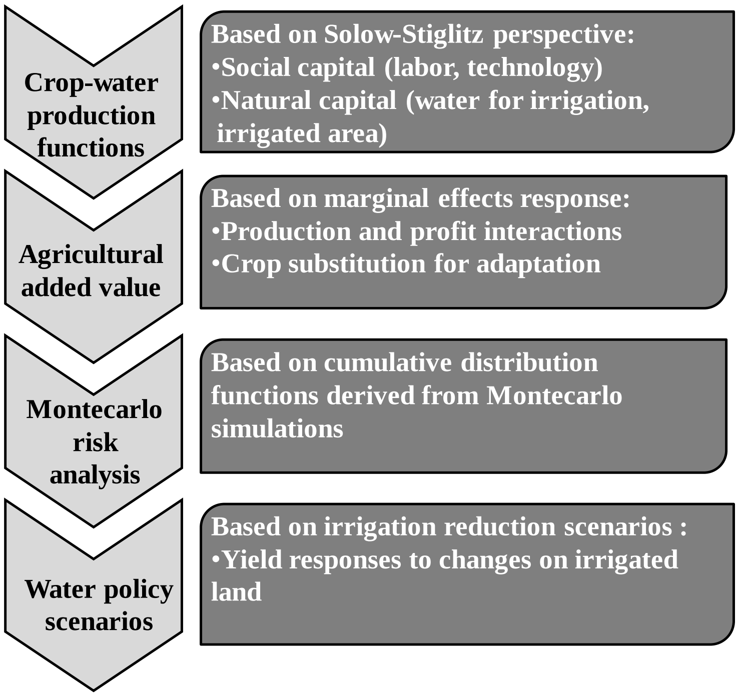
The methodology developed in this study is applied to selected crops in Ebro basin. Relative to the total agricultural area in the Ebro basin, alfalfa, wheat, grapevine, olive, potato, maize and barley are the seven most representative crops in the Ebro basin since they account for almost 60% of the total agricultural area in this region. Rice does not represent a large percentage of the total cultivated area in the overall basin, but it is the most important crop in the Ebro delta area and it is an intensively irrigated crop. Alfalfa, maize, potato and rice are mainly irrigated while wheat, barley, grapevine and olive are primarily rainfed crops (Table 1). Models are obtained for each of 8 crops in order to estimate the risk of water variability and policy scenarios.

Table 1. Percentage of agricultural area for selected crops

Crop	Percentage of the total agricultural area			Total cropland (Ha)			Percentage of cropping system	
	Rainfed	**Irrigation**	**Total**	**Rainfed**	**Irrigation**	**Total**	**Rainfed**	**Irrigation**
Wheat	18.97	9.55	17.00	774864	102720	877584	88.30	11.70
Barley	29.90	13.04	26.38	1221483	140156	1361639	89.71	10.29
Rice	–	0.87	0.69	–	35379	35379	0.00	100.00
Maize	0.16	9.94	2.20	6700	106874	113574	5.90	94.10
Potato	0.07	1.04	0.27	2868	11191	14059	20.40	79.60
Alfalfa	0.95	13.01	4.39	38758	139837	179180	21.63	78.04
Grapevine	4.36	3.72	4.22	177957	39975	217932	81.66	18.34
Olive	5.13	2.64	4.61	209595	28413	238008	88.06	11.94
Total	**59.53**	**53.80**	**59.77**	**2432225**	**604545**	**3037355**	**80.53**	**19.45**

The methodology includes the following 4 steps: [1] we estimate linear regression models by ordinary least squares (OLS). Statistical models of yield response have proven useful to estimate the water requirements at different locations for selected crops and have also proven useful to evaluate the effects of extreme contingencies and other socioeconomic variables. Extensive literature exists about the estimation of crop production functions to compute the climate effects over crop production (Lobell et al., 2005; Lobell et al., 2006; Parry et al., 2004; Iglesias et al., 2000; Hussain and Mudasser, 2007). Some papers focus specifically on the crop-water relationship for irrigated yields (Al-Jamal, 2000; Alcalá and Sancho-Portero, 2002; Echevarría, 1998; Acharya and Barbier, 2000). Socio-economic factors have also been included as explanatory variables (Iglesias and Quiroga, 2007; Quiroga and Iglesias, 2009; Griliches, 1964). In this paper, we have linked bio-physical and socio-economic factors introducing environmental, hydrological, technological, geographical and economic variables to characterize crop yield for the main Mediterranean crops in the Ebro river basin. The goal was to analyse economic component (labour and capital) as opposed to the natural component (water for irrigation and irrigated area components of the production function) together. Literature on this specific area includes Acharya and Barbier, 2000; Alcalá and Sancho-Portero, 2002; Echevarría, 1998; and Hussain and Mudasser, 2007. [2] In a second step, we try to understand the interactions between agricultural production and profit functions focusing on water demand. To do so, we analyze the total agricultural gross added value (GAV) of the region and its interaction with the aggregate crop yield. [3] We use the Montecarlo method that it is a simulation technique from which statistical distributions and characterizations can be derived. We apply this method to derive statistical distributions and characterizations of crop yield in response to water patterns or policy adjustments. This method is a powerful and commonly used technique for analyzing complex problems and conducting experiments to evaluate probabilistic risk (Rubinstein, 1981). In agriculture, this method is used to derive statistical distributions and characterizations of crop yield in response to climatic variables and other inputs (Lobell and Ortiz-Monasterio, 2006; Iglesias and Quiroga, 2007). [4] Finally, we simulate the structural adjustments, in this case a decrease in irrigated area (ha) that could allow the agricultural sector, to cope with increased water restrictions for the agricultural sector. See Figure 1.

Figure 1. Steps on methodology



In our approach, the estimation of the crop production function plays a fundamental role, since it is then used to evaluate the added value as well as the risk and policy implications. Estimation of production functions is always controversial and each approach has strengths and limitations. Here we have followed the Solow-Stiglitz perspective (Solow, 1974; Stiglitz 1979, 1997), as specified below. According to Solow (1956), there are two factors of production to obtain output, capital (K) and labour (L). Where its technological possibilities are represented by a production function:

$$Y = F(K, L) \quad [1]$$

It is assumed that production shows constant returns to scale. Therefore the production function is homogeneous to the first degree. This is equivalent to assuming no scarcity of non-augmentable resources such as land. If we assume scarce-land, this would lead us to decreasing returns to scale in capital and labor and the model would become more Ricardian. Nowadays, it is well known that natural resources are very important to economic growth and environmental sustainability. In this context we use an extended production function named the Solow-Stiglitz model (Solow, 1974; Stiglitz 1979), which includes natural resources (*R*).

$$Y = K^{\alpha_1} L^{\alpha_3} R^{\alpha_2} \qquad \text{with } \alpha_1 + \alpha_2 + \alpha_3 = 1 \text{ y } \alpha_i > 0 \qquad [2]$$

Where: K is capital, L is labour, R is natural resources and $\alpha_1, \alpha_2, \alpha_3$ are parameters and represent the elasticity of substitution among the factors. In order to put our work in the viewpoint of the productivity literature we used the Solow-Stiglitz perspective. Moreover, we follow Solow (1956) in the sense that we are modelling a production technology in order to identify productivity change. Some experts have criticized this function because of the assumption that *R* and *K* are substitutes, what is not true, since, they are complementary (Daly, 1997). However, nowadays it is extensively used to represent production processes (Stiglitz, 1997). Our approach differs from Solow's initial model from that we use more than two factors of production to obtain output. It is good to say that based in this model we specifically use the usual Cobb-Douglas specification, as it allows a simple estimation and the coefficients obtained have a very intuitive interpretation in terms of elasticities. There are empirical studies that have shown that in agriculture, statistical models of yield response proved to be useful to estimate input requirements at different locations for selected crops (Lobell and Ortiz-Monasterio, 2006; and Lobell et al., 2005, 2007; Parry et al. 2004). Limitations of our approach arise from the simplicity of the empirical models and the quality of observed data. The use of statistical models for projections in a different context has been commonly questioned. Nevertheless, regression models are robust within the data range in which they are calibrated. Here, we have used several years of climate data, including a range of temperatures and precipitation extremes, to estimate the models. The data include a range of temperatures and precipitation extremes that vary more than the average changes projected by most of the climate change models, so the limitations in terms to the extent are reduced and the models can be reliably extrapolated since the projections are inside the range in which the regression models apply. In addition, we introduce risk aspects in the evaluation by selecting several geographical locations within each agro-climatic area, several crops and multiple years for the simulations. The result shows cumulative distribution functions to deal with the probabilistic variation.

2.2 Data

To characterize our model we use regional, national and international sources of data. Table 2 describes the variables included in this study and the source of data. We have included observed historical data about crop yield, water and climate requirements and socio-economic and geographic characterization of eight representative crops in the 18 regions in the Ebro basin from 1976 to 2002. Crop yield (Y) is defined as the ratio between production (t) and agricultural total area (ha) and data were obtained from the Spanish Ministry of Environment (MARM). Economic and geographic variables were mainly obtained from the Spanish Institute of Statistics (INE) while technological variables were taken from FAOSTAT and Food and Agriculture Organization (FAO). To build a proxy variable for irrigation, we used Ebro basin management authority local data, (CHEBRO, 2004) about net water needs of crops. Finally, historical climatic data such as total precipitation, maximum and mean temperatures, and number of days below 0ºC degrees were taken from the Spanish Meteorological Agency (AEMET) to characterize the impact of climate.

2.3 Crop-water production function

We have estimated a crop-water production function that establishes the relationship between crop yield and water applied for a range of crops that represent irrigated agriculture in the Ebro basin. This function is not unique and varies among crops and zones. The specified model is:

$$lnY_t = \alpha\, lnY_{t-1} + \beta_0 + \beta_1 L_t + \beta_2 Mac_t + \beta_3 Mac_{t-n} + \beta_4 Altitude_t + \beta_5 Area\_ebro_t + \beta_6 Irrig\_area_t +$$

$$+ \beta_7 Irrig_t + \beta_8 Irrig_t^2 + \beta_9 \Pr ec_{it} + \beta_{10} T\_Max_{it} + \beta_{11} T\_Mean_{it} + \beta_{12} Fr_{it} + \beta_{13} Dro_t + \varepsilon_t \qquad [3]$$

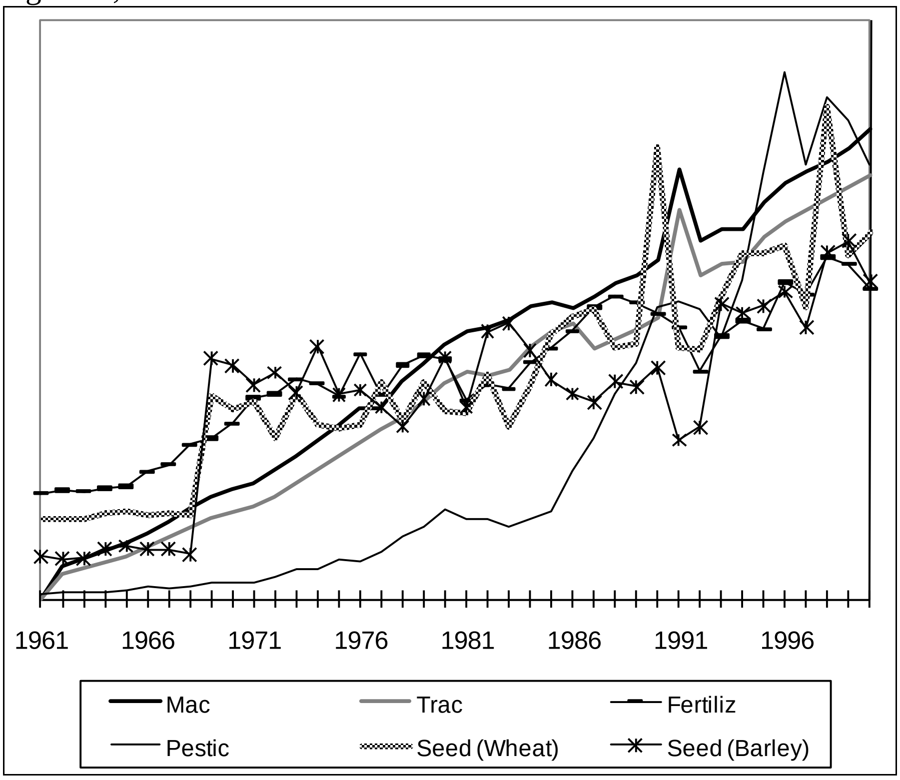
Where the dependent variable (lnY_t) is the natural logarithm of the crop yield for a site in year t. The logarithmic scale for the dependent variable is used in order to homogenize the variance. For strictly positive data, for which a relative scale appears to be natural, taking a log-transformation may be not unimportant (Egozcue et al, 2006). This transformation is widely used, not only for economic variables but also in several areas such as geophysical analyses (Egozcue et al, 2006; Sánchez-Arcilla et al, 2008). The explanatory variables were described on Table 2. The subscript *i* on climate and some water variables refers to the three months periods (*i* = *def* (Dec, Jan, Feb), *mam* (Mar, Apr, May), *jja* (Jun, Jul, Aug) and *son* (Sep, Oct, Nov)).

Table 2. Description of variables

Type of variable	**Name**	**Definition**	**Unit**	**Source of Data**
Economic	Y_t	Crop yield at a site in year t	t / ha	MARM
	GAV_t	Gross added value of agriculture a site in year t	K€ current prices	MARM and INE
	L_t	Total employment of agricultural sector at a site in year t	People (thousands)	Labour Force Survey (LFS). INE
Water	$Irrig_{it}$	Net water needs of crops in the ith month in year t	m / month	Planning Hydrographic Office - CHEBRO
	$Prec_{it}$	Total precipitation in the ith month/ 3 month period in year t	mm / month	AEMET
Managment	Mac_t	Machinery in year t	Nº (thousands)	FAO
	I_t	Irrigated area by crop type	ha	MARM
Geographic	$Altitude_t$	Variables indicating 0-600, 601-1000 and more than 1000 meters		INE
	$Area\_ebro_t$	Dummy variables indicating the 3 main areas of the basin: Northern, Central and Low Ebro		Own elaboration
Climate	T_Max_{it}	Maximum temperature in the ith month / 3 month period in year t	° Celsius	AEMET
	T_Mean_{it}	Average temperature in the ith month / 3 month period in year t	° Celsius	AEMET
	Fr_{it}	No. of days with temperatures below 0° C in the ith month/ 3 month period in year t		AEMET
	Dro_t	Dummy variable indicating drought years	1 or 0 as a function of SPI critical value	SPI calculated from AEMET precipitation data

Agricultural time series are nonstationary since they always present a trend. When variables are nonstationary, normal regression analysis requires a transformation of the data. When there is not enough information about the causes of a such trend, the transformation needed to generate a stationary variable may be attained by simply removing deterministic trends (that is by directly subtracting the trend value from the observations or "detrending"); by taking first-differences, that is the variable in year t (Yt) minus the variable in year t-1 (Yt-1); or by introducing and autoregressive term as a the independent or explanatory variable (Iglesias, Quiroga, 2007). In our case, we assume that there is a causal relationship between yield increase and technological change, and therefore we consider a management variable, the farm equipment power (Mac), to explain yield trend. A range of management indicators such as farm equipment power (Mac), tractors (Trac), nitrogen fertilizer (Fert), pesticide consumption (Pest), or seeds improvement (Seed) have a high correlation (Quiroga and Iglesias, 2010) since they can be considered as a proxy variable for technology and investment in a farm or in the farming sector of a district or country (see Figure 2).

Figure 2. Evolution of management indicators: farm equipment power (Mac), tractors (Trac), nitrogen fertilizer (Fert), pesticide consumption (Pest), or seeds improvement (Seed). Source: Quiroga and Iglesias, 2010.



We used OLS to estimate the coefficients, this is a statistical technique used to compute estimations of parameters and to fit data by generating a line that minimizes the sum of the squared vertical distances from this to the observed responses, in other words, OLS method minimizes the sum of squared residuals. To facilitate the improvement of particular model estimation for each crop, 95% confidence intervals were estimated assuming normality of the residuals, and significant relations were considered into the estimated model. White's general test (White, 1980) was used to check conditional heteroscedasticity under null hypothesis (Ho) of homoscedasticity or constant variance (Johnston and Dinardo, 2001). Heteroscedasticity exists when the variance of the error term is different for each sample observation. Durbin-Watson statistics are used to check errors autocorrelation existence (Durbin and Watson, 1950). This problem arises when, with time series data, the error terms for different periods are correlated.

When the parameters β_i are estimated, the marginal effect of a change in the explanatory variables is given by:

$$\frac{\partial E[\ln Y | X_i]}{\partial X_i} = \beta_i \quad [4]$$

The signs and magnitude of the marginal effects indicate the effect of a particular input variable X_i over the crop yield. In this case, the coefficients of the model have to be interpreted as semi-elasticities because the model presents a semi-logarithmic transformation. The interpretation is that semi-elasticity is responsible for the percent increase of yields produced by a unit change in the input variable.

In the Ebro basin there exists a very high variability in precipitation and it is common to observe that recurrent drought periods affect agricultural production. To date, it is difficult to characterize droughts because of their spatial and temporal properties and the lack of a universally accepted definition (Tsakiris et al., 2007; Hayes 2004; Keyantash and Dracup, 2002; Bradford, 2000). In this work, we use the frequently used Standardized Precipitation Index (SPI, McKee et al., 1993). This index, based on the probability of precipitation for any time scale, calculates the difference in accumulated precipitation between a selected aggregation period and the average precipitation for that same period. The calculation of the SPI for any location is based on the long-term precipitation record for a desired time. This long-term record is fitted to a probability distribution, and is then transformed into a normal distribution, implying values that vary around 0. This allows areas with different climates to be relatively compared (McKee et al., 1993; Steinmann et al., 2005). We have selected 12 months as the aggregated period for calculation. To define the criteria for a drought event we follow McKee et al.'s (1993) table where a drought event occurs when SPI values are -1.0 or less (see Table 3). This criterion was followed in previous detailed works in Spain (Iglesias et al., 2007; Garrote et al., 2007). We, then, construct a dummy variable that equals 1 if the year t is a drought year (with SPI smaller than -1) and 0 in other cases.

Table 3. SPI Values and drought intensities

SPI Values	
2.0 o more	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
−0.99 to 0.99	near normal
−1.0 to −1.49	moderately dry
−1.5 to −1.99	severely dry
−2 and less	extremely dry

Due to the large number of correlated variables the selection of explanatory variables for model specification is important. Greene (2003) shows two alternatives to follow: (a) an inductive approach, which consists in starting with a reduced model and amplifying it by including more variables to a general model. The main problem associated with this approach is that the computed statistics can be biased and inconsistent if the hypothesis is incorrect. (b) A deductive approach, which consists in starting with a given general model to set up a correct fitted model. This approach is frequent in recent analyses since, although inefficient, the estimates and test statistics computed from this over-fitted model are not systematically biased. We therefore, we use the second approach in this paper. As usual the choice of the explanatory variables to include in the final specification follows a deductive approach based on the Akaike (1973) and Schwarz (1978) criteria and adjusted R squared criteria, which are widely used to describe the goodness of model parameterization. A full description of the methods can be found in Greene (2003). To complete this process of variable selection, we observe a strong relationship between some of the explanatory variables which might be a source of collinearity problems. To detect a potential problem in each regression, we calculated the variance inflation factor (VIF) for each of the explanatory variables:

$$VIF(x_k) = \frac{1}{1 - R_k^2} \qquad [5]$$

VIF represents the squared standard error (or sampling variance) of $\hat{\beta}_k$ in the estimated model divided by the squared standard error that would be obtained if x_k were uncorrelated with the remaining variables (Chatterjee and Hadi, 2006). So we have a VIF factor for each variable. Then, we follow the following criteria: (i) values larger than 10 give evidence of collinearity and, (ii) a mean of the VIF factor considerably larger than one suggests collinearity. We then proceed to eliminate variables which have a VIF value larger than 10. The criteria for elimination of variables when collinearity exists have been to eliminate the variable presenting lower impact on the goodness of model. We proceed in an iterative way when collinearity persists.

2.4 Agricultural added value

Agricultural added value variations are characterized as a function of crop yields as follows:

$$\ln GAV_t = \alpha_0 + \alpha_i \ln Y_{it} + + \varepsilon_t \qquad [6]$$

Where the dependent variable ($\ln GAV_t$) is the natural logarithm of agricultural gross added value for a site in year t and the subscript *i* refers to the different crops considered and α_0, α_i are parameters. In this case, the coefficients of the model can be understood as elasticities because the model presents a logarithmic transformation. The interpretation is that elasticity is responsible for the percent increase of yields produced by a one percent increase in the input variable. The coefficients have been estimated by OLS and diagnostic tests were conducted as in the crop-water production function estimation process.

2.5 Montecarlo risk analysis

Risk analysis bridges the gap between impact evaluation and policy formulation by focusing policy's interest on consequences (i.e. crop yield) rather than agents (i.e. rainfall or irrigation). There are many definitions of risk but, in a wide sense, risk can be defined as the capacity of a system to suffer losses when it is exposed to an external stressor. In this paper, the probability distribution of production functions for each crop is estimated using the Montecarlo method, which is a key component of uncertainty and probabilistic risk evaluation, since it allows us to generate random samples of statistical distributions to measure risk (Robert and Casella, 2004; Iglesias and Quiroga, 2007; Hammersley and Handscomb, 1975). The approach consists of generating a synthetic series of yield variables using the Monte Carlo method and Latin Hypercube sampling (Just and Weninger, 1999; Atwood et al., 2003.).

In agriculture, Montecarlo simulation offers a flexible and accurate approach for investigating and understanding statistical properties of crop yield in response to inputs like irrigation and rainfall (Lobell and Ortiz-Monasterio, 2006). In terms of water policy, we analyze marginal effects on the statistical model to calculate how a reduction in irrigated area could affect crop yield (Iglesias and Quiroga, 2007; Llop, 2008). Using Montecarlo simulations we obtain 10,000 random values of statistical distributions of every crop yield and then analyze the distribution of probabilities to obtain a certain yield (risk level).

2.6 Water policy scenarios

Under climate change, drought events in the Mediterranean are likely to increase in frequency, duration and intensity and thereby affect crop production in Spain. The understanding of the dynamics of extreme events, including droughts, in future climate scenarios for the Mediterranean is being improved continuously. Although we do not analyse climate change scenarios of runoff, we explore policy implications if runoff is reduced. It is clear that River Basin Management Plans need to be revised to cope with Water Framework Directive (2000), and information about the consequences of changes on water allocation for irrigation and changes on irrigated land is relevant for the decision-making process. In this paper we present information to deal with these alternatives: (i) a risk analysis for changes on water allocation, (ii) theoretical policy scenarios analysis for changes on irrigated land. These policy scenarios are not directly linked to climate change scenarios of runoff. However we present an impact assessment exercise quantifying the implications on agricultural yield of water restrictions, what we think is a necessary first step to discuss possible policies.

We have evaluated three policy scenarios considering a reduction of agricultural irrigated land of 10%, 20% and 30%. These scenarios are consistent with a perspective of increased water scarcity and reflect the policy implications of environmental concerns. The European Water Framework Directive states that it is necessary to restore and conserve the ecological health of rivers, thus the Hydrological Plan of the Ebro Basin must accommodate the irrigated land area, review current concessions and seriously consider the removal of salinised irrigated areas as well as those that consume too many resources due to their low profitability. On the other hand, the establishment of environmental flows in some sections of the Ebro Basin Rivers means that current irrigation areas will have to be reduced. Currently, there is a provisional minimum flow of between 5% and 10% of current annual average flow which is made by sections. It is important to observe that the minimum ecological flow in the Ebro river mouth has been set at 100 m^3 seg^{-1}. This amount is practically arbitrary, due to the absence of more detailed studies. At this moment, some complementary actions are being taken in order to improve the systems' basin efficiency. For instance, existing or future infrastructure needs to respect the minimum ecological flow required downstream (Herranz-Loncán, 2008; CHEBRO, 2004).

Also, it is well known that irrigated area is a crucial element when talking about agricultural water demand. In Table 4, we can observe a summary of irrigated areas by Community. These are grouped by large and small irrigation systems for each of the nine Autonomous Communities contained within the basin. According to the CHEBRO, the existing concessional irrigated areas' demand, in the current situation of distribution by crop, is 6310 hm^3 $year^{-1}$ while the current concessional irrigable area is 783,948 ha. Here, Aragón and Cataluña account for more than 77% of this area. It is important to say that this demand does not coincide with the annual supplied volume, which depends on the actually irrigated area, and the actual of annual crops among other factors (CHEBRO normative).

Under a hydrologic-hydraulics point of view and according to the regulation and concessional guidelines' adaptations, the maximum possible irrigation area in the future will reach 985,999 ha, corresponding to a demand of 8,213 hm^3. Under the same assumptions, it would expand to a maximum irrigated area of 1,271,306 ha with a demand of 9,879 hm^3. This represents partial increases of 202,051 ha and 285,307 ha for each of the two horizons. However, the effective development of these areas will depend on agricultural policy decisions taken by competent institutions. Nevertheless, the COAGRET Report (2007) says that the establishment of future environmental flows on some river sections will imply cuts in current irrigation extensions in order to follow the statements of the Water Framework Directive. It is therefore difficult to think about an increase in those ha.

Table 4. Irrigated area by irrigation systems

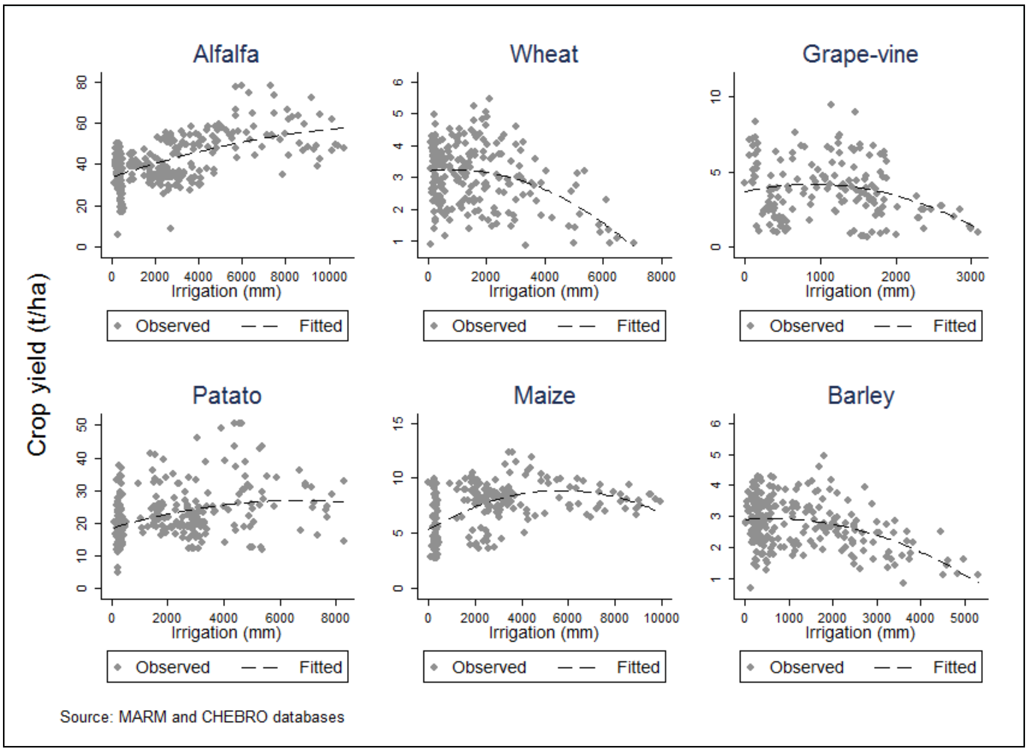
Region	Irrigation Area and Porcentages					
	Large systems		Small systems		Total	
	ha	%	ha	%	ha	%
Aragón	237,813	52.2	161,721	49.1	399,045	50.9
Cantabria	0	0.0	553	0.2	553	0.1
Cataluña	160,625	35.3	46,316	14.1	207,036	26.4
Castilla - La Mancha	0	0.0	241	0.1	241	0.0
La rioja	17,584	3.9	34,864	10.6	52,448	6.7
Castilla - León	0	0.0	8,913	2.7	8,913	1.1
Navarra	39,359	8.6	48,407	14.7	87,766	11.2
Valencia	0	0.0	275	0.1	275	0.0
País Vasco	0	0.0	27,277	8.3	27,277	3.5
Total land area	**455,381**	**100.0**	**328,568**	**100.0**	**783,948.69**	**100.0**

3 Results

3.1 Crop-water production functions and agricultural added value

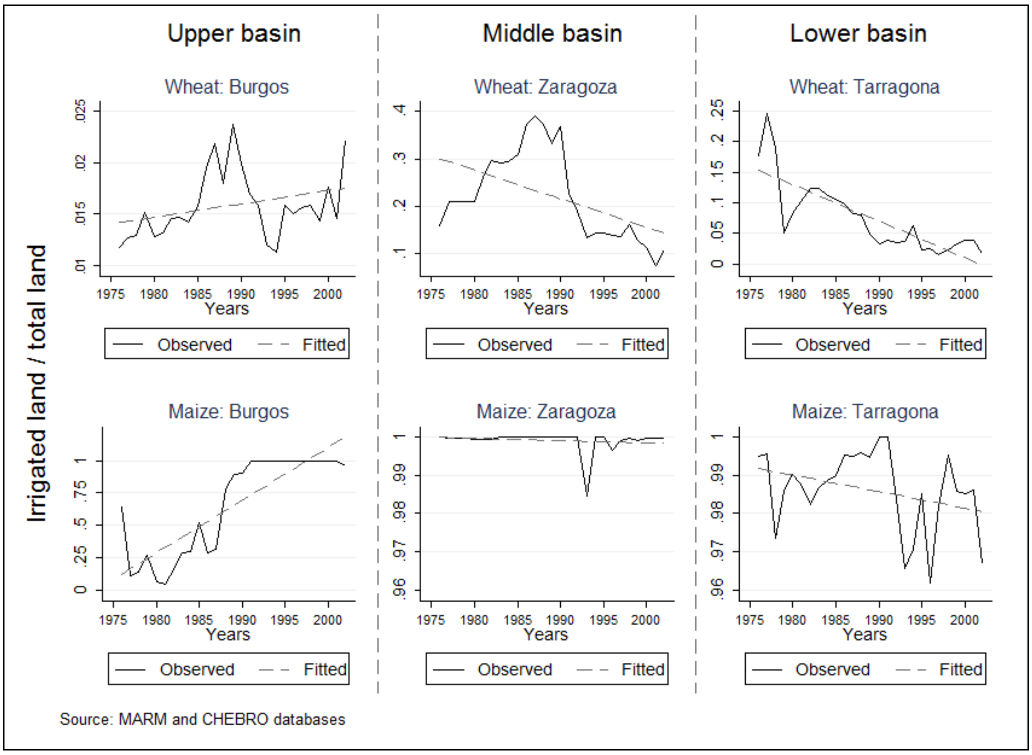
The relationship between crop yields and amount of water for irrigation in the six representative crops varies with crop and location (Figure 3). The relationship between crop yield and irrigation is obviously positive in an initial phase but the marginal decrease to scale. For alfalfa, potato and maize, the most irrigated crops considered, the decreasing phase is not observed within the range of irrigated values considered in this study. For wheat, barley and grapes, optimization of the amount of water is essential. In these crops, additional water beyond a threshold results in reduced output. Rice is not shown since it is always irrigated nor are olives since the amount of irrigated land in this region is relatively small compared to the irrigated land of the other crops.

Figure 3. Observed crop response to irrigation water applied



Irrigated land has evolved differently for each crop and area considered (Figure 4). In the upper basin (Burgos province) the proportion of irrigated area for the cereals crops increases during the period of analysis. This increase is a result of the lack of water scarcity problems in this part of the basin during the period of analysis. In contrast, in the middle basin (Zaragoza province) and the lower basin (Tarragona province) the trend is clearly downward, except in the case of maize in Zaragoza, where the tendency is almost constant. This reflects an increased limitation of irrigation due to prioritization of water for the environment.

Figure 4. Irrigated land for wheat and maize at representative areas of Upper (Northern, Central and Low Ebro: Burgos, Zaragoza and Tarragona.



We estimated crop-water production functions that explain the influence of water on crop productivity and also incorporate a wide range of variables (Table 5). The increasing trend in crop productivity is explained largely by technological and management variables. We assume that yield increases due to improved varieties are linked to more intensified management. We tested the adequacy of the functions to represent crop-water production functions as outlined in the methods section; in the cases where regressions present heteroskedasticity, these are estimated with the White method (1980) to obtain robust estimates (following Wooldridge, 2003).

In general the eight crop-water production functions present the expected signs according to the agricultural processes. Irrigation for alfalfa, wheat, rice, potato, maize and barley present a positive impact on the crop yield but this decreases after a given amount of water. Irrigation is not statistically significant for grapevine and olive yield. This may be due to the small area of these crops under irrigation and to the fact that irrigation in these crops is "deficit irrigation" used only to maintain yield during drought periods. Irrigation area also has an important impact on alfalfa, wheat, grapevine, potato, maize and olive. For this last crop, the effect of irrigation area is the largest. In contrast, drought does not show significant impacts for all irrigated crops. Only wheat, barley, and grapevine have negative significant impacts in this variable probably because these crops are rainfed. In other words, except for olives, irrigated crops do not show evidence of significant impact of drought on their yield. The quantity of machineries has a positive effect after one period (Mac(-1)) or even two periods (Mac(-2)). That can respond to a lag in the investments on machinery. In the case of agricultural labour, the variable is at macro level and the negative effect is responding to the decreasing returns to scale when additional labour force move to agricultural sector.

Table 6 shows the estimated profit function for each crop yield. The estimation of this function has been considered for all crops; however, we only took into account those that are significant. In other words the effects may be poorly specified for crops that are not represented in the entire geographic area. We note that when yields of alfalfa, maize, potatoes and wheat increase by 1 unit, the agricultural gross added value increases.

A strictly economic analysis might suggest the desirability of a stronger orientation of production towards wheat and maize, because an increase in the yield of these crops has a major impact on the region's agricultural GAV. However, this does not take into account the cost of virtual water. Even though today the Ebro Delta does not present problems of availability of water; the problems associated with the necessity of large amounts of irrigation water that are caused due to factors such as the crop's characteristics, natural ground permeability and capillary rise of salt water should not be ignored. Therefore, an analysis of water risk management is necessary. In the next section, we analyze the water risk of the selected crops and the impacts of potential changes in water policy. It is important to note that the contribution to the gross added value includes direct payments linked to crop productivity during the period of analysis (before 1986 from the agricultural policy in Spain and since 1986 from the EU Common Agricultural Policy). The recent decupling of productivity and payments, especially since 2008, may change the relative contribution of each crop to the gross added value.

Table 5. Estimated coefficients of crop-water functions, robust t-statistics and R^2

	Alfalfa	**Wheat**	**Rice**	**Grapevine**	**Olive**	**Potato**	**Maize**	**Barley**
$Ln(Y_{t-1})$				0.4441 [4.73]***				
L							-0.0116 [3.66]***	-0.0118 [3.66]***
Mac	-0.0067 [2.05]**	-0.0103 [3.19]***			0.0022 [4.74]***	0.0013 [9.62]***	0.0010 [5.61]***	0.0007 [3.25]***
Mac_{t-1}	0.0069 [2.16]**	0.0109 [3.39]***		0.0010 [3.39]***				
Mac_{t-2}			0.0005 [1.73]*					
$Altitude_{(0-600)}$		-4.80E-05 [4.24]***		-6.20E-05 [4.41]***				
$Altitude_{(601-1000)}$	-2.06E-05 [4.05]***	2.58E-05 [1.69]*						2.66E-05 [1.86]*
$Altitude_{(+1000)}$	-1.49E-05 [3.36]***	-8.94E-05 [6.54]***		-6.57E-05 [4.01]***			-1.38E-05 [2.16]**	-6.53E-05 [4.89]***
Cent_ebro	-0.0412 [1.28]	-0.1006 [1.69]*		-0.0781 [1.56]			-0.2954 [6.32]***	-0.2646 [4.15]***
Northern_ebro	0.2226 [4.53]***	-0.4780 [2.97]***		-0.3589 [3.08]***			-0.3249 [5.22]***	-0.6043 [4.07]***
Irrig_area	0.8531 [9.65]***	0.5964 [3.75]***		0.9993 [4.53]***	1.6479 [4.22]***	0.5693 [11.41]***	0.7691 [9.00]***	
Irrig	0.0963 [7.10]***	0.2024 [4.73]***	0.1543 [2.08]**			0.0355 [2.08]**	0.0766 [3.35]***	0.2496 [5.19]***
$Irrig^{\wedge 2}$	-0.0083 [5.69]***	-0.0447 [6.59]***	-0.0213 [1.89]*			-0.0002 [0.08]	-0.0027 [1.38]*	-0.0649 [6.24]***
$Prec_{def}$					0.0015 [2.41]**		0.0006 [3.49]***	
$Prec_{mam}$	0.0010 [6.52]***							
$Prec_{jja}$					0.0017 [2.58]**		0.0006 [2.88]***	
$Prec_{son}$		0.0005 [3.30]***					0.0000 [0.20]	0.0004 [2.33]**
$Prec_{year}$						0.0001 [1.80]*		
T_Max_{def}							0.0059 [2.17]**	
T_Max_{mam}		-0.0098 [3.39]***						-0.0133 [4.33]***
T_Max_{jja}				-0.0099 [3.10]***	-0.0273 [3.34]***			
T_Max_{son}		0.0092 [2.35]**					0.0069 [1.88]*	0.0187 [5.03]***
T_Mean_{year}	0.0474 [4.12]***	-0.0879 [3.00]***	0.0377 [2.24]**			-0.0685 [10.02]***	-0.0602 [2.95]***	-0.1394 [5.40]***
Fr_{def}		-0.0022 [1.67]*						-0.0019 [1.41]
Fr_{mam}		-0.0090 [1.66]*			-0.0297 [2.80]***			-0.0117 [2.53]**
Fr_{son}					0.0303 [2.79]***	-0.0120 [4.06]***	-0.0069 [2.11]**	
Dro		-0.1281 [2.22]**		-0.1328 [1.97]*				-0.1737 [3.75]***
Constant	2.3298 [13.36]***	2.4157 [5.08]***	0.5408 [1.60]	1.4124 [4.13]***	0.3029 [0.36]	2.5529 [15.34]***	0.6545 [1.83]*	2.4135 [5.05]***
Adj R-squared	0.65	0.63	0.17	0.84	0.41	0.62	0.77	0.55
White test: p-value	0.0008	0.4362	0.3695	0.0380	0.6504	0.0000	0.0154	0.5003

t statistics and robust t statistics in brackets, * significant at 10%; ** significant at 5%; *** significant at 1%

Table 6. Estimated coefficients of profit function (logarithm of the gross added value), robust t-statistics [in brackets] and R^2

	Coefficients
Yield_Alfalfa	0.04
	[4.58]***
Yield_Maize	0.11
	[3.56]***
Yield_Potato	0.02
	[2.49]**
Yield_Wheat	0.20
	[2.80]***
Constant	9.31
	[22.08]***
Observations	133
R-squared	0.31

Robust t statistics in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

3.2 Montecarlo risk analysis

Statistical properties of crop yield in response to water patterns were derived using Montecarlo simulations in order to asses risk levels. Figure 5 shows the cumulative density probability functions where significant differences in risk levels between crops can be observed. According to these cumulative distribution functions, the probability of having low yields is higher for olive, barley and wheat and lower for alfalfa and potato.

Figure 5. Cumulative density probability function of crop yield

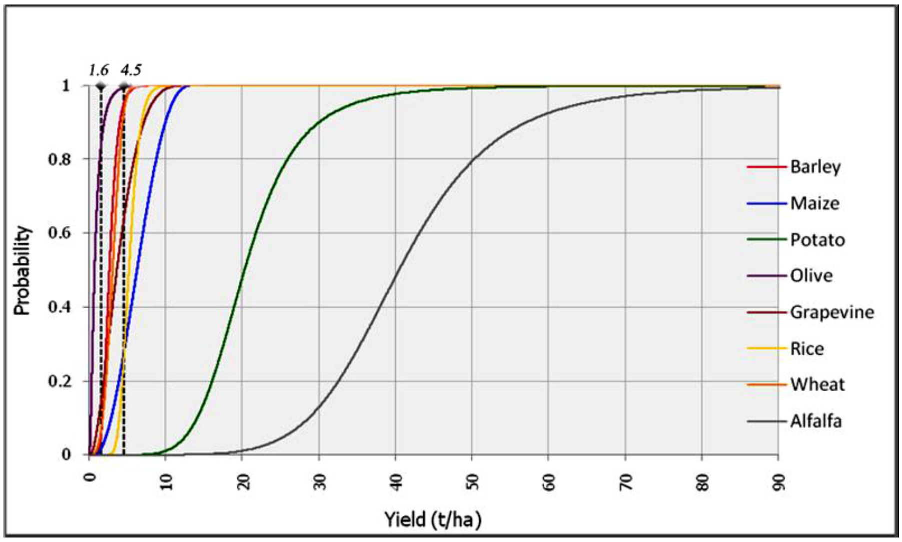
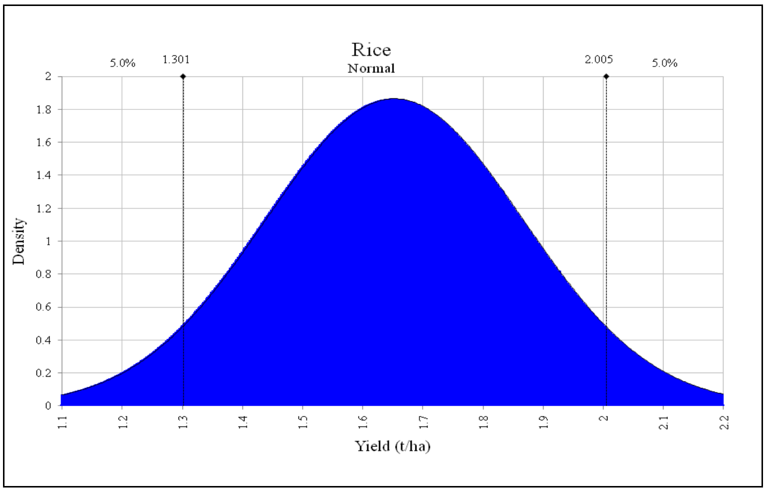


Table 7 provides the detailed statistical properties from Figure 5. Rice and alfalfa present a low variation coefficient (CV) while olive and grapevine have a high variability. On the other hand, we observed that the Skewness coefficient is above +1 in potato, olive, alfalfa and barley, indicating that they have an elevated probability of obtaining results above the mean. Also, the skewness coefficient is greater than 0, indicating that there is no large probability of having a low yield. The kurtosis coefficient for every crop yield is lower than 3, and we have a platykurtic distribution that indicates that the probability distribution functions of the crop yields have a wide peak (a lower probability than a normally distributed variable of values near the mean) and thin tails (a lower probability than a normally distributed variable of extreme values). Figure 6, presents the distribution function for rice, which is practically normal.

Table 7. Statistical properties of yield simulations

	Alfalfa	**Wheat**	**Rice**	**Grapevine**	**Olive**	**Potato**	**Maize**	**Barley**
Mean	42.149	3.092	5.343	3.973	0.970	21.602	6.352	2.814
Median	40.472	3.083	5.222	3.555	0.744	20.293	6.184	2.671
SD	12.565	0.995	1.157	2.300	0.781	7.705	2.648	0.933
CV	29.810	32.196	21.661	57.893	80.457	35.668	41.692	33.171
Maximun	183.797	7.150	13.232	11.513	7.307	162.001	13.075	9.475
Minimum	8.909	0.175	2.188	0.167	0.039	4.661	0.542	0.777
Skewness	1.547	0.088	0.668	0.678	1.843	2.984	0.216	1.029
Kurtosis	9.759	2.736	3.859	2.771	7.786	28.900	2.246	4.908

Figure 6. Distribution function of simulated rice yield in the low Ebro. Normal distribution with mean=1.62 and SD=0.21.



3.3 Water policy scenarios

Although irrigation contributes to social welfare in many regions, it cannot be rural development's the sole concern. As we mentioned before, nowadays there are no explicit restrictions on the irrigation area in the Ebro basin. However, within the context of increases of water demands and policy developments such as the Water Framework Directive restrictions, it is necessary that the Basin Plan consider adaptation measures such as changes in irrigated land to cope with environmental and sustainability constraints. Thus, we propose three possible scenarios, in which we assume a reduction of the irrigated area by 10%, 20% and 30%. Table 8 shows the yield changes responding to these scenarios.

Table 8. Yield changes for irrigated area policy scenarios

Decrease in irrigated land	**Changes in crop productivity**					
	Alfalfa	**Wheat**	**Grapevine**	**Olives**	**Potatoes**	**Maize**
-10%	- 4.8	- 0.7	- 1.5	- 2.2	- 4.3	- 4.8
- 20%	- 11.2	- 1.4	- 2.9	- 4.4	- 8.4	- 9.4
- 30%	- 15.5	- 2.0	- 4.3	- 6.6	- 12.3	- 13.7

Yield decrease

0 to -5%

-5% to -10%

< -10%

A substantial decrease in irrigated land, of up to 30 % of total, results in only moderate losses of crop productivity. The response is crop specific, wheat is the least affected and alfalfa is the most affected. These results contrast with the relative importance of the crop as measured by the gross added value (Table 6). Both indicators, the gross added value and the changes in crop productivity, are useful to choose adaptation strategies. For example, the contribution of maize to the gross added value is large and the yield is highly reduced as result of irrigated land reduction. Therefore the economic losses of irrigated land reduction in a maize producing area are significant. In contrast, although the yield reduction of alfalfa is comparable to that of maize, the resulting economic loss due to limitation in irrigated land is smaller because alfalfa's contribution to the gross added value is low.

The reductions are consistent given the uncertainty of future policy and our purpose is to show the implications in terms of production risk. Uncertainties of the analysis derive from the imperfect data (e.g., representative climate stations), limitations of the models to represent complex reality (statistical models of yield response are a simplification of the climate, agricultural, and social effects on crop yield), and the assumptions about the future (policy scenarios). Using the models presented in Table 8, we note that these scenarios imply yield losses, ranging from 1% to more than 15%. Regardless of the extent of the reduction in irrigated land imposed by the policy, we see that wheat and grapevine do not suffer major losses in yield performance, whereas alfalfa, potato and maize would be affected considerably given that they are mostly irrigated crops. Since the irrigation area was not significant for rice (which is 100% irrigated), we cannot observe, using this technique, the amount of decrease in its yield would most likely decline. One important factor to consider is the fact that the losses are not proportional. Therefore, the loss is larger when the irrigation area is reduced from 10%-20% scenarios than when it is reduced from 20%-30% scenario. Finally, the reductions in crop yields can be used to estimate the necessary incentives for the implementation of environmental goals (Iglesias and Quiroga, 2009).

4 Conclusions

Water scarcity in the Mediterranean is highly to increase as consequence of climate change and therefore this will emphasise pressures on food production. This paper presents an analysis of the factors that affect eight major crops in the Ebro river basin including latent risks as well as policies that could be implemented. We analyzed the marginal effects on the statistical model to calculate the effect of a potential reduction in irrigated area on crop yield. This study was based on an analysis of demand.

Extended water production functions by crop were estimated. These show the expected signs for most of the variables. Focusing on the hydrological variables, our results show that an increase in irrigation and in the irrigated area has a positive impact on crop yields. However, the impact of irrigation is not always positive given that after a certain quantity of water supplied to the crop, yield begins to decrease (negative sign in irrigation elevated to square).

The precipitation also shows a positive impact on crop yields, except for maize in the *son* quarter (Sep, Oct, Nov), which might be due to excessive water from irrigation, given the usual humidity of this time of the year. A strictly economic analysis might suggest that production could be oriented to wheat and maize, given their impact on agricultural gross value added of the area. However, this does not consider the cost of virtual water. Maize is a major crop in the Ebro Delta, in the low basin, that could suffer a reduction on water availability. An analysis of water risk management is needed. Rice and potatoes show a low variation coefficient, implying low variability. Olive shows low yield and high variability in this area, although under a reduction in irrigated area scenario, this crop is not severely affected. Potato, maize and alfalfa are the ones most affected by a reduction in irrigated area, because they are mainly irrigated crops.

We present crop responses to different policy scenarios of reductions on irrigated area. In a climate change context, more and more severe drought events are expected to happen in the Ebro basin. This could lead to the river basin management authority to reduce water availability. Although the national irrigation plan consider increases in irrigated land and some efforts are being made to make the irrigation systems more efficient, trying to reduce water consumption for agriculture, such an increase won't be likely to occur. Instead of this, we have considered the consequences for crop production of three policy scenarios where irrigated area is reduced. We quantify the implications on crop productivity and agricultural value added. To assess optimal water management among different crops it is necessary to know the priorities of policy-makers, since the large loss of production is not the main economic loss. Some crops are linked to rural landscapes or customs that sometimes is important to maintain, water demand is different for each crop and also economic revenues, so there is not a unique crop mix that minimize losses, since the definition of loss depends on the objectives. A multicriteria analysis can be performed in a further step, but it has not been addressed here. Finally, the methodology presented here can be extended to examine additional factors that affect crop yield and interact with water demand, such as climate change, irrigation systems, and fertilizer application.

Finally, here we present a list of limitations of our study:

1. Limitations to our study may arise from the simplicity of the statistical models to represent the complex reality and the quality of the observed data. Then, to obtain a better representation of the complex reality, we introduce linkages between socio-economic and biophysical aspects.
2. The estimation of production functions is controversial; however each approach has strengths and weaknesses. Here, we used the Cobb-Douglas production function because its simplicity and validity in terms of the estimated coefficients and its applicability in agricultural economics. However, one weakness of the Cobb-Douglas production function is that it excludes an analysis on substitutability and complementarity between inputs due to the nonexistence of cross-product terms involving these inputs.
3. We do not take into account that unobserved heterogeneity exists. We assume that the regressor is not endogenous, Cov(X, u) = 0, then OLS estimation is consistent.
4. The assumptions about the future, we use theoretical policy scenarios analysis for changes on irrigated land; however these policy scenarios are not directly linked to climate change scenarios of runoff.

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Chapter 3. Do water rights affect competitiveness and social disparities of crop production in the Mediterranean?[2]

Abstract

Due to the increasing water conflicts among sectors induced by climate change, the crop response to water pressure is one of the main concerns of adaptation policy. This paper evaluates the effect of changes in irrigation rights, as a policy instrument, over the efficiency and distribution of crop yields in the Ebro basin in Spain. Our analysis includes two components. First, we calculate a stochastic frontier production function for five representative crops using historical data to estimate technical efficiency. Second, we use a decomposition of the Gini coefficient to estimate the impact that changes in irrigation areas, have on yield inequality. Our results show that reducing the allowed irrigated area, which could be a potential policy response to face the environmental requirements of the EU Water Framework Directive, could have long term implications affecting farmer's competitiveness and increasing rural disparities.

Keywords: *Technical efficiency, yield inequality distribution, crop yield, climate change adaptation, water policy, agricultural policy.*

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1 Introduction

Agricultural sector is the largest user (over 70%) of total available water resources in the world. Given this figure and considering that irrigation is the most water demanding process in this sector, changes on water rights affecting irrigation activities are likely to play an important role in the sustainability of worldwide ecosystems (Bruns and Meinzen-Dick, 2000). However, due to wasteful irrigation schemes, agricultural water use is often very inefficient and only a fraction of the water consumed by this sector is in fact used for plant growth (Chakravorty and Umetsu, 2003; Pan, et al. 2003; FAO, 2002; Seckler, 1996). This limitation on water resources management includes Spain and many other European Union states (Gómez-Limón, et al., 2002).

Climate change will probably increase water conflicts among sectors, and then reductions in the water available for irrigation could be important to attend the environmental flows restrictions. Agricultural research has given priority to the adaptation of crop yields to water pressure focusing in the incentives to increase water efficiency (Gómez-Limón, et al., 2002). However, an important instrument used by water authorities is the management of irrigation rights. Then, reductions in irrigation water supply or reductions in irrigated areas are two possible instruments to have important water savings. It seems that at least in the short term, important reductions in irrigation area could imply not so severe effects in crop production (Liu, 2007; Pender and Gebremedhin, 2006), especially for cereals (Quiroga et al., 2011a). This paper focuses on the long run effects of irrigation area reductions on farm technical efficiency and income distribution. Our study is centered on the Spanish Ebro river basin, which is located in the Northeast of the Iberian Peninsula in the Mediterranean region. Nowadays, there are not explicit restrictions on the irrigated area in the Ebro river basin, but there exist big socio-economic conflicts about the possibility of transferring water to other highly stressed basins in the area.

According to the implementation's timetable of the Water Framework Directive (WFD), in the short run, EU members must accomplish environmental objectives. Focusing on the economic part, the WFD introduces two key principles. (i) It solicits to water consumers, as industries, farmers and households, to pay the costs of water related services they receive. (ii) The Directive calls on Member States to include economic analysis in the assessment of water resources (in example, characterization), and examine profitability as the costs and benefits of diverse options in the decision-making process. So, it is necessary an economic evaluation of water management activities. The review of current concessions of the irrigated land area can be a potential policy instrument to accomplish the legal requirements of the WFD (Atwi and Arrojo, 2007; Quiroga, et. al., 2011a).

Irrigated agriculture production is highly influenced by the EU policies. In particular, analyzing the interrelationship between the implementation measures to comply with WFD and the changes in the Common Agricultural Policy (CAP) will be determinant for the river basin decision makers in the near future. Since its introduction in 1962 CAP has been in constant evolution through successive reforms. Here we focus on the MacSharry reform (1992) which introduced the system of direct payments during 1993-1999, and was extended by Agenda 2000 (2000-2004). The main aim of the CAP is to promote higher liberalization and competitiveness of European agriculture at the international level, however, this objective seems to be opposed to the environmental character of the WFD. Then, there is important to have a greater knowledge about the impacts of the both policies over crop yields.

In this paper we focus on the analysis of the implications of water demand reduction for agricultural use based on the decrease of irrigated areas, taking into account CAP reforms and other related variables. Our analysis considers two economic aspects: (i) First we analyze the changes in the efficiency of the agricultural systems. For this purpose, we have estimated a stochastic frontier production function-- a Cobb-Douglas specification-- for the main crops in the area in the base of historical data for the Ebro basin in Spain. Our production functions and technical efficiency specifications depend on socioeconomic and biophysical factors as well as interactions of both. All crops have been estimated individually in order to examine how technical efficiency is related to water management variables but also crop specific. (ii) Second, we have explored the distributional aspects computing the marginal effect of irrigated area over crop yield inequality, using a decomposition of the standard Gini coefficient. The measurement of agricultural technical efficiency and its distribution provides information on the competitiveness and allocation of the crops in a particular region and the potential to increase their productivity considering social impacts.

The paper is structured as follows: (i) Second section shows the description of the all used variables and the two methodologies we use. (ii) Third section shows and describes the main results on efficiency and inequality distribution for some crop yields in the basin. (iii) Final section presents the conclusions of this paper. Figure 1 shows a general perspective of the paper objectives, methods and findings.

Figure 1. Steps on the study

Question	**Methods**	**Findings**
What is the effect of changes in irrigation areas, as a policy instrument, over the efficiency and distribution of crop yields?	An stochastic frontier production function with technical inefficiency effects. A decomposition of the Gini coefficient .	Production functions and factors affecting technical efficiency over time. Irrigated area as source of social distribution crop yield.
Discussion	Impacts on crop competitiveness and social disparities of changes in irrigation rights.	

2 Methods

In this paper, we apply technical efficiency and inequality measures to explore the impacts of changes in irrigated areas on production functions, considering water policies, socio-economic, agricultural and environmental effects. We integrate two current methodologies. First we estimate a stochastic frontier production function to analyze technical inefficiency effects. Then we calculate the Gini index and the factors decomposition of this index to evaluate inequality effects.

2.1 Data

We focus our analysis on five crops in Ebro basin. These crops are the most representative according to the total agricultural area in the basin: alfalfa, wheat, grapevine, maize and barley. They account for almost 55% of the total agricultural area in this region. Barley, grapevine and wheat are primarily rainfed crops while alfalfa and maize are mainly irrigated

(Table 1). Wheat, barley and maize are cereals of prime importance in Spain, as well as, in all EU Member States. This kind of crops occupies 40% of the total used agricultural area in the EU and about 47% in the Ebro basin. Spain is the first European country in the production of dried alfalfa; besides in 2010 it became the second main exporter of this crop (Spanish Association of Manufacturers of Alfalfa dehydrated - AEFA). Last, Spain is one of the largest wine producers in the world in terms of planted area, production and value, where the Ebro Basin plays an important role in terms of high added value.

Table 1. Percentage of agricultural area and prevalent crop system by crop

Crop	**% of the total agricultural area**	**Dominant cropping system**
Wheat	17.0 %	Rainfed
Barley	26.4 %	Rainfed
Maize	2.2 %	Irrigation
Alfalfa	4.4 %	Irrigation
Grapevine	4.2 %	Rainfed
Total	54.2 %	

We use an unbalanced panel of observed historical data for the period 1976-2002 and for 15 provinces in the Ebro river basin. This, involves the advantage of a large number of degrees of freedom for estimation parameters, and allows the examination of technical efficiency change over time. The socioeconomic and geographical differences among provinces confirm the insertion of climate and environmental variables into this study. A full description of the variables considered in the study and the data source are summarized in Table 2.

Table 2. Description of variables

Type	Name	Definition	Unit	Source (*)
Socio-economic and management factors	Y_{it}	Crop yield at a site in year t	T/ha	MARM
	L_{it}	Total employment of agricultural sector at a site in year t	1000 people	LFS; INE
	$Tech_{it}$	Principal component analysis (PCA) of fertilizers and machinery in year t	Standardized units	Own elaboration from FAOSTAT
	$Irrig_{it}$	Net water needs of crops in year t	mm / month	CHEBRO
	$Irrig\_area_{it}$	Irrigated area by crop type	ha	MARM
	$\%Irrig\_area_{it}$	Irrigated area by crop type as proportion of total agricultural area (%)	Ratio	MARM
	HDI_{it}	Human Development Index at a site in the year t (%)	Index	IVIE; Bancaja
	$MacSharry_t$	Dummy variable equal to 1 after MacSharry Reform introduction in 1994, 0 before this year	1 or 0 as a function of the introduction of the reform	Own elaboration
	$Agenda2000_t$	Dummy variable equal to 1 after Agenda2000 Reform introduction in 2001, 0 before this year	1 or 0 as a function of the introduction of the reform	Own elaboration
	T	Time trend, t=1 for 1976, t=27 for 2002.	Year sequence	Own elaboration
Biophysical factors	$Altitude_i$	Total area in Km^2 by altitude zone: 0-600, 601-1000 and more than 1000 meters of altitude	Km^2	INE
	$Area\_ebro_i$	Dummy variables indicating the 3 main areas of the basin: Northern, Central and Low Ebro	1 or 0 as a function of the area	Own elaboration
	$Prec_{it}$	Total precipitation at a site in the year t	mm / year	AEMET
	T_Mean_{it}	Average temperature at a site in the year t	º C	AEMET
	Dro_{it}	Dummy variable indicating drought year (1 for drought years, 0 in other cases)	1 or 0 as a function of SPI index	Own elaboration from AEMET

(*) Statistical Division of the Spanish Ministry of Environment, Rural, and Marine Affairs (MARM); Labor Force Survey (LFS). Spanish Institute of Statistics (INE); Planning Hydrographic Office Ebro basin Authority (CHEBRO); Spanish Meteorological Agency (AEMET); Valencian Institute of Economic Research (IVIE); Savings Bank of Valencia, Castellón and Alicante (Bancaja).

To characterize a technology indicator (*$Tech_{it}$*), we have incorporated a linear combination of the different kinds of fertilizers (nitrogen, phosphate, and potash fertilizers) and machinery like tractors and combines. These variables were obtained from FAO (FAOSTAT, 2010). These inputs are ordinarily highly correlated and can cause multicollinearity problems in regression analysis. To avoid this problem in the estimation of the model, we generated a new variable called $Tech_{it}$, using principal component analysis (PCA) (Kendall, 1957; Jeffers, 1967; and Jolliffe, 1982; Blattberg, R., et al., 2008). This method consists in combining a large number of variables into a smaller number of related variables, retaining as much information as possible of the original variables. We use the first component which have an Eigenvalue greater than 1 (Eigenvalue of the Component 1 = 4.25) and it explains 85% of the variability of data as an indicator for technology ($Tech_{it}$) (Quiroga et. al., 2011b). In our case, this first component presents high and positive correlations with all the technological factors considered; and then reflects the size of technology. That is, the more quantity of fertilizers, machinery, etc. we have; the higher scores on the first principal component we obtain.

Drought characterization is also difficult, given their spatial and temporal properties and a non-general accepted definition (Tsakiris et al., 2007). To characterize drought (Dro_{it}) in this study, we use the frequently used Standardized Precipitation Index (SPI, McKee et al., 1993). In a broad concept, this index is based on the probability of precipitation for any time scale. It is calculated as the difference in accumulated precipitation between a selected aggregation period and the average precipitation for that same period. The calculation of the SPI for any location is based on the long-term precipitation record for a chosen time. We follow McKee et al.'s (1993) table, to define the criteria for a drought event, where this event occurs when SPI values are −1.0 or less. For this study, we follow previous works in Spain (Iglesias et al., 2007; Garrote et al., 2007). Given that, we create a dummy variable that equals 1 if the year t is a drought year and 0 otherwise.

2.2 Stochastic frontier production function with technical inefficiency effects

The heart of the economic theory is centered on the agent optimizing behavior assumption. However, it is well known that not all producers (or consumers) succeed on solving optimization problem, neither technical nor economic. Given that, it is important to assess the distances to the technical and/or economic frontier. Deviations from the frontier indicate technical inefficiency and can be measure using the stochastic frontier analysis (SFA) with technical inefficiency effects. Among the main advantages of SFA, we can find that this methodology can capture data noise and allows the inclusion of climate variables into the production function to improve the accuracy of estimation; however it is important to keep in mind that SFA could have misspecification problems, see Hoang, V.-N., and Coelli, T. (2011). In this paper, the technical efficient effects of the stochastic frontier production function are modeled in terms of water management variables as irrigated area. One issue of particular interest is whether some crops are more technical efficient in some provinces than others. As we mentioned before, using an unbalanced panel data we investigate technical efficiency change over time.

We consider Cobb-Douglas[3] stochastic frontiers with neutral technological progress in which the technical efficiency effects are modeled for the five different crops in all provinces of the Ebro basin for unbalanced panel data (Battese and Broca, 1997; Battese and Coelli, 1995; and Huang and Liu, 1994). Predicted technical efficiencies of the five crops and estimates of the elasticities of crop production with respect to the different inputs are also included. Technical efficiency measures are the most studied component of productivity because it helps to generate helpful information for policy formulation and farm level decisions focused on the improvement of farm performance. Production functions are obtained in order to estimate their technical efficiency effects and their distribution across the whole basin.

Battese and Coelli (1995); and Huang and Liu (1994) models estimate inefficiency levels of particular economic agents and also explains their inefficiency in terms of possible explanatory variables:

$$Y_{it} = exp(f(x_{it}, \beta) + V_{it} - U_{it}); \; i = 1,....,N, \; t = 1,....T \qquad [1]$$

[3] The Cobb-Douglas production function was chosen because of its simplicity and validity in different works (Zellner et al., 1966, Giannakas et al., 2003). Nevertheless, we also tried to use the trans-log function, but we had problems of collinearity and degrees of freedom problems.

Where Y_{it} is logarithm of the production of the *i-th* "firm" in *t-th* period. $f(x_{it}, \beta)$ is a given function of *kx1* vector of (transformations of) x_{it} inputs of the *i-th* site in *t-th* period of observation and a vector of unknown parameters, β. V_{it} is a vector of random variables accounting for statistical noise in outputs, which is assumed to be *iid*, ($V_{it} \overset{iid}{\sim} N(0,\sigma_v^2)$) and independent of U_{it}, where U_i is a random variable which is assumed as the technical inefficiency in production and is *iid* truncated at zero, $U_i \overset{iid}{\sim} N^+(z_{it}\delta, \sigma_u^2)$.

Our general models for all studied crops follow the next form:

$$ln Y_{it} = \beta_0 + \sum_{j=1}^{J} \beta_j \, ln\, x_{jit} + \beta_{it} t + V_{it} - U_{it} \qquad [2]$$

This formulation (Cobb-Douglas) is frequently used in recent researches. *t* is the time trend; in other words it is a variable added here to measure the Hicks-neutral technical change. According to these models, the technical inefficient is defined as:

$$U_{it} = z_{pit}\delta + W_{it} = \delta_o + \sum_{n=1}^{N} \delta_p z_{pit} + \delta_{it} t + W_{it} \qquad [3]$$

Where, z_{pit} is a *1xm* vector of the all technical inefficiency explanatory variables in a site *i* over time; and δ is an *m*x*1* vector of unknown coefficients. Then the technical efficiency is defined as: $TE_{it} = exp(-U_{it}) = exp(-(\delta_o + \sum_{p=1}^{J} \delta_p z_{pit} + \delta_{it} t + W_{it}))$. Given the assumptions of the model, the predictions of individual "agent" technical efficiencies are calculated from their conditional expectations: $TE_{it} = E[exp(-u_{it}) | \varepsilon_{it}]$. Measures of technical efficiency relative to the production frontier in the *t-th* year can be expressed as: $TE_i = E(Y_i^* | U_i, X_i) / E(Y_i^* | U_i = 0, X_i)$

The parameters of the model were estimated with the Maximun-Likelihood (ML) method. In this method, the temporal variation of technical inefficiency is modeled through the error component and not through the intercept of the production frontier. However, it is important to keep in mind that the maximum likelihood approach involves strong assumptions about the distribution of U_i: semi-normal and truncated normal (Battese-Coelli 1988, Kumbhakar 1990, Battese-Coelli 1992, Battese-Coelli 1995 and Cuesta 2000, among others). The method of maximum likelihood is suggested for the joint estimation of the parameters of the stochastic frontier and the model for the technical inefficiency effects. Battese and Coelli (1993) expressed the likelihood function in terms of the variance parameters. Then, keeping in mind the calculation of maximum likelihood estimates, we use the parameterization of Battese and Corra (1977) and we replace σ_V^2 and σ_U^2 with $\sigma^2 = \sigma_V^2 + \sigma_U^2$ and $\gamma = \sigma_U^2 / \sigma_V^2 + \sigma_U^2$. The parameter γ must be between 0 and 1, where the starting value can be obtained using an iterative maximization process (Coelli et. al., 1998).

To achieve the objective of this work, we apply the methodology described above including two general variables to characterize water use, which were defined in the data section. We do a test of the hypothesis that there is constant returns-to-scale technology. Moreover, we prove the null hypothesis $Ho: \gamma = 0$, which indicate that there not exist technical inefficiency; and $Ho: \delta_i = 0$ which specify that there is no technical inefficiency effects. In the technical efficiency model, the marginal effect of every z variable is calculated as:

$$\frac{\partial TE_{it}}{\partial z_{pit}} = \frac{\partial E[exp(-U)|\varepsilon_{it}]}{\partial z_{pit}} = TE_{it} \Psi \partial_p \qquad [4] ;$$

Where: $\varepsilon_{it} = V_{it} - U_{it}$ and

$$\Psi = \frac{1}{\sigma_w}\left[\sigma_w + \frac{\phi(\rho)}{1-\Phi(\rho)} - \frac{\phi(\sigma_w + \rho)}{1-\Phi(\sigma_w + \rho)}\right] \text{ and } \rho = \frac{1}{\sigma_w}\left[\delta_o + \sum_{p=1}^{J} \delta_p z_{pit}\right]$$

Where ϕ and Φ are the density and distribution functions of the standard normal random variable, respectively (Zhu, et al. 2008).

2.3 Distributional efficiency using the decomposition of the Gini coefficient

To characterize the inequality distribution of the agricultural output, we complement this analysis, using the Gini coefficient decomposition proposed by Pyatt et al. (1980) and Shorrocks (1982), and extended by Lerman and Yitzhaki (1985), which includes the marginal impact of different sources on overall yield inequality, focusing on the impact of water related variables.

The Gini coefficient is probably the most common inequality measure and is broadly used in a lot of fields, because its simplicity and its desirable properties. This concentration ratio is widely used in many fields of economics as well as in ecology and agronomics, but there are fewer applications in agricultural and environmental economics, together (Sadras and Bongiovanni, 2004; López-Feldman et al., 2007; Seekell et al., 2011). In a general context, it ranges from zero (equal distribution) to one (perfect inequality), and fulfills the properties of mean independence, population size independence, symmetry, and Pigou Dalton transfer sensitivity (Haughton and Khandker, 2009). However, this tool presents two main lacks, not easy decomposability as entropy measures, and a difficult statistical testability for the significance of changes in the index over time. Haughton and Khandker (2009) suggested that this last lack is not a real trouble because confidence intervals can usually be produced by means of bootstrap techniques.

Taking into consideration those points, we utilize the approach of Gini decomposition mentioned. In general, this methodology develops how each source's contribution to the Gini coefficient could be observed as the product of its share on total output, its own source’s Gini coefficient, and its correlation with the total output and can be expressed as:

$$G_{tot} = \sum_{k=1}^{K} S_k G_k R_k \qquad [5]$$

Where G_{tot} represents the Gini coefficient for the total yield; S_k is the share of component *k* in the total yield, this implies the question of how important the source is respect to total yield; G_k represents de relative Gini of source *k*, this part try to measure how equally or unequally distributed the income source is; R_k is the Gini correlation between yield from source k and the total yield distribution $R_k = Cov\{y_k F(y)\} / Cov\{y_k F(y_k)\}$, implying the question of how the income source and the distribution of total income are correlated. This decomposition of Gini coefficient is a good measure to help us to understand the determinants of inequality, and allows estimating the effect of small changes in a specific source of yield (income) on inequality, maintaining the other sources constant.

$$\frac{\partial G_{tot}}{\partial e} = S_k \left(G_k R_k - G_{tot} \right) \qquad [6]$$

3 Results and Discussion

3.1 Production functions and factors affecting technical efficiency over time

Table 3 shows the estimated crop production functions for the five crops in the study. According to the database, we select the Cobb-Douglas production function form for all studied crops. There are two reasons for choosing the Cobb-Douglas in these cases. First, due to its simplicity and validity (Zellner, Kmenta and Dreze, 1966) and its acceptance in the literature of production functions in agricultural economics (Lobell et al., 2005, 2006; Quiroga et al., 2011a). Second, due to the inherent problem of collinearity presented by the translog functions. To more detail on the problems of modeling and specification of the correct form of the production frontier, see Giannakas, Tran and Tzouvelekas (2003). For all crop models, we tested the significance of the γ parameter, we reject the null hypothesis that γ equals zero, which indicates that σ_u^2 is not zero, then U_{it} term should be in the model.

In most of the cases the five crop production functions present the expected signs according to the agricultural processes. The technical component, represented by an index of farm machinery and fertilizers, results in yield increases for all crops in our study, except for maize. We suspect multicollinearity problems on this crop model, although its prediction capacity is good. Agricultural labor shows a negative and significant impact on the yield of maize, grapevine, and alfalfa; however we can find some studies related to the agricultural sector with this non-normal sign (Battese and Broca, 1997; Cuesta, 2000; Baten et al., 2009; Zhu and Oude-Lansink, 2010). There are some explanations about this contra intuitive sign. (i) This variable is at macro level and we can observe decreasing returns to scale when additional labor move from other sectors to agricultural sector. (ii) Another explanation is that as national agricultural productivity increase, farmers can produce more food with less labor. (iii) Moreover, it is reasonable to think that there is a labor surplus activity; this means that it is hiring more labor than the recommended level at a marginal productivity level (Baten, et al., 2009). (iv) The regional farms dedicated to these crops are in fact family farms, and then this variable could be showing a camouflaged unemployment problem. However, as we mentioned above the calculation of technical efficiency is based on the estimation of the residuals, then what really matters is the model as a whole. The individual parameter estimates are of little relevance in measuring efficiency what is our final aim in this paper.

Irrigation has also a positive and significant impact in wheat, maize and alfalfa. This fact implies that reductions in water availability for irrigation will cause a decrease of crop yields. Irrigation area also has an important impact on maize grapevine, and alfalfa. Drought has a negative and significant impact for wheat, grapevine and barley, which are mainly rainfed crops, while irrigated crops do not show evidence of significant impact of drought on their yield.

Table 3. Cobb-Douglas crop production functions

Dependent variable: ln(Yield)	Wheat	Maize	Grapevine	Alfalfa	Barley
Tech	0.0818***	-0.0327**	0.0058	0.0074	0.0800***
	[0.022]	[0.014]	[0.026]	[0.012]	[0.021]
ln(L)	0.1359*	-0.2176***	-0.5492***	-0.0713**	0.0835
	[0.070]	[0.053]	[0.095]	[0.028]	[0.072]
Cent_Ebro	-0.0931	-0.1030**	-0.3556***	-0.0542	-0.0701
	[0.075]	[0.045]	[0.100]	[0.037]	[0.072]
Northern_Ebro	-0.3647***	-0.1185*	-0.7678***	-0.1121**	-0.3980***
	[0.137]	[0.070]	[0.198]	[0.051]	[0.114]
ln(Irrig)	0.0488*	0.0558**	-0.1740**	0.1418***	-0.0084
	[0.025]	[0.022]	[0.069]	[0.013]	[0.022]
ln(Irrig_area)	-0.0301	0.0381***	0.1350***	0.0243***	-0.0527***
	[0.023]	[0.012]	[0.020]	[0.008]	[0.020]
ln($Prec_{year}$)	0.1851***	0.0245	-0.0262	0.1374***	0.1072*
	[0.065]	[0.041]	[0.078]	[0.032]	[0.062]
ln(T_Mean_{year})	-0.8508**	-0.1174	1.5134***	0.3849***	-1.2215***
	[0.371]	[0.188]	[0.439]	[0.130]	[0.279]
Dro	-0.1297**	-0.0258	-0.1471**	-0.0195	-0.2269***
	[0.051]	[0.035]	[0.058]	[0.029]	[0.050]
T	0.0035	0.0198***	0.0098	0.0073**	-0.0017
	[0.007]	[0.005]	[0.008]	[0.004]	[0.007]
Constant	1.5550	1.9793***	-0.5115	0.7496	3.6684***
	[1.416]	[0.604]	[1.120]	[0.456]	[1.022]
Observations:	276	239	164	306	265

Standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table 4. Technical inefficiency model

Technical Ineficiency = U					
	Wheat	Maize	Grapevine	Alfalfa	Barley
Altitude$_{(0-600)}$	0.0007***	0.2519*	0.0031	0.0003	0.0007***
	[0.000]	[0.144]	[0.002]	[0.000]	[0.000]
Altitude$_{(601-1000)}$	0.0001	-0.0006**	-0.0024*	-0.0000	-0.0000
	[0.000]	[0.000]	[0.001]	[0.000]	[0.000]
Altitude$_{(+1000)}$	0.0007***	-0.0002	0.0023	0.0013***	0.0008***
	[0.000]	[0.000]	[0.002]	[0.000]	[0.000]
%Irrig_area	-0.1226*	0.0002**	-0.1471***	-0.1761***	-0.3870*
	[0.066]	[0.000]	[0.053]	[0.044]	[0.233]
HDI	0.3600	-0.0557***	0.5497	-0.2694	0.6372*
	[0.276]	[0.014]	[0.640]	[0.283]	[0.377]
MacSharry	1.1563*	-0.8561***	0.4204	1.2207	0.7645
	[0.666]	[0.324]	[1.027]	[0.751]	[0.922]
Agenda2000	1.7112**	-0.1879	0.9079	0.6947	2.3135**
	[0.684]	[0.766]	[0.993]	[0.726]	[0.959]
T	-0.2697*	2.1257**	-0.1977	-0.0061	-0.3585**
	[0.141]	[0.930]	[0.315]	[0.141]	[0.178]
Constant	-36.7713	76.0302***	-69.3678	22.3471	-60.6567*
	[23.993]	[28.069]	[52.776]	[24.382]	[33.044]
Observations	276	239	164	306	265

Standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1

Factors explaining changes in the technical inefficiency model are in Table 4, where a negative sing in the estimates implies that the variable has a positive effect on the efficiency. The results of the efficiency model suggest that irrigated area has a positive and significant effect in the technical efficiency of the all the considered crops, either these crops are irrigated or rainfed. The impact of the human development index of the site is negative for maize and barley, this indicate that more developed sites are more efficiency on those crops.

There is important to observe the effect of Common Agricultural Policy Reforms in the efficiency. Agenda2000 reform had a significant and positive effect on crop yield efficiency of wheat and barley. The impact of MacSharry reform is different across the crops, presenting a non-significant effect for grapevine, alfalfa and barley, while a negative and significant impact for maize, but positive for wheat. In general, it is interesting to see that under both reforms, there is a particular effect over wheat. This impact could be explained through the next reasons: (i) one reason could be that the MacSharry reforms focused only on cereals, oil seeds and protein crops apart from beef and sheep production. (ii) Even though, in 1992 MacSharry Reforms were implemented as the first radical steps to bring a certain budget discipline; these did not achieve the amount of reforms expected. (iii) This reform has as assumption that cereal production would increase at a rate of 1% and then stabilize, but by 1999 cereal production increased sharply tacking on more pressure on the already stressed CAP budget, and (iv) guaranteed prices for wheat fell relatively faster, not fully compensated by direct payments. Other variable that affect the technical efficiency of the crops studied is the altitude.

Figure 2. Predicted technical efficiency by region

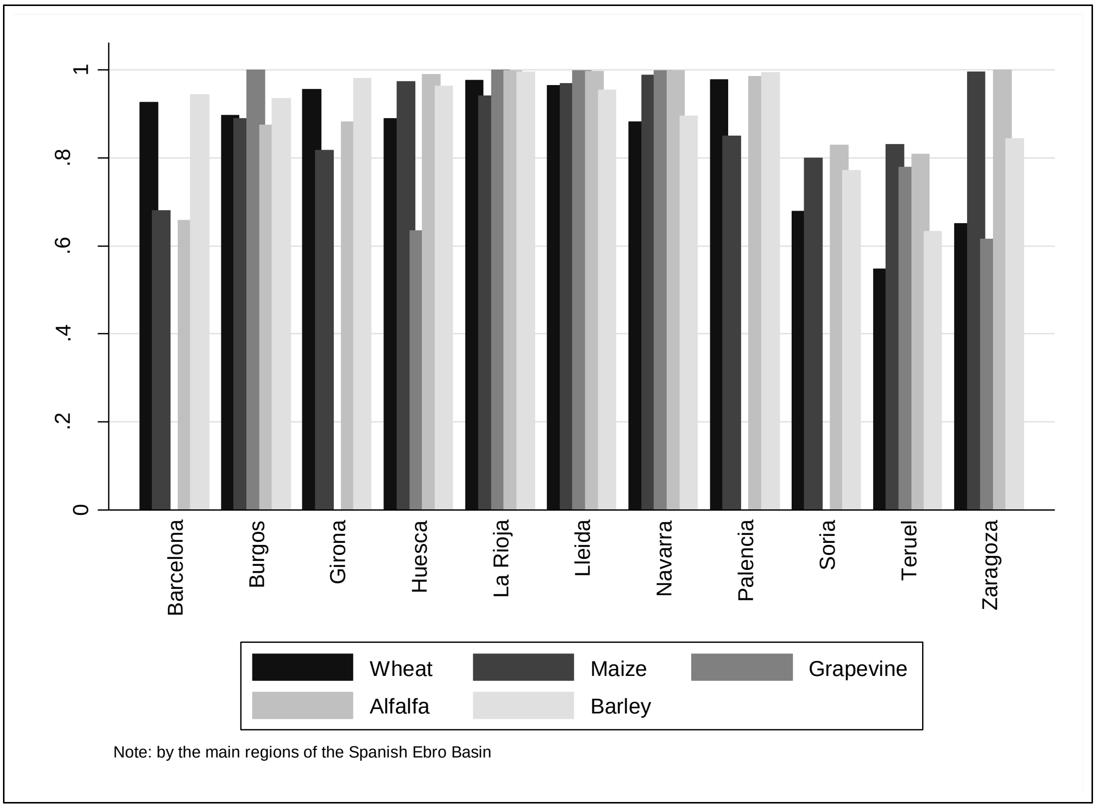
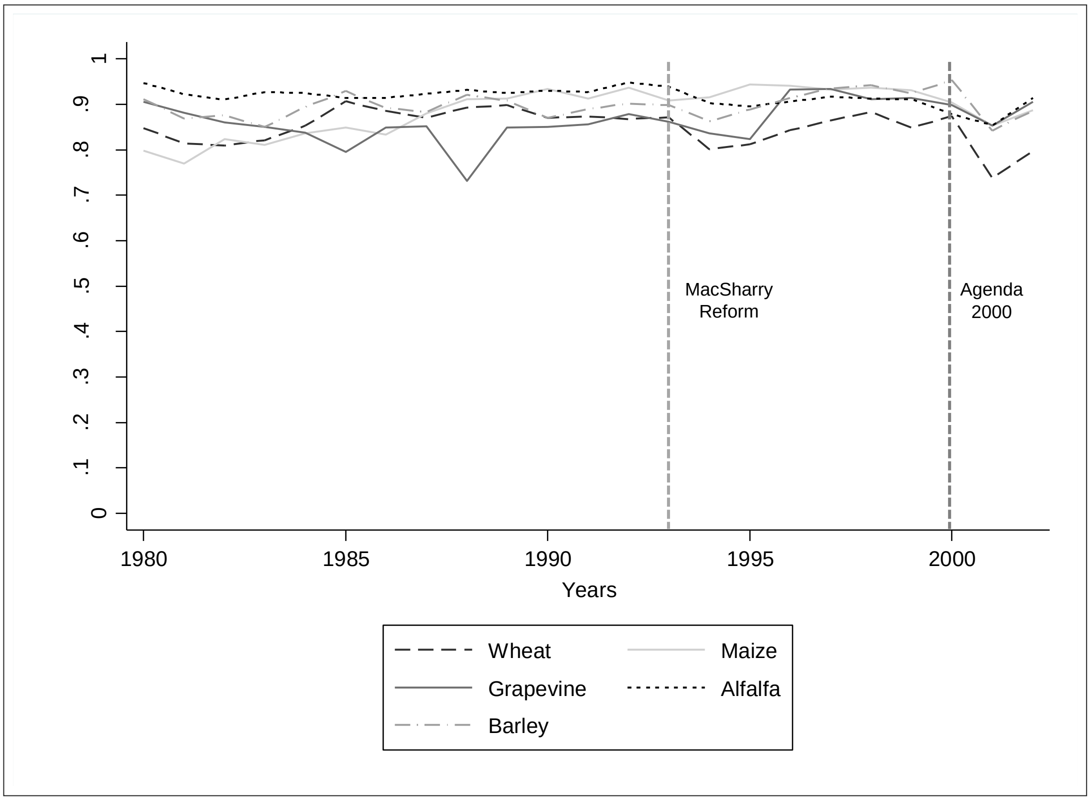


Figure 2 shows the predicted technical efficiencies in each site for each crop. We proved different model specifications for the technical inefficiency effects which have a common behavior on the predicted technical efficiencies for our data. Among the crops, the average technical efficiency for all studied counties in the Ebro basin during the period 1976-2002 is 85% for wheat, 91% for Alfalfa, 87% for Grapevine, 89% for Maize and 86% for Barley relative to the crop's own potential output. This means that the existing production technology is used almost efficiently for all crops (85% - 91%), however their production could be even higher using any extra input. Looking the results by provinces, in the whole spectrum for all crops, La Rioja presents the higher technical efficiency, in other words we can observe that for all crops this county has a technical efficiency over 0.95, Teruel and Soria show the lower one. These results could be related with the positive impact of the human development index in the efficiency of some crops. Moreover, among provinces crops present different levels of technical efficiency, in example, wheat is more efficient in Burgos, Barcelona, Girona, La Rioja, Lleida and Palencia and less efficient in Soria, Teruel and Zaragoza. However, the majority of sites have predicted technical efficiencies smaller than one; there are good results for some crops in some counties, as wheat, maize and grapevine in La Rioja.

Figure 3. Average technical efficiency by crop over time



In Figure 3, we can see that, during the period under study, the average values for maize and grapevine show a general growth in technical efficiency, while wheat and alfalfa shows a light decreased in technical efficiency average. It is important to note that wheat and barley showed a very similar trend in their behavior of technical efficiency before 1990, after that year, the technical efficiency of barley tend to increase, while, in the case of wheat, tend to decrease. This generates a bigger gap between them, although their fluctuations were similar. On the other hand, after 1993, alfalfa appears to have a slightly negative trend up to 2001. During the period 1992-1994, especially in 1993, with the entry into force of one of the most important reforms of the CAP (MacSharry reform), there were observed significant inflection points for wheat and for maize, although in opposite ways; wheat suffered a fall, while maize had a rise. Barley also appears to be affected by this reform, but the effect is not significant in the equation of efficiency. All these cereals were part of the first package of crops affected by the reform.

Looking at the Agenda 2000 reform's impacts, wheat and barley presented a significant negative impact; however grapevine and maize seem to be affected by this or other structural change. Moreover, all crops show a negative shift in the efficiency's trend in the years 2000-2001, when the Water Framework Directive and Agenda 2000 came into force, however in this study we cannot separate the effect of these policies. Wheat and barley present the highest impact while alfalfa shows the lowest one. After 2001, all the crops show a recovery in their level of efficiency. In the global spectrum, barley but mainly wheat are the two crops that appears to have the greater falls in both reforms, while alfalfa has a tendency in technical efficiency that does not seem to be affected by the reforms imposed. Finally, during the studied period all the crops except wheat show a convergence path in technical efficiency among then, despite their fluctuating trends.

3.2 Crop yield sources and their impact on social distribution

Looking at the Gini decomposition and its marginal effects, we present the main results obtained for irrigated area as source of crop yields inequality, including the estimation of bootstrapped confidence intervals (Table 5). Despite, there are other sources, for brevity and convenience of this paper, let us look at the results of just irrigated area, as a key factor, over the yield. These results show that a 1% increase on the share of irrigated area, all else being equal, the Gini coefficient decreases by 0.0166% for wheat, 0372% for maize, 0.0192% for barley, and 0.0032% for grapevine; while for alfalfa the Gini coefficient increases by 0.0016%. This means, that in the whole basin, a 1% increase in the share of irrigated area positively impacts the social equity of those crop yields and the opposite effect is observed for alfalfa. This change is statistically significant; 95% bootstrapped percentile confidence intervals are showed in brackets. Regard to the share of this component in the total yield (S_k), we can see that the irrigated area is more heavily represented in the case of maize and less in alfalfa, although both are mostly irrigated crops. Moreover, irrigated area is more or less unequally distributed depending of the crop; in this study we can observe that G_k ranges between 0.20 for maize and 0.66 for grapevine. This means, that irrigated land is more unequally distributed for grapevine and more equally distributed for maize.

Table 5. Gini decomposition for irrigated area by crop

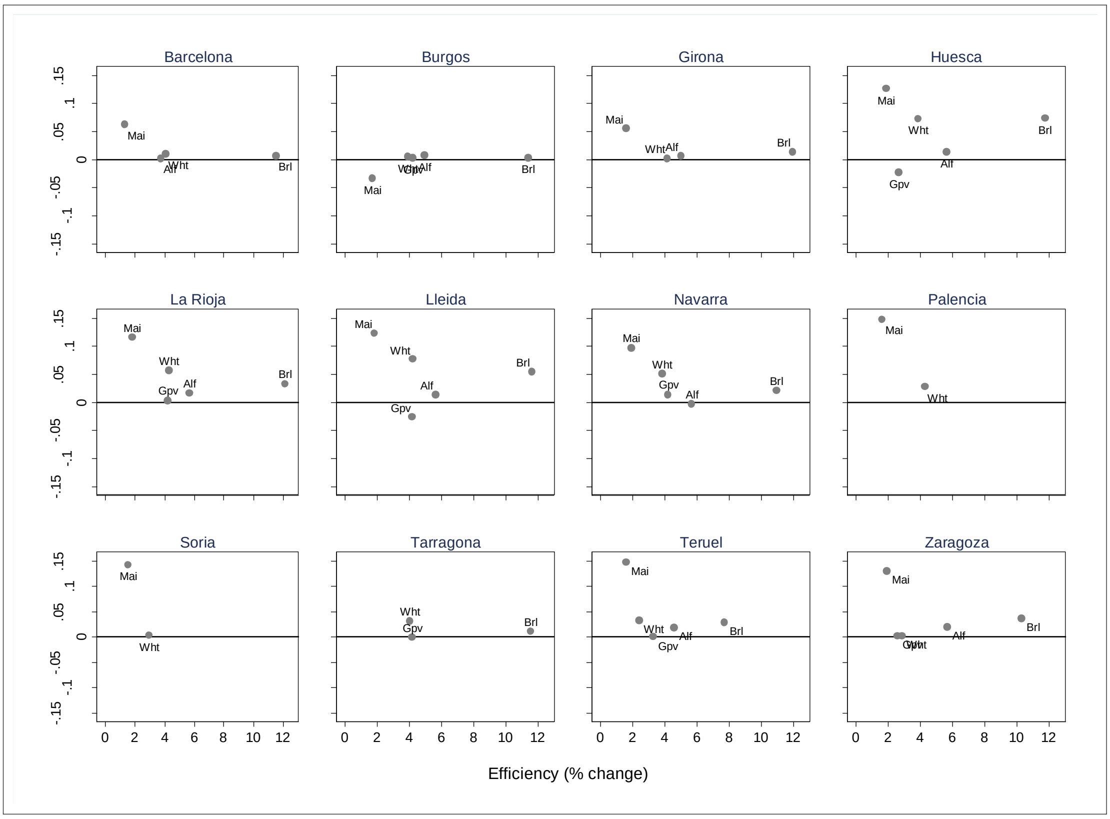
Crop	G	$S_{k=\text{Irrigated area}}$	$G_{k=\text{Irrigated area}}$	$R_{k=\text{Irrigated area}}$	% Change	[95% Conf. Interval]
Wheat	0.22	0.05	0.57	0.25	-0.0166	[-0.0320 -0.0066]
Maize	0.22	0.12	0.20	0.79	-0.0372	[-0.0491 -0.0256]
Barley	0.18	0.03	0.46	0.10	-0.0192	[-0.0241 -0.0136]
Alfalfa	0.16	0.01	0.28	0.62	0.0016	[-0.0004 0.0036]
Grapevine	0.32	0.02	0.66	0.41	-0.0032	[-0.0109 0.0013]

The Gini correlation between source and total yield is low (0.10 and 0.25) for grapevine and wheat, indicating that, in these cases, irrigated area favors the ‘poor’, the sites with lower yields. In the opposite site are maize and alfalfa. Observing the wheat, irrigated land has a slight equalizing effect on the distribution of total yield, because although it has a relatively high Gini coefficient (57%), the Gini correlation between source and total yield is low. These findings shows that a relatively high source Gini does not imply that a yield source has an unequalizing effect on total-crop-income inequality. A yield source may be unequally distributed yet favor the poor, as is the case for wheat and barley. For detailed examples of Gini decomposition by income source, see Lopez-Feldman, (2006).

3.3 Water policy implications on technical efficiency and social equity

In Figure 4 we analyze together the effect of irrigation duties, such as irrigated area in technical efficiency and social equity of crop yields. The measurement of agricultural technical efficiency and its distribution provides information on the competitiveness and allocation of the crops in a particular region and their potential to increase their productivity considering social impacts, which is helpful for a better management of water resources. We can see that on average an increase of 1% in irrigated area in the provinces of study, has a greater impact on technical efficiency of barley and alfalfa. However in the case of the social distribution of crop yields, this increase is higher in favor of equity of the three cereals in most of the sites. Following the analysis of the wheat, we find that even though irrigated area has a slightly higher Gini coefficient, in the long term this variable not only has a stabilizing effect on the distribution of yield, because it favors to the most poor, but in addition an increase of 1% of irrigated area positively impacts the social equity of crop yields in all studied provinces and it also favors the increase of technical efficiency.

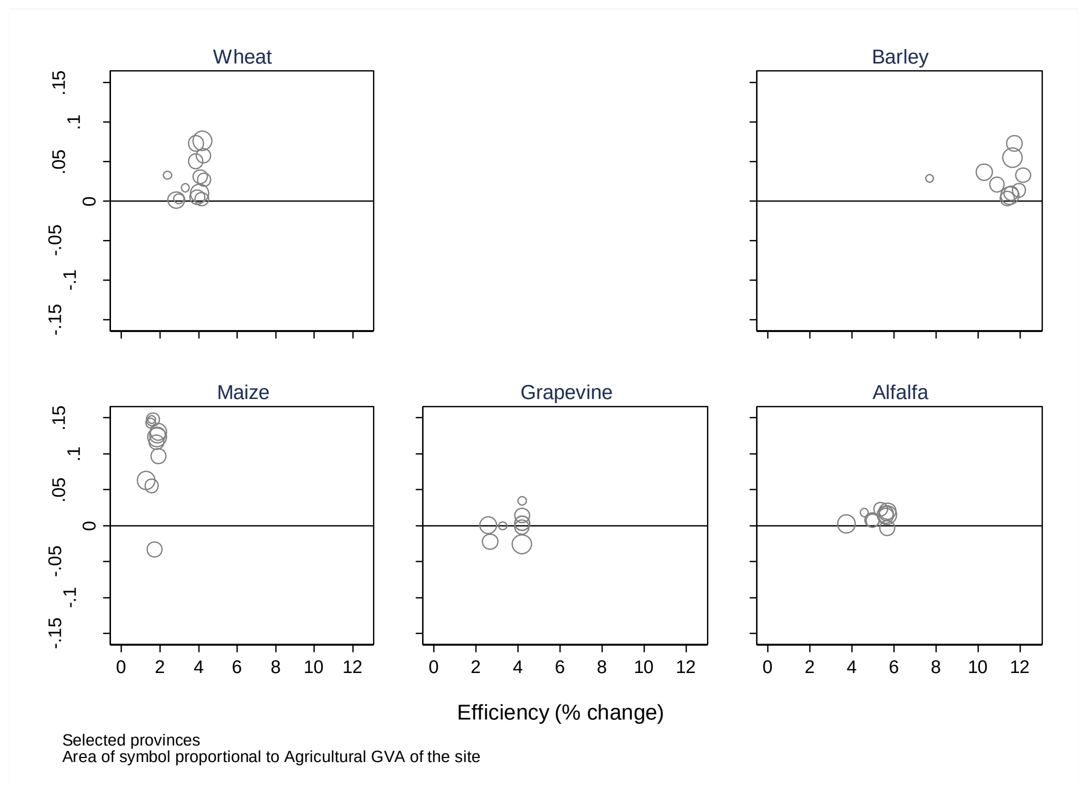
Figure 4. Marginal effects of the irrigated area on competitiveness (efficiency) and income distribution (equity) by province in % change



According to the results in the previous section, policies of reducing area under irrigation can be a non dramatic solution for production (Liu, 2007; Pender and Gebremedhin, 2006; and Quiroga et al., 2011a), but in the long term they negatively affect the competitiveness and increasing social inequality in agriculture. The approaches, provided here, can be used in other fields of public policy for agriculture because can be extended to analyze other factors such as the effect of the modernization of irrigation, fertilizer application and agricultural subsidies.

Figure 5 shows the marginal effect of the irrigated area on competitiveness and income distribution looking at province level and taking into account the agricultural gross value added. We can observe that the effect shows really different patterns for each crop. For example, if we focus on alfalfa production, the marginal impact of irrigated area in the different locations is highly homogenous on technical efficiency and also there is low variation in terms of equity. A different effect can be observed in the case of maize where the distributional aspects seem to be really dependent on the location. Also, there is interesting to observe that in the case of maize the impact of irrigated area over equity is higher for the poorest and richest regions in terms of agricultural income.

Figure 5. Marginal effects by crop and agricultural GVA of the irrigated area on competitiveness (efficiency) and income distribution (equity) in % change



4 Discussion and conclusions

A major challenge for water policy in the near future is the adaptation of crops to increasing water pressure, since climate change tend to increase the existing water conflicts among sectors. In this paper, we evaluate the effect of changes in irrigation duties over the efficiency and distribution of crop yields in the Ebro river basin in Spain. The results presented here, show that in the long term irrigated area has a stabilizing effect on the distribution of the yield of wheat and grapevine, because it favors to the most poor, but in addition it also favors the increase of technical efficiency. This means that policies of reducing area under irrigation can be a non dramatic solution for production in the short run; but could seriously affect social aspects in the long term since they negatively affect the competitiveness and increase social disparities in agricultural incomes. This study is relevant for the revision of River Basin Management Plans in order to face the specifications of the EU Water Framework Directive (WFD) and national policies taking into account reforms to the CAP, within the context of climate change. The methods presented here can be extended to examine other issues as the effects of modernization on irrigation systems, fertilizer application and agricultural subsidies.

Limitations to our study may arise from: (i) the simplicity of the statistical models used. The estimation of agricultural production functions has always been controversial, and each approach has strengths and limitations. In this study we use an extended Cobb-Douglas because of its simplicity and validity and its wide acceptance in the agricultural economics literature, however it excludes an analysis on substitutability and complementarity between inputs due to the nonexistence of cross-product terms involving these inputs. (ii) The quality of the observed data, and (iii) although we introduced the linkages between those socio-economic and biophysical aspects, we ignore soil conditions, quality in the irrigation system, climate change scenarios, and other important factors.

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Chapter 4. The role of the new CAP subsidy schemes in cross-country convergence of agricultural technical efficiency[4]

Abstract

There is now high concern about effectiveness of current Common Agricultural Policy (CAP), since EU has proposed major changes to farm support as the decoupling of subsidies from production (CAP's 1st pillar), and the reinforcing of the CAP's 2nd pillar (rural development). Here we evaluate the effects of CAP on productivity using Stochastic Frontier Analysis (SFA). We include four types of subsidies from both pillars among other variables. Many studies have treated to subsidies as exogenous variables; however we follow the approach that subsidies should be treated as "facilitating" instead of "traditional" inputs, since they affect economic and technical performance. Additionally, convergence analysis is applied to determine if the regional differences in Europe are being reduced by the of current scheme subsidies. Under the premise that subsidies to the production can be manipulated by farmers and there is no evidence that subsidies are for the most efficient regions, we present an equation system taking into account the endogeinity of this variable. We find that the different kinds of subsidies impact in a different way on technical efficiency in all countries of our study. In general farmers support shows an equalizing effect in the distribution of the agricultural output efficiency.

Keywords: *Subsidy effects on technical efficiency, EU policy, CAP's 1st and 2nd pillar, Convergence among European Union members, Climate change adaptation*

[4] Previous versions of this paper were presented in the local seminar of the Groupe d'Analyse et de Théorie Economique (GATE) Local Seminar. Ecully (Lyon), Francia. 19 jun-2012.

1 Introduction

Subsidies play a key role in agriculture around the world; by affecting crop-productivity and by maintain fair living standards for farmers. This means that, they may affect crop production decisions and competiveness, throughout distortions in the input-output prices, farm income, off-farm labor supply, investment decisions and farm growth and exit (Kumbhakar and Lien, 2010; Piet, et al., 2012). Then any structural change could result in increasing, constant or decreasing agricultural productivity and technical efficiency, even if the initial production of the entire sector is the same. Nowadays, economic crises exacerbated the fragile situation in rural income, which is on average 50% less than urban income. Focusing on European Union, the primary sector represents about 5% of added value and almost 16% of total employment. Looking at the recent statistics, France is the main agricultural producer, accounting almost 18% of EU farm output, which is followed by Germany with about 13.4%. Here regional and national subsidies have a big presence, with a recent tendency to decouple from production. Focusing on the EU Common Agricultural Policy (CAP), the distribution of subsidies favors significantly to the 15 older EU member states. Observing national distribution, France benefits the most, accounting 17% of CAP payments. Spain (13%), then Germany (12%), Italy (10.6%) and the UK (7%) are also important beneficiaries.

The Common Agricultural Policy (CAP) plays a key function protecting and supporting EU farmers and growers, with subsidies that represent almost 35% of the total EU expenditure budget (OECD, 2005). Since its introduction in 1962, CAP has been in constant evolution through successive reforms towards adapting to new challenges. In this study we will focus on the reforms of the last 20 years. In 1992 came the MacSharry reform which introduced the system of direct payments (1993-1999), and were extended by Agenda 2000 (2000-2004). Agenda 2000 converted to rural development as CAP’s 2nd pillar, bringing some structural and territorial measures as Least Favored Areas (LFAs) and integrated policy for the sustainable development of all EU rural areas. The 2003 Mid Term Review (Fischler reform) decoupled the majority of direct aid, introducing the single farm payments scheme and weakened the link between subsidies and production (2005-2008). This decoupling of direct payments was further reinforced with the approval of the Health Check of the CAP in 2008;

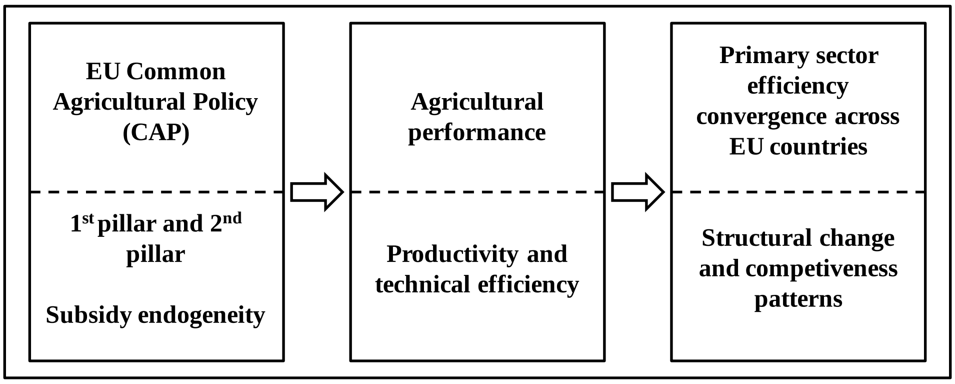
however there are still some coupled payments in some member countries. The reforms introduced in 2003 and in 2008 try to modernize the sector and make it more market-oriented, favoring substantially the level of agri-environmental payments, meaning that the two pillars are complementary to achieve the CAP objectives.

Currently, there is a discussion process about CAP future under the Europe 2020 strategy and some proposed issues in the policy overhaul are the next: (i) to put a ceiling on subsidies to individual farms; (ii) to establish a minimum limit per farmer to receive direct payments, depending on the characteristics in each member state, and a progressive increase from 5% to 10%of the rate of compulsory modulation; (iii) to dedicate 30% of any direct aid for crop diversification, pasture maintenance and ecological reserves preservation, (iv) to do a commitment to end the block quota of sugar and (v) to favor entrepreneurship aids to catch the interest younger people in agriculture. Additionally, the new reform states that the only payments that may remain coupled are the suckle cow premium, the premium for sheep and goats, and the specific payment for cotton. Moreover, it is important to see in the Central and East-European Countries, where CAP represents a great challenge because of importance of agriculture in terms of their gross domestic product (GDP) and employment (Fernández, 2002) and structural adjustments are still under way.

There are many studies explaining and valuating agricultural technical efficiency from parametric and non-parametric methods, taking into account a lot of socio-economic and biophysical factors as explanatory variables. Focus on parametric methods, there are several studies using Stochastic Frontier Production Functions (SFA) with Technical Inefficiency Effects (Battese and Coelli, 1995; Battese and Broca, 1997; Coelli, Prasada-Rao and Battese, 1998; among others). Moreover, following econometric approaches we find many studies analyzing the subsidies effects on farm performance. In general, we observe three main modeling methodologies to analyze the subsidies effects on farm performance. (i) The first observed group evaluates the direct influence of subsidies on productivity, treating them as traditional input in the production function (Guan and Oude Lansink, 2006; and Skuras, et al., 2006). However, it is important to keep in mind that subsidies are not a traditional input because they are not necessary for production and cannot produce any output by itself. (ii) The second group uses stochastic frontier analysis and treats subsidies as a facilitating input affecting productivity only throughout the technical efficiency equation (Hadley, 2006; Zhu and Oude-Lansink, 2010; and Zhu, et al., 2008, 2011). This last approach escapes to the above mentioned lack but forgets the direct relationship between productivity and subsidies. (iii) Finally, the third one approach treats subsidies as endogenous variable, introducing them in the production function and in the technical inefficiency model; this alternative is more sophisticated and advanced (Kumbhakar and Lien, 2010). However in our knowledge, there are very few authors who treat subsidies as endogenous factor affecting both productivity and technical efficiency and decomposing their individual contributions on technical efficiency and observing convergence patterns in this issue.

Given the above and that the European Union has proposed major changes to farm support post-2013, it is important to know the effectiveness of current CAP policy and how these management variables can improve agricultural-economic performance in all European agro-climatic regions. Then, we analyze the role of agricultural subsidies on technical efficiency of crop-output in Europe, taking into consideration the endogeneity of crop-subsidies and adding an analysis of β-convergence among some European Union member states. The remainder of this article is organized in the following way: Section 2 shows the data description and the methodologies we use. Main results on efficiency and cross-country convergence are showed in Section 3. Section 4 presents the concluding remarks and discussion of this paper. The key issues and structure of this paper are drawn in Figure 1.

Figure 1. Key issues and structure of this paper



2 Methods

There is important to evaluate the impact and effectiveness of current CAP policy since EU has proposed major changes to farm support, which emphasize the tendency to decouple subsidies and include an additional payment for the protection or enhancement of the environment and rural development. In this paper, we apply stochastic frontier analysis to assess the effects of subsidies on productivity, including other explanatory variables. We observe the impact of four types of subsidies on agricultural performance in representative European countries. We analyze the effects of coupled and decoupled subsidies (CAP' 1^{st} pillar), Least Favored Areas (LFA) subsidies and environmental subsidies (2^{nd} pillar) on technical efficiency as key issues copping the performance of European agricultural policies and their impact among countries. Finally, we use β- and σ-convergence criteria in terms of technical efficiency, to determine more precisely the mobility and dispersion of this issue among these European countries.

2.1 Data

The methodology used here, is applied to ten representative countries in the European Union. The selected countries represent different geographical regions, with the objective of capturing the heterogeneity in their dependence on subsidies as well as other characteristics, as farm structure and cropping patterns. To characterize the whole model we use data from the EU Farm Accountancy Data Network (FADN) which is proved be a consistent dataset for evaluating Common Agricultural Policy impacts. This public database contains mean-values per farm at regional level. It have 98 regions for the ten countries during 14 years: 4 in Finland, 22 in France, 9 in Germany, 4 in Greece, 7 in Hungary, 21 in Italy, 5 in Portugal, 17 in Spain, 3 in Sweden and 6 in United Kingdom. A 14-years panel data is good in terms of degrees of freedom to estimate the parameters, and allow the analysis of both technical efficiency and convergence patterns over time, capturing some macroeconomic aspects and policy evolution during more than a decade, in which, CAP experimented important and transcendental reforms. This dataset was deflated using annual averages of the harmonized indices of consumer prices (HICP) from EUROSTAT with 2005 as base year. Variables are deflated by a national price index, because we do not have access to accurate indexes at regional level.

In our equation system, we use as a dependent variables the total of output of crops and crop products (Y_{1it}) and the share (in %) of crop-subsidy payment received over crop-production (Y_{2it}). Y_{1it} includes cereals, potatoes, sugar beets, protein crops, energy crops, industrial crops, oilseed crops, vegetables and flowers, fruit, wine and grapes, olive and oil, forage and other crop such as seeds, other areal crops and permanent crops. This variable is in constant Euros. Meanwhile, the variable related to total subsidies on crops includes all farm subsidies on crops, including compensatory payments, area payments and set-aside premiums.

To get a more explanatory model and avoid some problems as multicollinearity, we redefined some variables from the database. To characterize agricultural technology, we use principal components analysis (PCA) to obtain an index called $Tech_t$. The variables used to construct this index were: seeds and plants, seeds and plants home-grown, fertilizers, buildings, machinery, and energy. All these variables are highly correlated, and then PCA help us to avoid the multicollinearity problem in the regression analysis. Roughly, this method generates a small number of uncorrelated variables which contain most of the variance from a larger number of correlated variables. PCA uses a linear combination and retains as much information as possible from the original variables (Blattberg, R., et al., 2008). We chose the first component for all studied countries, because it has an Eigenvalue greater than 1 and explains almost the 50% of the variability of data in Spain, 72% in France, 71% in Italy, 83% in Germany, 80% in Hungary, 70% in Sweden, 86% in Greece, 67% in Finland, 73% in Portugal and 78% in United Kingdom. This component presents high and positive correlations with all variables; therefore, it appears to reflect the size of this technology. There is important to mention that after applying Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, some variables were eliminated in the construction of the index in some countries because they have KMO values lower than 0.69. Variable called buildings was dropped for France, seeds and plants home-grown and buildings for Italy, buildings and machinery for Sweden, and seeds and plants home-grown for Greece.

In this study, we include four types of subsidies to catch their separated effect on productivity. These subsidies are part of the 1st and 2nd pillar of the CAP. We can expect, *a* *priori*, both positive and negative effects from subsidies on technical efficiency through income effect. This means that subsidies might increase the technical efficiency only if they supply farmers the necessary means to keep the suitable and updated technology or to make investments that increase the efficiency of the firm. In the opposite way, subsidies might decrease technical efficiency if this extra-income causes less motivated farmers with a poor performance. The role of coupled subsidies on production function also could be positive or negative. Finally, the inclusion of environmental and less favoured area (LFA) payments is interesting because they have been substantially increased in the last CAP reforms. Variables definition and the reasons for their use are presented in Table 1.

2.2 Econometric tools

As we say above, EU Common Agricultural Policy has experimented crucial changes in its scheme of subsidies since 1992 and mainly since 2005, as the decoupling of subsidies from production, being the Single Farm Payment the largest one. By definition, decouple subsidies do not affect farmers' short term marginal production decision, in a context of perfectly competitive markets, no economics of scale and risk-neutral producers. However, these assumptions do not hold at all in practice, and then even decoupled subsidies could influence production in several ways. In theory, coupled and even decoupled subsidies impact production through four mechanisms: (i) by affecting relative prices of inputs and outputs, (ii) throughout income and then investment decisions and on- and off-farm labor quantity and quality because farmers are less constrained, (iii) through changes in risk perception because subsidies' insurance effect, and (iv) through farm growth and exit of the industry (Kumbhakar and Lien, 2010; Zhu and Oude-Lansink, 2010). Changes in farmer work-motivation, investment decisions and distribution of inputs-outputs could be given if there is a combination of income and insurance effect with farmer characteristics (Kleinhanss, et al., 2007). Then, we can expect that these mechanisms affect economic and technical performance of farms through production function and inefficiency equation.

Table 1. Variables Description

Equation	Variable	Label	Definition	Reason of use
Coupled subsidies equation	w_1	Agri_area	Total utilized agricultural area of holding. It also includes agricultural land temporarily not under cultivation for agricultural reasons or for agricultural policy measures (Ha)	How total utilized agricultural area influences the level of coupled payments?
	w_2	Agri_area^2	The square of Agri_area	Is it a linear impact?
	w_3	Year	Time trend, t=1 for 1996, t=14 for 2009	To check if coupled subsidies increase/decrease over time
	w_4	Change	Dummy denoting structural change in subsidies on crops scheme. The year of change depends of the country	To catch the policy change on this kind of subsidies
Production function	x_1	Tech	Technology index by country using principal component analysis (PCA)	To observe technification of the crop production avoiding multicollinearity
	x_2	L_{tot}	Total labor input (Hours)	Is Agriculture a labor surplus activity? There are decreasing o increasing returns to scale?
	x_3	Eco_size	Proxy of agricultural land. Economic size of holding expressed in ESU (European size units)	If we used "Agri_area" we were having problems of opposite sign and significance, possibly because of endogeneity.
	t	Year	Time trend, t=1 for 1996, t=14 for 2009	To check if crop-production increase/decrease over time
	x_1*t	x_1*Year		
	x_2*t	x_2*Year	Each input variable multiplied by time trend	To check how the elasticity output, of these variables, changes over time. Change is neutral or not?
	x_3*t	x_3*Year		
	Y_2^*	Subsi_output _index	An instrumented variable. The predicted values obtained in the subsidy equation	This variable is endogenous in the production function because can be manipulated by farmers through production quantity
Inefficiency equation	Y_2 or z_1	Subsi_output	Share of crop subsidies over total crop output (%); not instrumented	
	z_2	Decoup_pays	Decoupled payments: Single farm payment and single area payment scheme, additional aid included. In constant Euros	To see the disaggregated effect of CAP's 1st and 2nd pillar through the different types of subsidies
	z_3	Enviro_subsi	Environmental subsidies, including part of the measures of the Art. 69- Regulation 1782/2003; in constant Euros	
	z_4	LFA_subsi	Less favoured area (LFA) payments in constant Euros	
	z_5	Debt_asset	Share of short, medium and long-term loans in total assets (%)	To observe if total debt is playing a disciplinary role
	z_6	Gini_index	Calculated Gini coefficient by region	How does inequality impact on inefficiency
	z_7	Fam_labor	Share of total unpaid labor input in total labor (%)	What happens if family labor is more motivated or better skilled?
	t	Year	Time trend, t=1 for 1996, t=14 for 2009	To check if inefficiency decrease or not over time

In this paper, we follow the approach that subsidies cannot be treated as a "traditional" input, because they are not necessary for production; implying that subsidy alone cannot produce any output. However subsidies should be treated as "facilitating" inputs, since they have an indirect impact over crop-output through three ways: (i) by changing productivity of traditional inputs (technology effect), (ii) through shifting the technology (technological change), and (iii) by influencing technical efficiency (McCloud and Kumbhakar, 2008; Kumbhakar and Lien, 2010). In summary, subsidy is a "*facilitating input"* in the production of output, if it complies the following statements: (i) it is not necessary for the production of output, (ii) subsidy alone cannot produce any output, and (iii) it affects productivity through at least one channel (McCloud and Kumbhakar, 2008). Studies that only analyze the effect of subsidies (especially crop-subsidies) through one way are not adequate because they forget the whole relationship between productivity and all kind of subsidies.

Subsidies linked to the production are likely to be endogenous because there are not distributed randomly. This means that the endogeinety problem could be derived from the distribution process of the payments. There is known that farmers can influence the amount of crop-subsidies received, therefore, subsidies cannot be introduced as an exogenous variable. Here, we model crop-subsidies as an endogenous variable in the production function, but as an exogenous variable in the inefficiency model. Our premise is based on that this variable is endogenous in the production function because it is a subsidy to the production and farmers can manipulate them. However endogeneity does not appear in the technical inefficiency equation because there is no evidence that subsidies are for the most efficient regions (if that were the case it would be treated as endogenous). According to the dataset, we take the share of crop subsidies on total crop output as coupled subsidies because there are directly linked to the production activities. On the other hand, we assume that single farm payment, single area payment scheme and additional aid (decoupled payments); environmental subsidies; and less favored area (LFA) payments are mostly decoupled from crop production. We include the effect of last two subsidies to observe the impact of the CAP's 2nd pillar in agricultural performance and to distinguish their effect.

In this paper, we characterize the above described, using a triangular equation system, which is estimated with a two-step method, after that, we predict technical efficiency and finally we observe the patterns in non-spatial convergence, focusing on β-convergence and σ-convergence. Then our general equation system has the next form. The complete specification and the methods used to estimate this system will be described in detail in the following sub-sections.

$$ln Y_{1it} = f(x_{jit}, Y_{2it}; \beta, \varphi) + v_{it} - u_{it} \qquad (1a)$$

$$Y_{2it} = h(w_{it}; \theta) + c_i + \varsigma_{it} \qquad (1b)$$

Where $ln Y_{it}$ is the natural logarithm of the average crop-production per farm in the *i-th* "region" in *t-th* period. $f(x_{jit}, \beta)$ is a Cobb-Douglas function of x_j inputs-vector of the average farm in the *i-th* region in the *t-th* period and β and φ are two vectors of unknown parameters. To allow the presence of neutral technical change in this production function, we add a time-trend *t*. The error component is $\varepsilon_{it} = v_{it} - u_{it}$, where v_{it} is a vector of random variables accounting for statistical two-sided noise in outputs, and it is assumed to be iid, ($v_{it} \overset{iid}{\sim} N(0, \sigma_v^2)$). Finally u_{it} is the nonnegative technical efficiency element which follows truncated normal distribution and is *iid*, $u_{it} \overset{iid}{\sim} N^+(z_{it}\delta, \sigma_u^2)$. Cobb-Douglas production function is a special case of Translog function, where $\beta_{jk} = 0, j \leq k = 1,2...K$. Y_{2it} is the share of crop-subsidy payment received over crop-production. The equation *1b* contains as dependent variable the endogenous variable (Y_{2it}), where the predicted values obtained from this equation will be included only in the production function. $h(w_{it}; \theta)$ is a function of w_{it} variables which denote farm characteristics, time trendç and structural change. θ is the vector of parameter to be estimated. $c_i = N(0, \sigma_c^2)$ is the unobservable individual specific effect and $\varsigma_{it} = N(0, \sigma_\varsigma^2)$ is the random disturbance.

2.2.1 Subsidy equation

Given equation *1b,* our specific model is the next:

$$Y_{2it} = \theta_0 + \theta_1 Agri\_area + \theta_2 Agri\_area^2 + \theta_3 Year + \theta_4 Change + c_i + \varsigma_{it} \qquad (1b')$$

To estimate the factors that impact the crop-subsidies model (equation *1b'*), we use random effects (RE). With this method, c_i capture the site effects in the subsidy function, this term is assumed to be random and independent of the noise term ς_{it} (Baltagi 2001). To corroborate the use of random effects instead of fixed effects (FE) we applied Hausman's (1978) specification. Moreover, we used Breusch-Pagan Lagrange multiplier test, to confirm the use of this method, instead of an OLS regression (Breusch and Pagan 1980). To test the presence of heteroskedasticity and autocorrelation problems, we apply the modified Wald test for heteroscedasticity, which works even when the normality assumption of errors is not fulfilled and the Wooldridge flexible test for autocorrelation. If one or both problems exist, the parameters could be estimated through Feasible Generalized Least Squares (FGLS) or Panel Corrected Standard Errors (PCSE). Beck and Katz (1995) showed that the standard errors estimated by PCSE are more precise than those estimated by FGLS.

2.2.2 Stochastic frontier production function with technical efficiency effects

Technical efficiency measures are broadly studied as a component of competitiveness because they help in the policy formulation through looking into two components of productivity and farm performance: input elasticities and technical efficiency. Given the highly random conditions existing in the agricultural sector, in this paper we apply Stochastic Frontier Analysis (SFA) instead of Data Envelopment Analysis (DEA). Additionally, SFA contains a rich specification in the case of panel data, explaining inefficiency in terms of many possible explanatory variables (Hadley, 2006 and Zhu and Oude-Lansink, 2010). Then, it helps in policy formulation as well as regional and farm level decisions, taking in mind specific variables related with the improvement of farm performance. Broadly, frontier production function is defined as the maximum feasible output (*y*) obtained with an input vector ($x \in \Re^N_+$). Deviations from the frontier can be measure using SFA with technical inefficiency effects.

As we mentioned above, to characterize our model, we consider Cobb-Douglas stochastic frontier models with neutral and non-neutral technological progress for unbalanced panel data for average farms in ten European countries (Battese and Broca, 1997). The selection of Cobb-Douglas production function instead of Translog is due to two reasons: (i) Translog functions inherent problem of collinearity (Giannakas, Tran and Tzouvelekas, 2003). In this study, we tried to use the Translog production function; however there were collinearity and degrees of freedom problems. (ii) Cobb-Douglas broad acceptance in the literature of production functions in agricultural economics (Lobell et al., 2005, 2006; Quiroga et al., 2011), given its simplicity and validity (Zellner, Kmenta and Dreze, 1966). Then our model is the next.

$$ln\,Y_{it} = f(x_{jit}, Y_{2it}; \beta, \gamma) + \varepsilon_{it} = \beta_0 + \sum_{j=1}^{J} \beta_j \ln x_{jit} + \beta_{it} t + \varphi_j Y_{2it} + v_{it} - u_{it} \qquad (1a')$$

The variable (Y_{2it}) is the predicted value obtained from subsidy equation. The technical inefficient equation is defined as:

$$u_{it} = z_{pit} \delta_p + w_{it} = \delta_o + \sum_{p=1}^{J} \delta_p z_{pit} + \delta_{it} t + w_{it} \qquad (2)$$

Where, the set of exogenous variables on technical inefficiency is represented by the *1xm* vector $z_{it} \in \Re^J$; and δ is an *mx1* vector of unknown parameters to be estimated. w_{it} is the error term, and is defined by the truncation of the normal distribution with zero-mean and variance $w_{it} \sim N(0, \sigma_w^2)$, σ_w^2; it is truncated from below a the truncation point $-z_{it}\delta$, i.e., $w_{it} \geq -z_{it}\delta$. Then the technical efficient is defined as:

$$TE_{it} = exp(-u_{it}) = exp(-(\delta_o + \sum_{p=1}^{J} \delta_p z_{pit} + \delta_{it} t + w_{it})) \qquad (3)$$

Given the assumptions of the model, the predictions of individual output-oriented technical efficiencies can be calculated from conditional expectations $TE_{it} = E[exp(-u_{it}) | \varepsilon_{it}]$. This kind of models is estimated with Maximun-Likelihood (ML) approach, which imply the joint estimation of the parameters in the stochastic frontier as well as in the model for the technical inefficiency effects. The maximum likelihood method implies strong assumptions about the distribution of u_{it}: semi-normal and truncated normal (Battese-Coelli 1988, 1995; Kumbhakar 1990). Using $\varepsilon_{it} = v_{it} - u_{it}$ and the parameterization of Battese and Corra (1977), σ_v^2 and σ_u^2 are replaced with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma_v^2 + \sigma_u^2$. The parameter γ must be between 0 and 1, and its starting value is obtained by an iterative maximization process (Coelli et. al., 1998).

To test the correct functional form, no technical change and the existence of technical inefficiency and technical inefficiency effects, we use the generalized likelihood-ratio formal tests. The null hypothesis ($Ho:\ \beta_{jk} = 0,\ j \leq k = 1,2...K$), indicates that Cobb-Douglas is the adequate representation of the data. If the null hypothesis $Ho: \gamma = 0, Ho: \delta_i = 0$, and $Ho: \delta_{it} t = 0$ are not rejected, there not exist technical inefficiency, no technical inefficiency effects and no technical change, respectively.

2.3 Convergence analysis

In a broad concept, convergence means the disparities decreasing or equalizing. In this paper we follow neoclassical growth theory (Solow, 1956), which is also called convergence optimism, because predicts income disparities decrease, given the decreasing returns to capital. First, we focus on the traditional and widely used β-convergence analysis, also called as growth-initial level regression (Barro, 1984; Baumol, 1986; Barro and Sala-i-Martin, 1991, 2004). Specifically, we assume the absolute or unconditional β-convergence hypothesis. Under this assumption, countries or regions per capita incomes tend to converge among them in the long-term, despite their initial conditions. In other words, all countries-regions meet the same unique and globally stable steady state equilibrium, because there is a negative relation between initial income levels and average growth rates, implying that poorer economies tend to grow faster than richer ones (Barro and Sala-i-Martin, 2004). This hypothesis is logical when we have a more homogeneous sample of countries-regions as the case of the member states of the European Union (Sala-i-Martin, 2004; Arbia et al., 2005; Paas, et al., 2007; Monfort, 2008).

Then, in this paper we use the convergence equation developed by Barro y Sala-i-Martín (1990) which is based on Solow's growth equation. This methodology consists in a cross-sectional regression of the average growth rate, in this case, of technical efficiency over its initial level for the set of economies. The equation form for the whole period is the following:

$$\frac{1}{T} Ln\left(\frac{TE_i^{2009}}{TE_i^{1996}}\right) = \alpha + \beta \, LnTE_i^{1996} + \varepsilon_i$$

Where, TE_i is the agricultural technical efficiency of the average farm in the region $i\ (i = 1,2,3,...,N)$. Then TE_i^{1996} and TE_i^{2009} reflect the initial and final levels of efficiency of the average farm at region level in their respective country. T is the length of the period under consideration. The α-parameter is a constant reflecting the variables that determine the steady state. β coefficient represents the speed at which regions converge to the stationary state. In order to satisfy the convergence hypothesis, this parameter β must be negative and statistically significant. This means that there should be a negative relationship between the initial level of efficiency and its growth rate in the period. ε is the error term which represents unexpected changes on production conditions or preferences, which is distributed independently of the explanatory variable with zero mean and constant variance.

Empirical studies have demonstrated that a β-value of 2% implies that the amount of time needed to cover half the distance separating the current distribution from the stationary state is 28 years. This concept is called half-life, which is measure as:

$$Half - life = -\frac{ln(2)}{ln(1+\beta)}$$

According to this formula, as β tends to zero, half life index tends to infinity, implying that a rapid speed of adjustment results in a short half-life.

The principal advantage of this equation is that it can be estimated by Ordinary Least Squares (OLS). However, there is important to keep in mind, the main lacks of this analysis is that the effects of spatial dependence are not taken into account. Moreover, the use of cross-sectional data may generate bias in the estimation of parameters. Here, Bliss (1999) identifies three types of problems: (i) the existence of unit roots in the data generation, (ii) errors in the measurement of variables and (iii) serially correlated shocks.

The second concept used here refers to cross-sectional dispersion (Baumol, 1986; Barro and Sala-i-Martin, 1991, 2004), the well known σ-convergence. Following this approach, convergence takes place if the dispersion, regularly measured by the standard deviation of the logarithm of per capita income or in this case of the logarithm of technical efficiency across a group of countries or regions, declines over time. In few words, there is a reduction on the dispersion of the per capita income or technical efficiency among countries in time. However, in this study we also use the coefficient of variation and the Gini coefficient to draw solid conclusions about changes in the level of disparities. These two measures fullfil interesting mathematical properties as mean independence, population size independence, symmetry, and Pigou Dalton transfer sensitivity (Haughton and Khandker, 2009).

These both concepts, β- and σ-convergence are closely related[5]. Then, here we use both concepts of convergence, they are equally interesting and there is no a consensus on which is preferable. Following to Sala-i-Martin (1994), these two concepts are useful in the sense that they help to compute convergence or divergence in a different way, giving different information. This author favors the use of β-convergence, because it helps to respond questions as: (i) how less efficient economies are predicted to grow faster that most efficient ones? (ii) How fast the convergence process is? (iii) Is the convergence process conditional or unconditional? (iv) How different is the process of convergence between groups of economies with diverse structures? Independently, whether the σ convergence analysis shows

[5] See Chapter 11 in Barro and Sala-i-Martin (2004) to deepen in this relationship.

that the aggregate variance is declining or increasing over time, all the above questions can be answered by doing a β-convergence analysis. However it is well know that β-convergence is a necessary but not a sufficient condition for σ-convergence. Additionally, given the limitations of β-convergence mentioned in a previous paragraph, many scholars suggest the use of σ-convergence which provides a better approximation of reality, because it directly describes the distribution of technical efficiency among the economies without the estimation of any particular model. Then looking these arguments, both concepts appear to be complementary and cannot replace each other.

3 Results and Discussion

3.1 The subsidy payment equation

We estimated random effects to observe the factors influencing coupled subsidy payments. Hausman test and Breusch and Pagan Lagrangian multiplier test favored this estimation method. We correct for heteroskedasticity and autocorrelation problems in the cases of France, Hungary and Greece. Sweden presented heteroskedasticity problems and Portugal had autocorrelation type AR (1). For all these countries we used Feasible Generalized Least Squares (FGLS) or Panel Corrected Standard Errors (PCSE). Table 2 shows the results by country.

The estimated parameters show that agricultural area is positive and statistically significant in six countries (Spain, France, Germany, Hungary, Portugal and Greece) suggesting as we expect, that average agricultural area per farm positively influence the ratio of coupled subsidies. Moreover, in the first five countries, we can note that the quadratic term of agricultural area is negative and significant, indicating its impact decreases after a given amount of land, showing an inverted U shape. In Greece, the quadratic term is no significant. On the other hand, Italy and Sweden show a U shape in the effect of agricultural area. These both terms were not significant in the cases of Finland and UK. The observed coefficient of the time-trend (Year) is negative and statistically significant in some countries, suggesting that the share of coupled subsidies per farm decrease over time. In the case of Finland, this was the opposite. According to the country, this decrease or increase is gradual or abrupt. In example, in Hungary, this tendency is negative but we do not include the dummy variable indicating structural change because it's especial characteristics into the European Union (it is a New Member State). The foregoing suggest a gradual decrease since 2004, showing that the removal of such subsidies in this country has been more slow, without abrupt changes as in other European Union countries. In the case of those countries where the variables time-trend and structural change dummy are negative and statistically significant, we can observe that coupled subsidies decrease over time with changes in the policy scheme.

Table 2. Subsidy Equation

	Spain	France	Italy	Germany	Hungary	Sweden	Greece	Finland	Portugal	UK
	RE	RE(+)	RE	RE	RE(+)	RE(++)	RE(+)	RE	RE(+++)	RE
Agri_area	0.6569***	0.5744***	-0.4835**	0.1897***	0.1702**	-9.6836***	8.4068*	1.0283	0.8124***	0.0981
	[0.162]	[0.187]	[0.210]	[0.034]	[0.077]	[1.585]	[4.457]	[0.905]	[0.194]	[0.075]
$Agri\_area^2$	-0.0046**	-0.0025**	0.0045	-0.0003***	-0.0013**	0.0482***	-0.4632	-0.0110	-0.0064***	-0.0002
	[0.002]	[0.001]	[0.003]	[0.000]	[0.001]	[0.008]	[0.313]	[0.010]	[0.002]	[0.000]
Year	-0.4695**	-0.0903	-0.2898**	0.0376	-1.9085***	1.5577	-0.1555	1.0422**	-0.4360	-0.6285***
	[0.184]	[0.224]	[0.147]	[0.281]	[0.175]	[1.309]	[0.335]	[0.454]	[0.336]	[0.232]
Change	-9.3353***	-21.1921***	-10.3456***	-32.3493***		-45.4635***	-18.0212***	-39.5874***	-6.1264***	-22.1403***
	[1.603]	[1.123]	[1.135]	[2.350]		[10.392]	[2.823]	[2.960]	[2.084]	[1.823]
Constant	5.2871	0.0415	22.1645***	17.1555***	8.2135***	499.3402***	-8.2447	14.9258	5.7397	20.1876***
	[3.250]	[7.377]	[2.602]	[3.261]	[2.596]	[73.074]	[14.240]	[18.932]	[3.567]	[5.936]
Observations	222	294	294	196	42	42	56	56	66	84
Num. of regions	16	21	21	14	7	3	4	4	5	6
R-squared		0.644			0.743	0.776				

Standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. RE: Random Effects

(+) RE with correction of heteroscedasticity and autocorrelation type AR (1)

(++) RE with correction of heteroscedasticity

(+++) RE with correction of autocorrelation type AR (1)

3.2 The SFA model with inefficiency effects

According to the FADN database, we estimate the Cobb-Douglas stochastic frontier production function form with and without neutral technological progress for all countries. The results for every country are presented in Table 3. Assuming that the Cobb_Douglas is nested in the Translog function, we use generalized likelihood-ratio test (Griffiths, Hill and Judge, 1993) and no reject the null hypothesis that the Cobb-Douglas function is a good representation of the data. The predicted values obtained from the subsidy payment equation are including as a linear term in the production function.

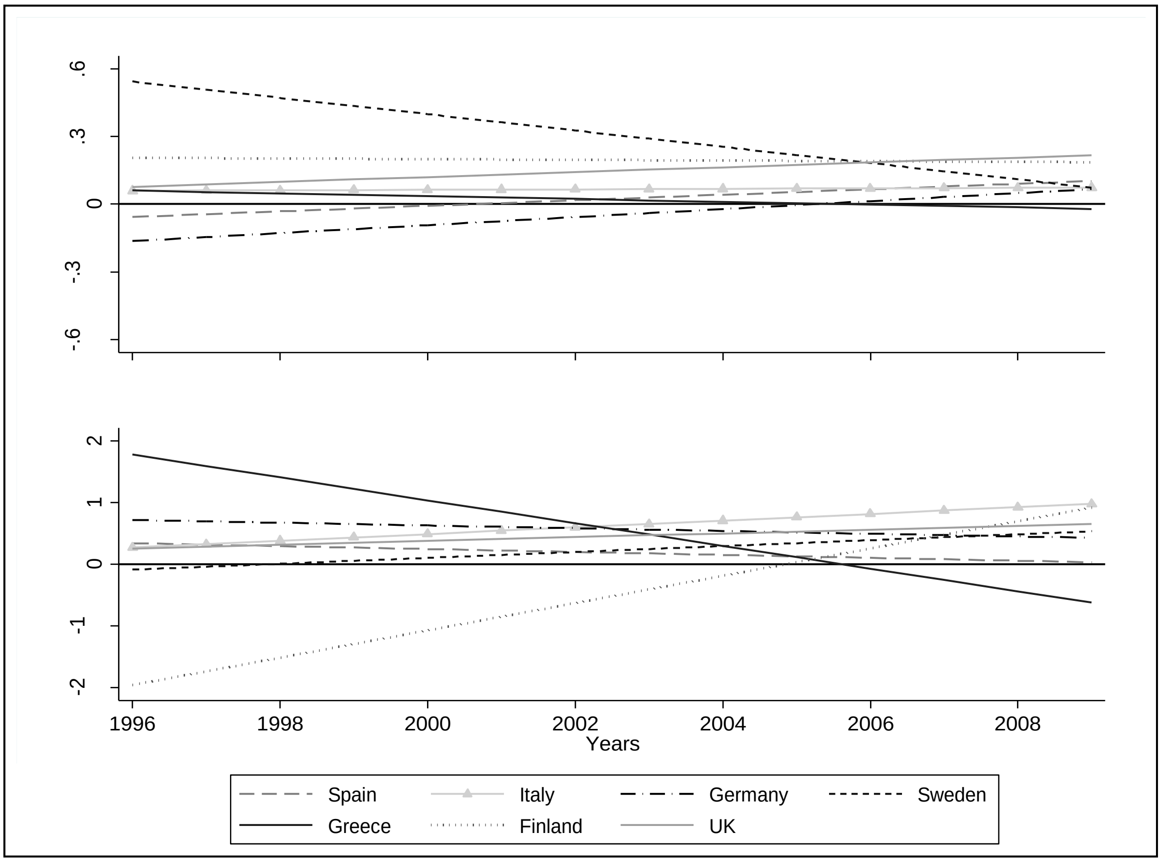
In countries where the production function is estimated as a Cobb-Douglas with neutral technological progress, the elasticity with respect to technology, labor and economic size is given by $\beta_j + \beta_{jt}$. In this case, the elasticity of the j-input is not constant because it varies over time. In case of a traditional Cobb-Douglas production function, the elasticity output of the inputs is constant and then $\beta_{jt} = 0$. Using the estimated coefficients in Table 3, we calculate temporary paths of output elasticities of technology and labor, which are presented in Figure 2. The estimated values of the parameters in the production function imply increasing and decreasing paths in the elasticity of these both inputs. In example, Sweden presents a reduction in the output elasticity of technology over time but an increment in the elasticity of labor, which went from negative in 1996 to positive in 2009. The estimated values of output elasticities for technology in 2009 are higher in Finland, UK, Spain and Germany, than they were in 1996. It is interesting to note that the output elasticities of technology for the different countries tend to converge.

Table 3. Production function by country

	Spain	France	Italy	Germany	Hungary	Sweden	Greece	Finland	Portugal	UK
Tech	-0.0683**	0.0304***	0.0580*	-0.1809**	0.1387***	0.5791***	0.0664***	0.2071***	0.1172***	0.0660
	[0.033]	[0.008]	[0.032]	[0.085]	[0.028]	[0.131]	[0.013]	[0.045]	[0.020]	[0.050]
$\ln(L_{tot})$	0.3624**	0.4921***	0.2149	0.7376***	0.5707***	-0.1382	1.9566***	-2.1815***	1.0722***	0.2214
	[0.170]	[0.103]	[0.142]	[0.268]	[0.122]	[0.917]	[0.288]	[0.475]	[0.246]	[0.537]
ln(Eco_size)	1.1638***	0.8909***	0.6551***	0.8248***	-0.2122	-2.1753*	0.4704***	0.8900	0.2762***	2.1439***
	[0.166]	[0.058]	[0.107]	[0.172]	[0.134]	[1.322]	[0.100]	[0.557]	[0.075]	[0.406]
Year	0.3860***	-0.0061	-0.2982**	0.2521	0.0151	-1.1401*	1.4869***	-1.0550***	0.0026	0.4163
	[0.127]	[0.007]	[0.133]	[0.214]	[0.113]	[0.689]	[0.245]	[0.337]	[0.007]	[0.424]
Tech*Year	0.0122***		0.0011	0.0177**		-0.0361***	-0.0062***	-0.0015		0.0108*
	[0.003]		[0.003]	[0.008]		[0.009]	[0.002]	[0.006]		[0.006]
ln(Ltot)*Year	-0.0236		0.0544***	-0.0223		0.0478	-0.1844***	0.2213***		0.0307
	[0.019]		[0.017]	[0.029]		[0.068]	[0.029]	[0.057]		[0.058]
ln(Eco_size)*Year	-0.0904***		-0.0325***	-0.0219		0.2155*	-0.0003	-0.2152***		-0.1584***
	[0.021]		[0.012]	[0.021]		[0.116]	[0.022]	[0.077]		[0.053]
Subsi_output_index	-0.0291***	-0.0074***	0.0141***	-0.0107***	-0.0146	-0.0014	0.0096***	-0.0065***	-0.0083***	-0.0060*
(Y2*)	[0.003]	[0.002]	[0.004]	[0.002]	[0.058]	[0.001]	[0.002]	[0.002]	[0.003]	[0.003]
Constant	4.6961***	3.6779***	6.0419***	1.7788	6.1566***	18.8023	-7.3883***	24.6450***	-0.2036	-0.7042
	[1.133]	[0.887]	[1.065]	[2.141]	[1.574]	[12.113]	[2.356]	[3.070]	[1.988]	[3.895]
Observations	222	294	294	194	42	42	56	56	66	84

Standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1

Figure 2. Evolution of the elasticity output of technology and labor



The elasticity for economic size which is a proxy of agricultural land area is the largest respect to labor and technology in all estimated models (for all countries). It is indicative that crop production depends strongly on the area used. However, there are technological change effects in some countries. Finland, UK and Spain present an important fall during the whole period, while Italy, Germany and Greece also tend to decrease but more slowly and on the other hand Sweden tends to increase. According to estimations of FAO (2000), from 1960 to 2000 almost one-quarter of worldwide production increase of some important cereals was given to expansion of harvested area. However, Pinstrup-Andersen et al. (1999) estimated that the contribution of cultivated areas will be smaller in the future increase of grain production. Also, there is necessary take into account the quality of used and potential cropland as well as soil degradation. In example, in Spain about 40% of land is suitable for cultivation and only around 10% could be considered as excellent, the remaining soil is in general of poor quality. On the other side, high-quality land is evident in Eastern Europe, where nowadays countries as Hungary has only about 2% of agricultural area as irrigated arable land (CORINE 2006).

Calculating scale economies, which are the sum of the elasticities of all inputs included in the production function, we can observe that there are increasing returns to scale in Spain, Germany, Greece, Finland and UK. The calculated sum of the elasticities ranges from 1.38 in Germany to 2.49 in Greece and there are statistically different from one. France, Italy, Sweden and Portugal present constant returns to scale, while Hungary has decreasing returns to scale. All these results were tested statistically. Time trend variable is significant and positive in Spain and Greece, indicating growth in crop production per average farm over time. Technological changes are not statistically significant in France, Germany, Hungary, Portugal and UK.

In most of the countries we can observe that the predicted subsidies have a negative impact on crop production, implying that they probably generate disincentives and affect farm competitiveness. Then, ceteris paribus, if subsidies are eliminated, the farms of the selected countries will be more productive. Two possible explanations to these results could be the next: (i) subsidies disincentive investment in capital or capital deepening; (ii) generous subsidies incentive the option to get another job and therefore agricultural productivity is affected in a negative way. This result is in accordance with previous studies as Guan and Oude-Lansink (2006) and Kumbhakar and Lien (2010).

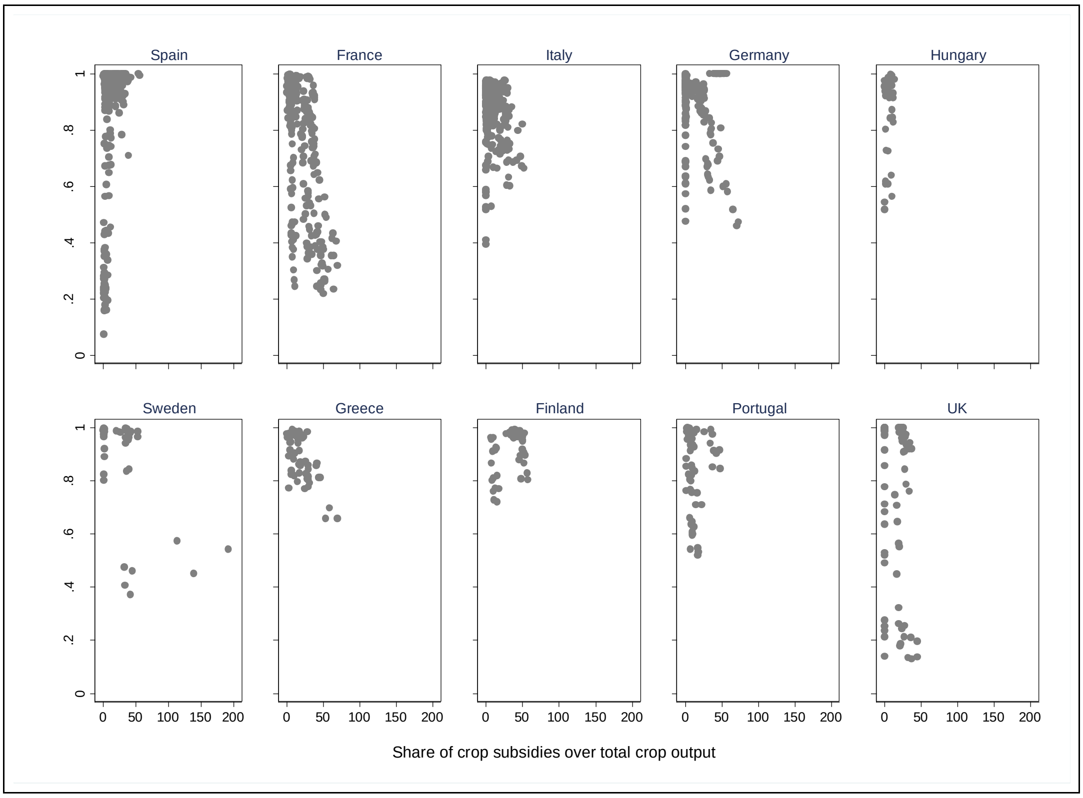
Table 4 shows the estimated parameters in the inefficiency model. Here the direction of the effect of a given variable is represented by the sing of the parameter. It is important to keep in mind that a negative sing implies that the variable has a positive impact on efficiency. Looking the impact of the share of crop subsidies over total crop output in the technical inefficiency equation, only Spain presents a significant negative sing, implying that this kind of subsidies present a insurance effect. However, Italy, Germany, Hungary, Greece and Finland have a positive and significant sing, suggesting that farmers are less motivated to work efficiently when they have an additional income. Additionally, as crop subsidies were divided on total crop output, a positive effect in the inefficiency equation implies that technical efficiency decrease when an increasing proportion of total crop output obtained from this kind of subsidies. Figure 3 shows the positive impact of this kind of subsidies on technical efficiency in Spain, and the negative influence in the countries above mentioned.

Table 4. Technical inefficiency equation by country

	Spain	France	Italy	Germany	Hungary	Sweden	Greece	Finland	Portugal	UK
Subsi_output	-0.0691*	0.0223	0.0868***	0.0635***	0.4914**	0.0210	0.1028***	0.2075**	0.0381	0.0668
(Y2)	[0.037]	[0.014]	[0.020]	[0.023]	[0.226]	[0.017]	[0.031]	[0.103]	[0.044]	[0.048]
Decoup_pays	-0.0002	-0.0000	0.0001	0.0001**	0.0005	0.0002	0.0004*	0.0006*	0.0008**	0.0001*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Enviro_subsi	0.0018*	0.0004*	0.0009***	0.0001	0.0016***	0.0007*	-0.0051	-0.0005	0.0040**	-0.0002
	[0.001]	[0.000]	[0.000]	[0.000]	[0.001]	[0.000]	[0.004]	[0.000]	[0.002]	[0.000]
LFA_subsi	-0.0007	-0.0002	-0.0000	-0.0002	0.0276	0.0003	-0.0016	-0.0006	0.0014	0.0000
	[0.001]	[0.000]	[0.000]	[0.001]	[0.018]	[0.000]	[0.003]	[0.000]	[0.002]	[0.000]
Debt_asset	-0.0361	0.1452***	-0.0935	-0.3406***	-0.3092**	-0.3742	-0.9239	0.0119	0.5090*	0.3631**
	[0.053]	[0.028]	[0.156]	[0.123]	[0.136]	[0.279]	[0.699]	[0.218]	[0.296]	[0.168]
Gini_index	-1.4620	3.8065***	-4.7295***	-3.9260	1.9109	-0.2456	-12.5034*	-2.3360	-12.8511***	-2.8119
	[1.659]	[1.254]	[1.817]	[3.269]	[5.372]	[0.522]	[6.979]	[8.044]	[4.298]	[4.465]
Fam_labor	0.3769***	0.2203***	0.0926***	0.1050**	0.1239	11.5230	0.0670	-0.0903	0.1526**	0.3627***
	[0.064]	[0.036]	[0.032]	[0.042]	[0.096]	[8.808]	[0.107]	[0.235]	[0.075]	[0.085]
Year	0.1136	0.1256*	0.3184***	0.0841	0.5850	-1.3681**	0.2133	1.0528	-0.5947***	-0.0828
	[0.090]	[0.070]	[0.084]	[0.151]	[0.547]	[0.688]	[0.155]	[0.859]	[0.217]	[0.200]
Constant	-36.0544***	-28.4753***	-13.7786***	-7.7773*	-13.1725*	25.1293	-9.8838	-6.8421	-14.5217**	-33.6477***
	[6.266]	[3.520]	[3.307]	[4.105]	[6.965]	[49.583]	[9.380]	[18.910]	[6.420]	[7.789]
Observations	222	294	294	194	42	42	56	56	66	84

Standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Figure 3. Technical efficiency and share of crop subsidies by country



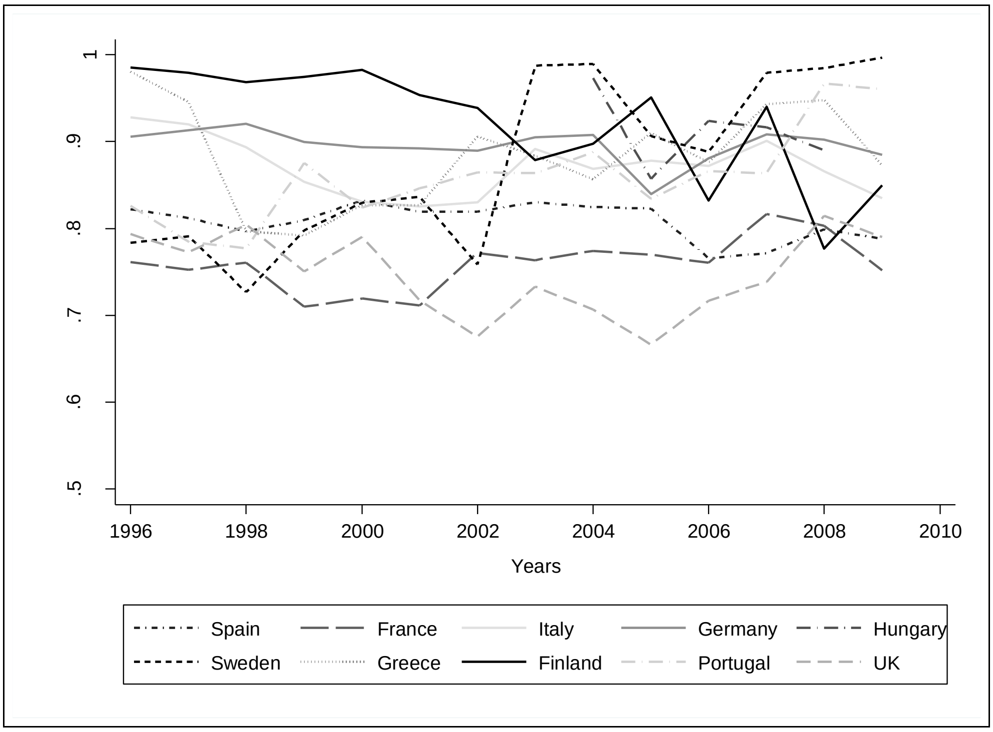
Previous studies as Zhu and Oude-Lansink (2010), and Zhu, et al. (2011), where subsidies impact productivity only through the technical efficiency way, found a negative relation between technical efficiency and coupled subsidies in Germany and between technical efficiency and the share of total subsidy payments in the total farm revenue in Greece. However the impact of the share of coupled subsidies over technical efficiency was positive for Sweden (Zhu and Oude-Lansink, 2010). Kumbhakar and Lien (2010) found positive relation between TE and subsidies in Norway, this last study also treats subsidies as facilating input, although with slight differences in the modeling of subsidies. Looking the impact of all grants, we can observe that the different kinds of subsidies impact in a different way on technical efficiency of farms in all countries of our study.

According to these results, LFA payments present a negative sing in the inefficiency equation in Spain, France, Italy, Germany and Finland, although the effect is not significant. One might expect that LFA subsidies promote the arrival of new farmers and help to the consolidation of the smallest farms, especially in the poorest regions, helping to prevent the concentration of production in a few producers. Additionally, we can observe that the share of total debt plays a disciplinary role in Germany and Hungary, while inequality index favors technical efficiency in Italy, Greece and Portugal. In Sweden and Portugal, we can observe that technical efficiency increase over time.

Moreover, LFA payments provide compensation for producing under less efficient circumstances, with the aim of keeping land in marginal areas under production. The results correspond with Pufahl and Weiss (2009) who analysed the effects of LFA payments schemes in Germany by comparing similar farms with and without LFA payments. They find that LFA payments keep land into production and have a small positive production effect. The agri-environment measures aim to encourage farmers and other land managers to introduce or maintain production methods compatible with the protection of the environment, the landscape and its features, natural resources, the soil and genetic diversity that go beyond mandatory standards. They are designed to provide compensation for income foregone as a consequence of lower land productivity, extra labour and other costs. Pufahl and Weiss (2009) show that agri-environment payments can generate an increase in land use and in particular in marginal. For the decoupled payments, the fact that the magnitude of the values appear to be very small is perhaps an indication that these payments do not affect production decisions (they are designed not to).

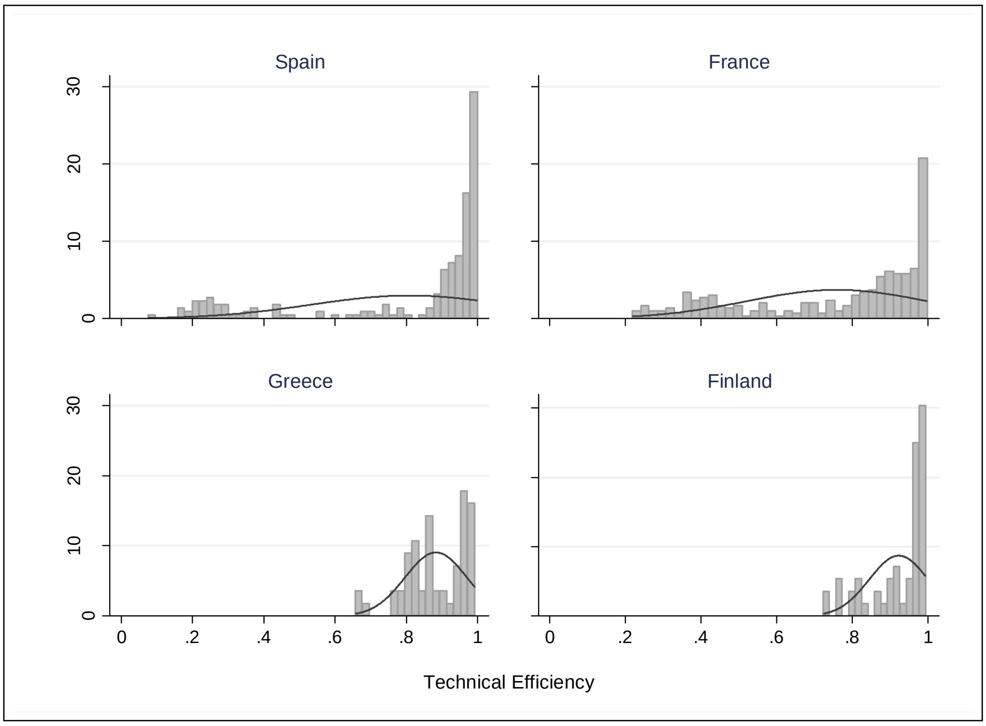
The average technical efficiency for average farms in all studied countries during the corresponding period is 81% for Spain, 76% for France, 87% for Italy, 90% for Germany, 87% for Hungary, 88% for Sweden and Greece, 92% for Finland, 85% for Portugal and 75 for UK. In example, this means that, on average, crop production of German farms could have been 10% higher without using extra inputs. In other words, looking among the countries, France and UK got the lowest average TE (75-76%) relative to the own potential output of the country. In the opposite way, farms in Germany and Finland appear to use its actual production technology more efficiently (90-92%) relative to the other countries. Figure 4 shows the average technical efficiency by country over time.

Figure 4. Technical efficiency by country over time



The previous results appear to be contradictory, because it is well known that France is the main European agricultural economy, which had an agricultural production of 61 billion Euros in 2009, representing the 19% of European agricultural goods and the largest agricultural area used. Then it is necessary to look behind the mean. Figure 5 shows the histogram for four countries, the two countries with the smallest dispersion and the two countries with the highest dispersion. As is showed in the histogram, we can observe large variation among sites in France and Spain. These results are consistent if we consider that the different regions of France are specialized in one kind of primary sector's production. The regions with the lower technical efficiency are those that produce mainly livestock products, and we should not forget that in this study we are assessing only crop production. In example, Auvergne, which is located in the mountain chain called Massif Central, is mainly dedicated on bovine and dairy production. Other regions with low technical efficiency in France are Limousin, Basse-Normandie, Franche-Comté and Bretagne, which have an important production of beef, pork, poultry, milk, cheese, etc., as well as Lorraine, which is targeted on mining and high technology. A similar case is observed in Spain in the regions of Cantabria, Asturias and Galicia.

Figure 5. Efficiency distribution in four countries



3.3 EU convergence path Convergence results

Table 5 shows the estimated model for β-convergence of technical efficiency for the whole period (1996-2009) and for seven-year sub-periods (1996-2002 and 2003-2009). The three regressions contain country dummies for every period to proxy for divergence in the steady-state values of technological progress rate and the technical efficiency steady-state level, as well as for countrywide fixed effects in the error terms. To obtain more robustness in the results, the test was performed with the conventional variance-covariance matrix and the corrected matrix obtained by bootstrap (Lozano and Pastor, 2006; Simar and Wilson, 2003). Looking at the whole period, β-parameter (log of technical efficiency at the start of the period) is significant and shows a negative sign which supports the existence of beta convergence. Then, this estimation provides evidence in favor of technical efficiency convergence among European countries during 1996-2009. It is interesting that both the whole period and the second sub-period present convergence, however it is not observed in the first period, there is evidence of divergence in countries' technical efficiency. The estimated speed of convergence at which average farm technical efficiency converges for the regions within each of the countries is 1.35% per year for the whole period and 3.47% for 2003-2009 period. Then convergence towards the stationary state is quite slow for the whole period with a half-life of almost 52 years, against a half-life of 20 years needed for current disparities to be halved for the sub-period 2003-2009.

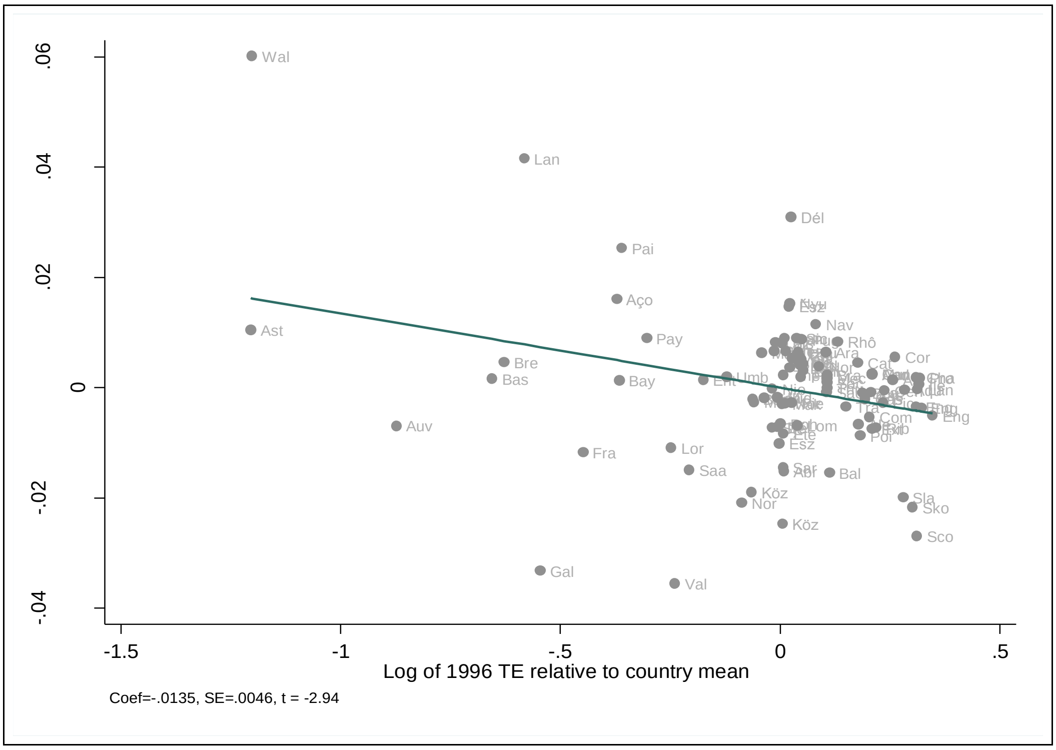
Figure 6 shows the relation between the growth rate of technical efficiency during 1996 and 2009, and the log of technical efficiency at the beginning of the studied period for the average farms in the 98 regions in the 10 countries. The negative relation confirms the idea of absolute convergence in homogenous areas. Previous studies found this relation in per capita GDP (income) among other related variables in European countries, U.S. states and within other countries. The observed correlation between both variables is -0.34. The growth rate and level of technical efficiency are measured relative to the country means. Hence, there is necessary to note that Figure 6 shows that absolute β convergence exists for the regions within countries, rather than between countries given we used estimates that include country dummies.

Table 5. Beta-convergence estimation

Dependent variable: Technical efficiency change					
(2009-1996)		(2009-2003)		(2002-1996)	
ln_te1996	-0.0135*	ln_te2003	-0.0347**	ln_te1996	0.0138*
	[0.008]		[0.015]		[0.008]
Spain	-0.0109*	Spain	-0.0129	Spain	-0.0128**
	[0.006]		[0.009]		[0.005]
Germany	-0.0095**	Germany	-0.0093*	Germany	-0.0172***
	[0.004]		[0.006]		[0.006]
Greece	-0.0143***	Greece	-0.0084	Greece	-0.0247***
	[0.005]		[0.006]		[0.007]
Hungary	-0.0732***	Hungary	-0.0704***	Hungary	---
	[0.011]		[0.010]		---
Italy	-0.0151***	Italy	-0.0172***	Italy	-0.0303***
	[0.005]		[0.006]		[0.006]
France	-0.0113***	France	-0.0150***	France	-0.0080
	[0.004]		[0.006]		[0.005]
Sweden	0.0128	Sweden	-0.0012	Sweden	-0.0101
	[0.014]		[0.006]		[0.015]
Finland	-0.0166***	Finland	-0.0117	Finland	-0.0200***
	[0.006]		[0.009]		[0.007]
UK	-0.0050	UK	0.0113	UK	-0.0422*
	[0.009]		[0.016]		[0.025]
Constant	0.0055	Constant	0.0021	Constant	0.0132***
	[0.004]		[0.006]		[0.005]
Observations	99	Observations	100	Observations	92
R-squared	0.690	R-squared	0.612	R-squared	0.255

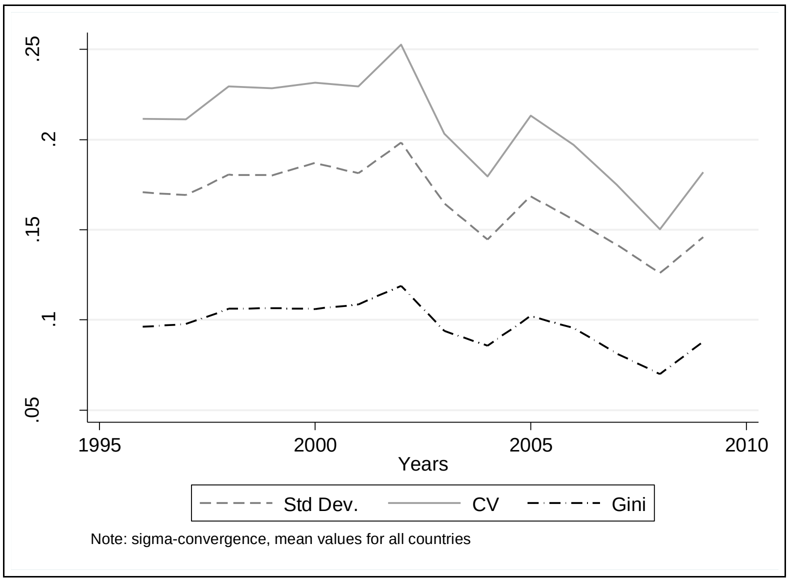
Standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Figure 6. Beta convergence within countries



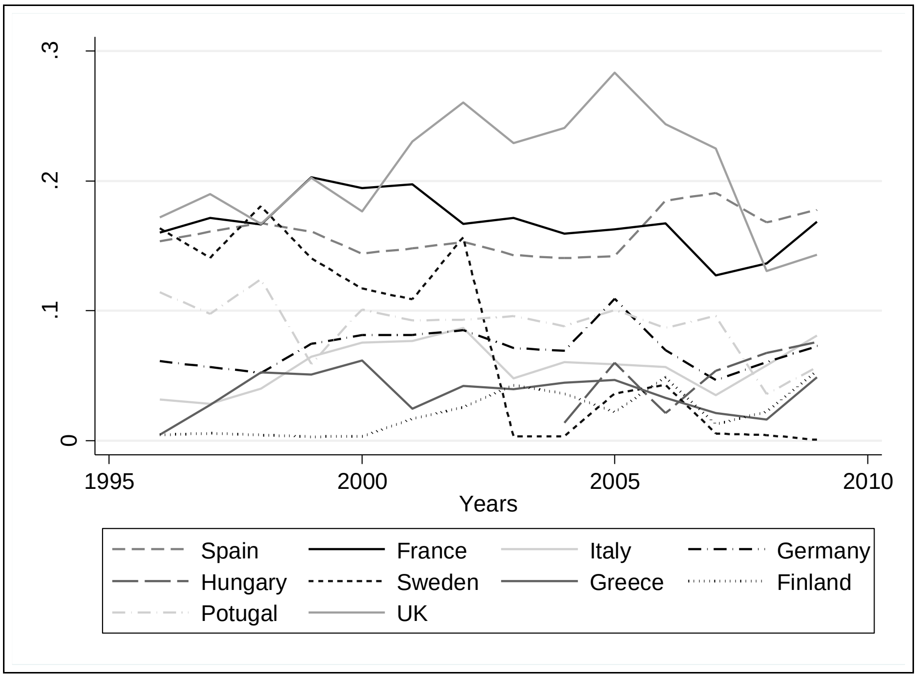
Given the catching-up processes observed through β-convergence, it is necessary to look for a reduction of disparities among regions and countries during the studied period. Figure 7 shows the evolution of the standard deviation, the coefficient of variation and the Gini coefficient calculated for the whole period. In general, we can observe the same pattern for the three measures. However, the trend in the dispersion calculated by the Gini coefficient is relatively flatter than the estimated by the two others. The dispersion declined from 1996 to 2009 but with an important peak in 2002, observing an increase of disparities from 1996 to 2002. Two possible explanations of the increase in this last period could be the adaptation to the new scheme of subsidies given the heterogeneity of the studied countries or a temporary influence of the business cycle. This fact could conclude that if σ-convergence exists is due to that the less efficient countries present a catching up process respect to richest ones. It is necessary to consider that these three measures present lacks related with the data distribution, i.e. coefficient of variation can be affected by changes in the upper part of the distribution, while Gini coefficient is responsive to changes in disparity about the median. Moreover, although these measures are helpful given the simplicity in their calculation and the good synthesis of the information, it is important to keep in mind that they do not permit for an in detail analysis of the distribution of data.

Figure 7. Sigma convergence across 10 European countries



The fact that disparities decline when we consider the EU as a whole does not avoid increasing disparities within Member States. Figure 8 displays the evolution of the Gini coefficient calculated individually for the regions of the studied countries. We can observe that disparities increased in the case of Spain from 0.15 in 1996 to almost 0.18 in 2009, in the opposite side we found to Portugal. These disparities presented in some countries could be due to the fact that each country presents local differences in the growth process.

Figure 8. Sigma convergence within countries



4 Conclusions

There is now an elevated concern about food security which is highly stressed by global warming and overpopulation. Given this, governments are trying to adapt to these challenges by improving the schemes of farm program payments, throughout more market oriented subsidies and including environmental and rural development features. In the case of European Union, the main objectives of the Common Agricultural Policy (CAP) are to improve competitiveness and sustainability of European agriculture, moving from intensive practices to more sustainable practices. Then, there is important to evaluate the effectiveness of current CAP policy since EU has proposed major changes to farm support, which will start in 2013. In this paper we studied the effects of subsidies on productivity, technical efficiency, and convergence patterns among 10 European countries. Specifically, we focused on the effects of coupled and decoupled subsidies (CAP' 1st pillar) and Least Favored Areas and environmental subsidies (2nd pillar) on technical efficiency as key issues copping the performance of European agricultural policies and their impact among countries.

As far as we know, there are few studies investigating the empirical effect of subsidies in regional agricultural performance and technical efficiency, taking into account the endogeneity of these political instruments and their influence achieving convergence in technical efficiency among regions. Here, we characterized a triangular equation system, which was estimated with a two-step method, after that, we predicted technical efficiency and finally we observed the patterns in non-spatial convergence, focusing on β-convergence and σ-convergence. Stochastic frontier analysis was carried out using Cobb-Douglas production function, with and without neutral technological change, as a good representation of our data. To avoid endogeinity, we introduced the predicted values obtained from the first step (subsidy payment equation) as a linear term in the production function.

In general, the elasticity for economic size which is a proxy of agricultural land area is the largest respect to labor and technology in all estimated models (for all countries), indicating that crop production depends strongly on the area used. However, there are technological change effects in some countries. In this case, is necessary to take into account that the contribution of cultivated areas will be smaller in the future increase of grain production given the quality of used and potential cropland as well as soil degradation. Output elasticities of technology for the different countries seem to tend to converge.

In most of the countries we can observe that the predicted subsidies have a negative impact on crop production, implying that they probably generate disincentives affecting farm competitiveness. Then, ceteris paribus, if subsidies are eliminated, the farms of the selected countries will be more productive. However, looking at the impact of subsidy scheme in the technical efficiency equation, we could observe that the different kinds of subsidies impact in a different way on technical efficiency of farms in all countries of our study. In example, in Spain, the share of crop subsidies shows a negative sing in the technical inefficiency equation, implying an insurance effect, but in Italy, Germany, Hungary, Greece and Finland, the results suggest that with this kind of subsidies, farmers are less motivated to work efficiently. Moreover, LFA payments present a negative sing in the inefficiency equation in Spain, France, Italy, Germany and Finland, although the effect is not significant; this type of subsidies promote the arrival of new farmers and help to the consolidation of the smallest farms, especially in the poorest regions, helping to prevent the concentration of production in a few producers.

The average technical efficiency during the corresponding period was 81% for Spain, 76% for France, 87% for Italy, 90% for Germany, 87% for Hungary, 88% for Sweden and Greece, 92% for Finland, 85% for Portugal and 75 for UK. France and UK got the lowest average TE (75-76%) relative to the own potential output of the country, in the opposite way, farms in Germany and Finland appear to use its actual production technology more efficiently (90-92%) relative to the other countries. However these results appear to be contradictory, especially in the case of France, given its importance in the European agricultural economy, but looking behind the mean, the results are consistent because there are some regions specialized on livestock and we do not take into account that activity.

The analysis of β-convergence of technical efficiency provides evidence in favor of technical efficiency's convergence among European countries during 1996-2009. Dividing the sample in two seven-year sub-periods (1996-2002 and 2003-2009), we found evidence of divergence in the first period and convergence in the second one. Additionally, convergence towards the stationary state is quite slow for the whole period with a half-life of almost 52 years needed for current disparities can be halved, against a half-life of 20 years for the sub-period 2003-2009. A possible explanation could be a good response to the new scheme of subsidies. From 1996 to 2009, the evolution of disparities (σ-convergence) among European regions in fact presents a clear downward trend, although there are some peaks and an increase in the dispersion during 1996 and 2002.

This kind of analysis could help policy makers generate better oriented agricultural policies. In other words, there is necessary that policy makers deepen into the form that the different kinds of subsidies change input-output decisions and affect economic performance in terms of productivity and efficiency. Finally, there could be interesting to add to this study the effect from farmers' characteristics and other external factors as off-farm jobs and national subsidies because they seem to play an important role in technical efficiency, however FADN does not have this issues. Furthermore, an analysis of spatial convergence should be interesting.

Limitations to our research are: (i) the simplicity of the statistical models used, although we introduced the linkages between those socio-economic and biophysical aspects, we ignore other important variables. (ii) The simplicity of Cobb-Douglas production function, which ignore substitutability and complementarity between inputs due to the nonexistence of cross-product terms involving these inputs. (iii) The quantity and quality of the observed data, the number of observations is at the lower limit to run our regressions, and probably there are problems related with the lack of variability. (iv) We do not take into account the effects of spatial dependence when we calculated β-convergence.

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Capítudo 5. Conclusiones Generales

Actualmente, existe una gran preocupación por la seguridad alimentaria, la cual está altamente afectada por las consecuencias del cambio climático (ejemplo: aumento de la temperatura y escasez del agua) y la sobrepoblación mundial. Dado lo anterior, a nivel mundial y en nuestro caso a nivel europeo, es relevante la necesidad de estudios que ayuden a profundizar en la revisión de los planes de gestión de cuenca hidrológicas con el fin de hacer frente a las especificaciones de la Directiva Marco del Agua (DMA) de la Unión Europea así como a las políticas nacionales, teniendo en cuenta las recientes reformas de la Política Agraria Común (PAC), en un contexto del cambio climático. En este estudio se presentaron diferentes metodologías basadas en un análisis de demanda, usando funciones de producción Cobb-Douglas extendidas.

Específicamente en el Capítulo 2, usando mínimos cuadrados ordinarios, se estimaron funciones de producción estadística, vinculando los factores biofísicos y socioeconómicos, a fín de caracterizar el rendimiento de los principales cultivos mediterrános y su impacto en el VAB agrícola, así como el riesgo asociado de estos cultivos (simulaciones de Montercarlo). También se hicieron simulaciones-predicciones de políticas de adaptación a través de reducciones en el área de regadío. En el Capítulo 3 se evaluaron cambios en los derechos de regadío, como un instrumento de política de agua, sobre la eficiencia y la distribución social, a través de funciones de producción de frontera estocástica estimandas por máxima verosimilitud y de una descomposición del coeficiente de Gini. Estos dos capítulos hacen referencia a la cuenca del Ebro en el noreste de España. Finalmente en el Capítulo 4, se estudiaron los efectos de los subsidios como inputs facilitadores en la productividad agraria a través de la eficiencia técnica, así como los patrones de convergencia en la eficiencia en países representativos de Europa. Por lo tanto, tomando en cuenta la endogeneidad de estos instrumentos de política, se estimó un sistema triangular de dos ecuaciones a través de un método de dos etapas. En la primera etapa se obtuvieron los valores predecidos de los subsidios acoplados usando técnicas de datos de panel. Dichos valores se introdujeron en una función de producción y se realizó un análisis de frontera estocástica a través de máxima verosimilitud. Después estimar la eficiencia técnica por país, así como la beta- y la sigma-convergencia entre las diferentes regiones europeas.

En un sentido más extenso y mostrando los principales resultados, en un primer análisis, observamos el efecto de cambios en los derechos de regadío en la productividad agrícola, con el fin de observar cómo una reducción en las tierras de regadío puede resultar en pérdidas moderadas o significativas de la productividad de los cultivos. Se estimaron funciones de producción cultivo-agua que explican la influencia de las diversas variables de agua en la productividad de los cultivos, estas funciones también incorporan un amplio rango de otras variables biofísicas y socioeconómicas. En general en el análisis de regresión, las variables mostraron los signos esperados. Sin embargo en esta primera aproximación no consideramos el efecto de las políticas relacionadas a la competitividad. Un análisis estrictamente económico puede sugerir la conveniencia de una fuerte orientación de la producción hacia el trigo y el maíz, porque un incremento en el rendimiento de estos cultivos tiene un mayor impacto en el VAB agrícola de la región. Sin embargo esto no toma en cuenta el costo del agua virtual ni los niveles de riesgo, tampoco toma en consideración que el desacoplamiento los pagos agrícolas de la producción y demás reformas de la PAC, especialmente desde 2000, pueden cambiar la contribución relativa de cada cultivo al VAB. Sin embargo, es importante tener en cuenta que durante el periodo de análisis (1976-2002), la contribución al VAB agrícola incluye pagos directos ligados a la productividad de los cultivos, antes de 1986 pagos provenientes de la política agrícola en España y desde 1986 subsidios de la PAC.

En este primer análisis se observa que una disminución de hasta 30% de la tierra de regadío no afecta proporcionalmente al rendimiento de los cultivos, sin embargo se debe tener en cuenta el más largo plazo así como el efecto del nuevo esquema de subsidios a la producción y al desarrollo rural. Es decir, de acuerdo a estos resultados, podría decirse que las políticas de reducción de área de regadío podrían ser una solución no dramática para la producción (Liu, 2007; Pender and Gebremedhin, 2006), sin embargo es necesario tener en cuenta las consecuencias a largo plazo sobre la competitividad y la distribución social en la agricultura.

En resumen, hasta ahora los efectos de la escasez de agua como una respuesta al cambio climático o a las restricciones de política han sido analizados con funciones de respuesta, considerando sólo los efectos sobre la productividad de los cultivos, que son fundamentalmente efectos a corto plazo. Por lo tanto, en un segundo análisis se toman en cuenta los efectos a largo plazo sobre la eficiencia técnica y la distribución social de los ingresos. Los efectos a largo plazo son importantes, sin embargo en nuestro conocimiento no han sido extensamente evaluados hasta ahora. Adicionalmente, la nueva agenda para la Política Agrícola Común europea incluye más incentivos para el cumplimiento ambiental de las actividades de los agricultores. Esto será particularmente importante en el caso de la gestión del riesgo hidrológico principalmente en los países de la región Mediterránea. Dentro de los nuevos retos se encuentra la evaluación de algunos de instrumentos para reducir la demanda de agua a nivel de cuenca y así poder cumplir con los requisitos de la Directiva Marco del Agua.

En este estudio se analizaron las implicaciones de los cambios en los derechos de agua de regadío como una respuesta de política a estos desafíos. Se analizaron dos aspectos importantes para la toma de decisiones: (i) Los efectos sobre la productividad de los cultivos y la eficiencia técnica. Algunos estudios previos, han analizado la eficiencia técnica de los cultivos como una respuesta a la Política Agrícola Común, pero no incluyen el riesgo hidrológico en su análisis. Aquí, vinculamos ambos enfoques a través de la estimación de fronteras de producción estocásticas para diversos cultivos mediterráneos en España. (ii) Los efectos sobre la distribución del ingreso rural a través del rendimiento agrícola. En nuestro enfoque, también el aspecto social debe ser evaluado pues se sabe que en los problemas de escasez de agua, la aceptación pública de las políticas es un componente muy importante. Se realizaron estimaciones empíricas para calcular los efectos marginales sobre los dos aspectos considerados. Al igual que antes, en nuestros cálculos se tuvo en cuenta tanto los aspectos biofísicos como los socioeconómicos para obtener una mejor conclusión de las implicaciones a largo plazo sobre la competitividad y las desigualdades sociales. Se encontraron disparidades en las estrategias de adaptación dependiendo del cultivo y de la región analizada. Por ejemplo, los resultados presentados aquí, muestran que en el largo plazo la superficie regada tiene un efecto estabilizador sobre la distribución de los rendimientos del trigo y del viñedo, ya que favorece a las regiones más pobres, pero además favorece el aumento de la eficiencia técnica en ambos cultivos. Este efecto se contrapone con los resultados del primer análisis, pues precisamente la pérdida de rendimiento del trigo y el viñedo es bastante moderada dada una disminución del 30% del área de regadío.

Finalmente en un tercer análisis, tomando como referencia los importantes cambios propuestos por la Unión Europea a la Política Agraria Común, se analizó el efecto de los estos subsidios sobre la productividad, la eficiencia técnica y los patrones de convergencia entre diez países representativos de las diferentes regiones climáticas europeas. Esta parte del estudio se centró en los subsidios acoplados y los desacoplados (primer pilar de la PAC), así como en los subsidios para las áreas menos favorecidas y los ambientales (segundo pilar de la PAC). Como se mencionó anteriormente, se tomó en cuenta la endogenidad de los subsidios a la producción, a través de un sistema de dos ecuaciones, para después predecir la eficiencia técnica por país y los patrones de convergencia. En general, las regresiones mostraron los signos esperados. Enfatizando en las variables de subsidios, se observó que los subsidios acoplados tienen un impacto negativo en la función de producción pues generan desincentivos que afectan la competitividad, es decir, ceteris paribus, si se eliminaran este tipo de subsidios, los productores agrícolas, de los países seleccionados, serían más productivos. Sin embargo, si analizamos el efecto de los diferentes tipos de subsidios sobre la eficiencia técnica, no se puede generar una conclusión común, pues estos afectan de diferente manera en todos los países del estudio. La eficiencia técnica prmedio estimada por país, es relativamente alta, sin embargo se observó que países como Francia y España presentan una mayor varianza en este punto, por lo tanto es necesario un análisis más allá de la media. Por último, tomando en cuenta los análisis de beta- y sigma-convergencia, se encontró evidencia de un proceso de convergencia en la eficiencia técnica. Una extensión a este análisis sería añadir el efecto de las características socioeconómicas de los agricultores así como otros factores externos como el empleo no agrícola y los subsidios nacionales, dado que parecen desempeñar un papel importante en la eficiencia técnica, sin la base de datos usada, no cuenta con estos componetes. Adicionalmente, un análisis de convergencia espacial es de gran interés.

Los enfoques metodológicos mostrados en este estudio pueden ser usados en otros campos de las políticas públicas en materia de agricultura y medio ambiente, ya que pueden extenderse para analizar el efecto de otros factores como la modernización del regadío, la aplicación de fertilizantes o la aplicación de políticas agrícolas locales. Limitaciones de nuestro estudio provienen de la simplicidad de los modelos empíricos así como de la calidad de los datos observados.