academicJournals

Vol. 6(3), pp. 124-131, March, 2014
DOI: 10.5897/JDAE2013.0534
ISSN 2006-9774 © 2014 Academic Journals
http://www.academicjournals.org/JDAE

Journal of Development and Agricultural Economics

Full Length Research Paper

The Ricardian analysis twenty years after the original model: Evolution, unresolved issues and empirical problems

Maria De Salvo[1], Diego Begalli[1] and Giovanni Signorello[2]

[1]Department of Business Administration, University of Verona, Italy.
[2]Department of Agri-food and Environmental System Management, University of Catania, Italy.

Accepted 19 December, 2013

This paper analyses the wide body of literature that concerns applications of the Ricardian approach to assess the economic effects of climate change on agriculture. Beginning with the original model proposed by Mendelsohn, Nordhaus and Shaw in 1994, the article discusses researchers' main criticisms of the model and the innovations suggested to overcome its limitations. Finally, the study summarises the unresolved issues and empirical problems that need to be examined in future research. New issues to be explored include the capture of future technologies, implementation of price changes, choice of the best variables to represent climate, simulation of seasonal effects and identification of the best technique to hypothesise the relationship between profits and climate. The paper also discusses operative problems, such as the availability of the most suitable data, the adoption of spatialisation techniques and the enlargement of the time horizon to be covered.

Key words: Climate change, economic effects, agriculture, Ricardian analysis.

INTRODUCTION

The literature proposes several methods to assess the impact of climate change on agriculture (United Nations Framework Convention on Climate Change [UNFCCC], 2008). However, an examination of the proposed models and the empirical evidence reveals that the Ricardian method is the most commonly used microeconomic approach. This method, proposed by Mendelsohn et al. (1994), was originally formulated to overcome the main limitation of the production function approach, which is based on a crop-specific analysis that fails to take into consideration the possibility for farmers to implement adaptation strategies to cope with the effects of climate change. The principal innovation introduced by the Ricardian analysis is a 'black box' treatment of farmers' adaptation strategies. This means that the model does not require to explicit adaptation strategies among the explanatory variables because these are considered in the model implicitly. The key idea is that farmers aim to maximise their profits through a specific combination of output and input, given the values of exogenous variables such as climate, soil, altitude and other constraints outside their control (Mendelsohn and Dinar, 2009). By regressing farms' net profits with these variables it is possible to estimate the marginal effects of climate

*Corresponding author. E-mail: diego.begalli@univr.it.

JEL Classification: C50, Q15, Q51.

change on farmers' profits. Moreover, by simulating changes of climate scenarios and projecting into the future the estimated relationship between economic performance and climatic variables, it is possible to measure the economic impact of the hypothesised climate changes on agriculture (Mendelsohn et al., 1994).

From the beginning, this method has produced scepticism and criticism (Cline, 1996; Fisher and Hanemann, 1998; Darwin, 1999; Quiggin and Horowitz, 1999). This has generated a profitable and stimulating debate among researchers over the last 20 years. Despite the initial doubts, the Ricardian approach has been applied to different geographical contexts and scales (Kurukulasuriya and Mendelsohn, 2007; Maddison et al., 2007; Mendelsohn and Seo, 2007; Strzepek and McCluskey, 2007; Seo and Mendelsohn, 2008; Van Passel et al., 2012). It was also adopted to account for climate change impacts on the agricultural sector in developed and developing countries (Kumar and Parikh, 1998; Weber and Hauer, 2003; Liu et al., 2004; Deressa et al., 2005; Schlenker et al., 2005; Seo et al., 2005; Deressa, 2007; Eid et al., 2007; Jain, 2007; Kabubo-Mariara and Karanja, 2007; Mano and Nhemachena, 2007; Molua and Lambi, 2007; Fleischer et al., 2008; Kabubo-Mariara, 2008; Wang et al., 2008; Mendelsohn et al., 2010). Recently, it was demonstrated that it is also possible to apply this method in very small regions (De Salvo et al., 2013).

Mendelsohn and Dinar (2009) raised some questions about the future evolution of the Ricardian analysis and, recently, some of these were answered fully or partially. These concerns: (i) the use of net revenue instead of land value as the dependent variable (Mendelsohn et al., 2007); (ii) the choice of the most appropriate functional form for the Ricardian function (Lang, 2007; Fezzi and Bateman, 2012); (iii) the independent factors included in the model as control variables (Deressa, 2007; Eid et al., 2007; Mano and Nhemachena, 2007; Kabubo-Mariara and Karanja, 2007); (iv) the treatment of the relationship between climate change, irrigation and the impacts on agriculture (Schlenker et al., 2005; Kurukulasuriya and Mendelsohn, 2008a); and (v) the stability of the estimated coefficients over time (Massetti and Mendelsohn, 2011). Other problems remain unresolved feeding the current debate among researchers. These mainly concern how the climate should be represented in the analysis and the need to take into account aspects not yet considered, such as how to capture the effects of technological innovations and prices changes.

This article focuses on a literature review of the Ricardian analysis and considers principally the most recent debate on its use. It aims to highlight the issues currently being debated among researchers in order to discuss the critical aspects and the potential development of the method, especially in relation to the questions not yet resolved. Final considerations concern the empirical problems faced by scholars in applying this approach.

ORIGINAL MODEL

Until the mid-1990s, the most popular microeconomic method used to measure impacts of climate change on agriculture was the production function approach, a crop simulation model that explains the agronomic relationship between production and climate, soils and management practices. The main limitation of this method is that it is a crop-specific analysis and endorses the so-called 'dumb-farmer' hypothesis. It fails to capture farmers' behaviour, especially as it concerns the switch from crops less suitable to crops more suitable to climate change (Mendelsohn and Dinar, 2009). As highlighted by Mendelsohn et al. (1994), the impacts assessed using this method are overestimated.

To overcome this limitation, Mendelsohn et al. (1994) propose the Ricardian approach, which assumes, in its original formulation, the following specification:

$$V = \int P_{LE} e^{-\varphi t}\, dt = \int [\sum P_i Q_i(X,F,Z) - \sum RX] e^{-\varphi t}\, dt \qquad (1)$$

where: P_{LE} is the net revenue per hectare; P_i is the market price of the crop i; Q_i is the output of the crop i; F is a vector of climatic variables; Z is a vector of soil and economic variables; X is a vector of purchased inputs (excluding land); R is a vector of input prices; t is the time; and φ is the discount rate.

Mendelsohn et al. (1994) base their model on the following two assumptions: (i) a perfectly competitive market for both outputs and inputs, and (ii) interest rate, rate of capital gains and capital per acre are equal for all plots of land. The latter assumption ensures proportionality between land value and land rent. Consequently, it is possible to reduce the profit maximisation function (1) to a cross-sectional analysis in which the land value (or, as most recently suggested, the farm's net revenue) is regressed against climate and soil characteristics, and other control variables. Obviously, the coefficients estimated are consistent only if the model includes all the relevant explicative variables. Otherwise, climate change effects on the dependent variable are mixed with the effects caused by other factors, and the consequent bias of coefficients is unknown in terms of both sign and magnitude (Deschênes and Greenstone, 2007).

In the Ricardian analysis climatic variables are included among the regressors to simulate climate change. Taking into account the agronomic literature on this topic, Mendelsohn et al. (1994) hypothesises a quadratic relationship between the net profit and climatic variables, choosing as proxies for these the long-run averages of temperature and precipitation (climate normals) measured during the period 1951 to 1990. They also simulate a seasonal effect, considering the value of each climatic variable for the most representative month of each season (January, April, July and October).

Recently, other authors have assumed new ways of representing the climate scenario as well as new hypotheses to estimate the relationship between profits and climate. Using satellite data, Mendelsohn et al. (2007) test the importance of climate normals and inter-annual variance for explaining the net revenue from cropland and the fraction of land used for cropland. Schlenker et al. (2006) suggest the use of ‘degree days’ between 8 and 32°C, instead of the average temperature, to represent climate in the model. They also suggest measuring the climatic variables during the growing season only (April–September). Massetti et al. (2013) criticise these choices, arguing that average temperatures provide a more accurate result than degree days, and that seasons matter in explaining the relationships between climate scenario and economic performance. Table 1 summarises the work of the most relevant scholars on these issues.

MAIN CRITICISMS OF THE ORIGINAL MODEL AND PROPOSED SOLUTIONS

The validity and robustness of the Ricardian approach have animated an international debate among researchers. Cline (1996) made one of the first criticisms, which concerns the partial equilibrium nature of this analysis because it implies no change in prices. Cline argues that as a consequence, underestimation of climate damages and overestimation of climate benefits occur.

The Ricardian method is also criticised for its static nature. The impacts of climate change on agriculture should be analysed dynamically, emphasising changes of climatic variables over time rather than at one level (Quiggin and Horowitz, 1999). Further, several scholars agree that one of the main weakness of the traditional formulation proposed by Mendelsohn et al. (1994) is the lack of irrigation modelling (Cline, 1996; Fisher and Hanemann, 1998; Darwin, 1999). In particular, Fisher and Hanemann (1998) demonstrate that the omission of irrigation from the analysis can lead to an incorrect estimation of climate parameters’ signs and magnitude.

Mendelsohn and Nordhaus (1999a, 1999b) respond to these criticisms. Mendelsohn and Nordhaus (1999b) support their approach through the estimation of a formulation in which they modify the hedonic function, taking into account the effect of irrigation in the constant term. However, this formulation fails to consider the other estimation coefficients, especially those related to climatic variables. Schlenker et al. (2005) estimate separate regressions for rainfed and irrigated lands, demonstrating that the Ricardian function differs in the presence and absence of irrigation, especially as it concerns the parameters related to the climatic variables. They conclude that irrigated and dry lands cannot be pooled in a single regression function. Consequently, the economic effects of climate change on agriculture need to be assessed using different variables for dry land and irrigated areas in the model specification.

Schlenker et al. (2005) treat irrigation as an exogenous variable, causing sample selection bias (Mendelsohn and Dinar, 2009). Some applications have introduced innovative changes to the original approach, suggesting the use of a ‘structural Ricardian model’ to take adaptation into account (Table 1). These applications match the estimation of a binary or categorical model to simulate farmers’ behaviour, with a second stage of analysis devoted to estimating the conditional net revenue for each considered choice.

In this way, Kurukulasuriya and Mendelsohn (2008a) discriminate between irrigated and rainfed lands, improving the Ricardian approach by treating irrigation as an endogenous variable. In addition, Kurukulasuriya and Mendelsohn (2008b) apply this approach to consider the possibility of farmers changing crops to cope with climate change. Seo and Mendelsohn (2008) apply this approach to livestock rearing, while Mendelsohn and Seo (2007) extend the application of the structural Ricardian model to different farm typologies.

One of the most significant difficulties affecting the estimation of the Ricardian model concerns data availability. In order to extend the application of this model to countries for which census data are not available, some authors propose using primary data from surveys of farms in different climatic zones (Lippert et al., 2009; Wang et al., 2008; Mendelsohn et al., 2010). In this case, more detailed data about farm activities are available, making it possible to consider net revenue instead of land price as the dependent variable. In relation to the choice of dependent variable, Mendelsohn and Dinar (2009) indicate that net revenue reflects short-term climatic variations, while land value reflects a long-term scenario. Moreover, net revenue is a more robust measure of land value than land price because it does not depend on discount rate assumptions about future revenues (Kurukulasuriya and Ajwad, 2007).

One further criticism of considering the net revenue as the dependent variable concerns its strong relation with the year of analysis. Mendelsohn et al. (2007) calculate a three-year average (1990, 1995, 2000) in order to provide a long-term measure of net revenue.

The use of farm survey data and net revenue as the dependent variables makes it possible to include in the analysis control variables as proxies for farmers’ strategies for coping with markets and to control the climate change effects on profits. Some authors consider control variables to be the specific characteristics of the agricultural sector in different local scenarios using socio-economic variables (Eid et al., 2007) and farmer profile variables (Deressa, 2007; Mano and Nhemachena, 2007; Kabubo-Mariara and Karanja, 2007). Others include in the model—as exogenous variables—proxies for farmers’ adaptation strategies (Molua and Lambi, 2007).

Recently, the scientific debate has focused on the

Table 1. Examples of some Ricardian model applications.

Authors	TH v. EM	Model type	CS v. PD	Agg v. Frm	NR v. LP	Functional form	Climatic variables	Seasonal effect?	Interaction effect?	Climatic variables' functional form	Case study
Mendelsohn et al. (1994)	TH EM	Ricardian	CS	Agg	NR	Linear	Temperature Precipitation	Yes	Yes	Quadratic	US
Kumar and Parikh (1998)	EM	Ricardian	CS	Agg	NR	Linear	Temperature Precipitation	Yes	No	Quadratic	India
Maddison (2000)	EM	Ricardian	CS	Frm	LP	Linear	Temperature Precipitation Wind Speed Foggy Days	Yes	No	Linear	Wales, United Kingdom
Weber and Hauer (2003)	EM	Ricardian	CS	Frm	LP	Linear	Temperature Precipitation	Yes	Yes	Non-linear	Canada
Mendelsohn et al. (2004)	EM	Ricardian	CS	Frm	NR	Linear	Temperature Precipitation	Yes	No	Quadratic	Sri Lanka
Schlenker et al. (2005)	EM	Ricardian	CS	Frm	LP	Linear	Degree days Precipitation	No	No	Quadratic	US counties east of the 100th meridian
Deressa et al. (2005)	EM	Ricardian	CS	Agg	NR	Linear	Temperature Precipitation	Yes	Yes	Quadratic	South Africa
Deschênes and Greenstone (2006)	TH EM	Fixed-effect	PD	Agg	NR	Linear	Degree days Precipitation	Yes	No	Quadratic	US
Deressa (2007)	EM	Ricardian	CS	Frm	NR	Linear	Temperature Precipitation	Yes	No	Quadratic	Ethiopia
Eid et al. (2007)	EM	Ricardian	CS	Frm	NR	Linear	Temperature Precipitation	Yes	No	Quadratic	Egypt
Jain (2007)	EM	Ricardian	CS	Frm	NR	Linear	Temperature Humidity	Yes	No	Quadratic	Zambia
Kabubo-Mariara and Karanja (2007)	EM	Ricardian	CS	Frm	NR	Linear	Temperature Precipitation	Yes	No	Quadratic	Kenya

Table 1. Contd.

Kurukulasuriya and Mendelsohn (2008a)	TH EM	Structural Ricardian	CS	Frm	NR	Linear	Temperature Precipitation	Yes	No	Quadratic	Africa
Lang (2007)	TH EM	Structural Ricardian	PD	Frm	LP	Quadratic Box–Cox	Temperature Precipitation	No	Yes	Non-linear	Germany
Mano and Nhemachena (2007)	EM	Ricardian	CS	Frm	NR	Linear	Temperature Precipitation	Yes	No	Quadratic	Zimbabwe
Molua and Lambi (2007)	EM	Ricardian	CS	Frm	NR	Linear	Temperature Precipitation	Yes	No	Quadratic	Cameroon
Mendelsohn and Seo (2007)	EM	Structural Ricaridan	CS	Frm	NR LP	Linear	Temperature Precipitation	Yes	No	Quadratic	Latin America
Fleischer et al. (2008)	EM	Ricardian	CS	Frm	NR	Linear	Temperature Precipitation	No	No	Quadratic	Israel
Kabubo-Mariara (2008)	EM	Ricardian	CS	Frm	NR	Linear	Temperature Precipitation	Yes	No	Quadratic	Kenya
Seo (2008)	EM	Structural Ricardian	CS	Frm	NR	Linear	Temperature Precipitation	Yes	No	Quadratic	Africa
Seo and Mendelsohn (2008)	EM	Structural Ricardian	CS	Frm	NR	Linear	Temperature Precipitation	Yes	No	Quadratic	Africa
Seo et al. (2008)	EM	Ricardian	CS	Agg	NR	Linear	Temperature Precipitation	Yes	Yes	Quadratic	Africa
Wang et al. (2008)	EM	Ricardian	CS	Frm	NR	Linear	Temperature Precipitation	Yes	No	Quadratic	China
Lippert et al. (2009)	TH EM	Structural Ricardian	CS	Frm	LP	Simple spatial error model	Temperature Precipitation	No	No	Linear	Germany
Massetti and Mendelsohn (2011)	TH EM	Ricardian (not standard)	PD	Frm	LP	Linear	Temperature Precipitation	Yes	No	Quadratic	US
Mendelsohn et al. (2010)	EM	Ricardian	CS	Frm	LP	Linear	Temperature Precipitation	Yes	Yes	Quadratic	Mexico

Table 1. Contd.

Fezzi and Bateman (2012)	TH EM	Ricardian (not standard)	PD	Frm	LP	Smoothing function	Degree days Precipitation	No	No	Linear	Wales, United Kingdom
De Salvo et al. (2013)	EM	Ricardian	CS	Frm	NR	Linear Log-linear Box–Cox	Temperature Precipitation	No	No	Quadratic	Province of Trento (Italy)

TH, theoretical paper; EM, empirical paper; CS, cross-sectional data; PD, panel data; Agg, aggregated data; Frm, individual farm data; NR, net revenue; LP, land price.

flexibility of the functional form and the possibility of using panel data for the estimation of the Ricardian function. According to Mendelsohn and Dinar (2009), the use of net revenue in the logarithm form as the dependent variable is most appropriate. Lang (2007) chooses land price as the dependent variable and introduces the use of a quadratic Box–Cox function to assess the impact of climate change on German agriculture. De Salvo et al. (2013) compare models estimated using the ordinal (linear and log-linear) net revenue formulations to those in which the dependent variable is specified as a Box–Cox transformation. Fezzi and Bateman (2012) propose the use of a smoothing function. However, the advantage of modelling the data without imposing a specific functional form is limited to continuous variables. Due to data unavailability, control variables are frequently expressed using dummy or categorical variables, for which it is not possible to use the smoothing function or Box–Cox transformation.

The need to adapt the Ricardian approach to panel data arises from different considerations. First, climate coefficients change over time (Mendelsohn and Dinar, 2009). Moreover, it is possible to obtain biased estimates if the dependent variable is the farm's net revenue measured in an unrepresentative year. Second, the use of panel data resolves the distortions caused by the correlation between climatic variables and farmers' strategies treated explicitly in the model (for example, irrigation).

Deschênes and Greenstone (2007) propose the use of a fixed-effect model that represents the climatic impacts on profit and yields through weather variables. They argue that the results of the Ricardian function are not stable over time. Massetti and Mendelsohn (2011) refute this conclusion and demonstrate a broader stability of the Ricardian climate coefficients using panel data. In particular, relying on several approaches, Massetti and Mendelsohn (2011) suggest the use of the Chang Hsiao technique (Hsiao, 2003).

Deschênes and Greenstone's (2007) approach is also criticised by Fisher et al. (2012), who list the aspects that plausibly explain divergences between Deschênes and Greenstone's (2012) results and those obtained in previous studies, including that scholars do not consider the spatial correlation (Anselin and Lozano-Gracia, 2008). As highlighted by Kumar (2011), spatial correlation could affect the Ricardian analysis, considering both the dependent variable and the errors. A bias in the estimates of the *t*-statistic could occur if these sources of correlation are ignored. Researchers who treat spatial correlation explicitly are Polsky and Easterling (2001), Schlenker et al. (2006), Lippert et al. (2009) and Kumar (2011).

UNRESOLVED ISSUES AND EMPIRICAL PROBLEMS

Since the publication of Mendelsohn et al.'s original (1994) article, and despite criticisms and doubts about its validity, the Ricardian model has become one of the most applied econometric approaches to measuring the economic impact of climate change on agriculture. According to Mendelsohn et al. (2010), this is because 'it is easy to estimate, yields geographically precise values, and captures adaptation'.

Over the past 20 years, researchers have recognised the potential of this method. They have enriched its application with variants and evolutions in attempts to remove its principal limitations, such as the lack of irrigation modelling and its endogenous nature, the inexplicit consideration of adaptation strategies, the time instability of the Ricardian climate coefficients and the lack of spatial correlation treatment. Further, they have enlarged the application of the model to individual farm data and tested different functional forms, identifying those more versatile and flexible. Finally, they have demonstrated the applicability of this method to a small scale. As a consequence, the use of this method has increased, despite the fact that some critical issues remain unresolved, including how to capture future technologies and how to consider changing prices. Other issues are currently under debate, including the choice of the best variables to represent climate, the need to simulate a seasonal effect, and the best method of hypothesising the relationship between profits and climate.

Further, to resolve technical issues, researchers undertaking original studies need to face operative problems, including those common to most empirical researches, such as data availability. Census data are frequently inaccessible and surveys are expensive. Consequently, alternative sources of information are required. For European countries, the Farm Accountancy Data Network (FADN)[1], which collects structural, economic and financial data from a representative sample of European farms, could be a data source of primary importance for Ricardian applications.

The technique used to link economic and climatic data is another relevant issue. Climatic data are frequently related to local meteorological stations, and the algorithm used to associate each observation with the values of the climate normals is key to ensuring variability and the significance of variables. To ensure the model's validity, the use of a local and specific spatialisation procedure is relevant, especially if it is applied on a small scale using farm data. However, data on farms' spatial coordinates are frequently unavailable. For instance, the FADN database do not contains farm's spatial coordinates and it is possible identify only the municipality where the observation is located.

A further concern is the time horizon covered by the available data. Frequently, data is available for only a single or a few consecutive years, and it is not possible to provide long-term statistics. This makes it impossible for an analysis to include the effect of changing output and input prices. For instance, the sampling procedure used by the FADN does not ensure the constancy of the investigated sample. Consequently, it is not possible to analyse farms' long-term changes in relation to other aspects that could be affected by climate change, such as soil usage, farmland, choices of capital and investments, and technological changes. This limits the possibility of estimating panel-data models, which seem to be the best solution to both unresolved critical issues and the numerous limits of the traditional Ricardian approach. As demonstrated, a panel-data approach removes year effects and produces more stable estimates of the climatic coefficients. Moreover, in order to consider the endogenous nature of the irrigation, the panel-data approach can be formulated to remove misspecifications due to the lack of consideration of adaptations and other phenomena that could occur in the long term as a response to climate change or other factors. However, a model that can meet all these requirements is extremely sophisticated and requires the use of unpopular software using handmade functions—a significant limitation to its application.

In conclusion many advances were made to the Ricardian analysis during the last twenty years but there are still many critical issues to be solved. A further and wider use of the model need to overcome the most common empirical problems such as the availability of data at the suitable spatial scale and time horizon. Finally, the estimation of panel data models also involves the availability of specific packages to be implemented in the most used software.

REFERENCES

Anselin L, Lozano-Gracia N (2008). Errors in variables and spatial effects in hedonic House price models of ambient air quality. Emp. Econ. 34(1):5-34.

Cline WR (1996). The impact of global warming on agriculture [comment]. Am. Ec. Rev. 86(5):1309-1311.

Darwin R (1999). The impact of global warming on agriculture: A Ricardian analysis [comment]. Am. Econ. Rev. 89(4):1049-1052.

De Salvo M, Raffaelli R, Moser R (2013). The impacts of climate change on permanent crops in an alpine region: A Ricardian analysis. Agric. Syst. 118:23-32.

Deressa T (2007). Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach. World Bank Policy Res. Work. P. 4342.

Deressa T, Hassan R, Poonyth D (2005). Measuring the impact of climate change on South African agriculture: the case of sugar-cane growing regions. Agrekon 44(4):524-542.

Deschênes O, Greenstone M (2007). The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather. Am. Econ. Rev. 97(1):354-384.

Deschênes O, Greenstone M (2012). The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather [reply]. Am. Econ. Rev. 102(7):3761-3773.

Eid HM, El-Marsafawy S, Ouda SA (2007). Assessing the economic impacts of climate change on agriculture in Egypt: A Ricardian approach. World Bank Policy Res. Work. P. 4293.

Fezzi C, Bateman I (2012). Non-linear effects and aggregation bias in Ricardian models of climate change. CSERGE Work. P. 2012-02.

Fisher AC, Hanemann M (1998). The impact of global warming on agriculture: Rethinking the Ricardian approach. Working Paper Series, Department of Agricultural and Resource Economics, Berkeley, California Agricultural Experiment Station, University of California.

Fisher AC, Hanemann M, Schlenker W (2012). The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather [comment]. Am. Econ. Rev. 102(7):3749-3760.

Fleischer A, Lichtman I, Mendelsohn R (2008). Climate change, irrigation, and Israeli agriculture: will warming be harmful. Ecol. Econ. 65(3):508-515.

Hsiao C (2003). Analysis of Panel Data, 2nd edn. Cambridge University Press, Cambridge.

Jain S (2007). An empirical economic assessment of impacts of climate change on agriculture in Zambia. World Bank Policy Res. Series Work. P. 4291.

Kabubo-Mariara J (2008). The economic impact of global warming on livestock husbandry in Kenya: a Ricardian analysis. Paper presented at the 16th Annual Conference of the European Association of Environmental and Resource Economists, Gothenburg, Sweden, 25-28 June.

Kabubo-Mariara J, Karanja FK (2007). The economic impact of climate change on Kenyan crop agriculture: a Ricardian approach. World Bank Policy Res. Series Work. P. 4334.

Kumar K (2011). Climate sensitivity of Indian agriculture: do spatial

---

[1] http://ec.europa.eu/agriculture/rica/

effects matter? Camb. J. Reg. Econ. Soc. 4:221-235.

Kumar K, Parikh J (1998). Climate change impacts on Indian agriculture: the Ricardian approach. In Dinar A, Mendelsohn R, Evenson R, Parikh J, Sangi A, Kumar K, Mckinsey J, Lonergan S (eds), Measuring the impact of climate change on Indian agriculture. World Bank Technical P. 402, World Bank, Washington, DC.

Kurukulasuriya P, Ajwad MI (2007). Application of the Ricardian technique to estimate the impact of climate change on smallholder farming in Sri Lanka. Clim. Ch. 81(1):39-59.

Kurukulasuriya P, Mendelsohn R (2007). Endogenous irrigation: the impact of climate change on farmers in Africa. World Bank Policy Research Working Paper 4278.

Kurukulasuriya P, Mendelsohn R (2008a). A Ricardian analysis of the impact of climate change on African cropland. Afr. J. Agric Res. Econ. 2:1-23.

Kurukulasuriya P, Mendelsohn R (2008b). Crop switching as an adaptation strategy to climate change. Afr. J. Agric Res. Econ. 2:105-126.

Lang G (2007). Where are Germany's gains from Kyoto?: estimating the effects of global warming on agriculture. Clim. Ch. 84:423-439.

Lippert C, Krimly T, Aurbacher J (2009). A Ricardian analysis of the impact of climate change on agriculture in Germany. Clim. Ch. 97(3-4):593-610.

Liu H, Li X, Fischer G, Sun L (2004). Study on the impacts of climate change on China's agriculture. Clim. Ch. 65(1-2):125-148.

Maddison D (2000). A hedonic analysis of agricultural land prices in England and Wales. Eur. Rev. Agric. Econ. 27:519-532.

Maddison D, Manley M, Kurukulasuriya P (2007). The impact of climate change on African agriculture: a Ricardian approach. World Bank Development Research Group, Sustainable Rural and Urban Development Team, Policy Research Working P. 4306.

Mano R, Nhemachena C (2007). Assessment of the economic impacts of climate change on agriculture in Zimbabwe: A Ricardian approach. World Bank Development Research Group, Sustainable Rural and Urban Development Team, Policy Research Working P. 4292.

Massetti E, Mendelsohn R (2011). Estimating Ricardian functions with panel data. Climate Change Econ. 2(4):301-319.

Massetti E, Mendelsohn R, Chonabayashi S (2013). How does temperature affect land values in the US? FEEM Seminars, available at http://www.feem.it/userfiles/attach/201362113121452013.06.20_Emanuele%20Massetti_presentation.pdf.

Mendelsohn R, Dinar A (2009). Climate change and agriculture: an economic analysis of global impact, adaptation and distributional effects. Elgar, Cheltenham.

Mendelsohn R, Nordhaus W (1996). The impact of global warming on agriculture [reply to Cline]. The Am. Econ. Rew. 86(5):1312-1315.

Mendelsohn R, Nordhaus W (1999a). [Reply to Quiggin and Horowitz]. Am. Ec. Rev. 89:1046-1048.

Mendelsohn R, Nordhaus W (1999b). [Reply to Darwin]. Am. Econ. Rev. 89:1053-1055.

Mendelsohn R, Seo N (2007). Changing farm types and irrigation as an adaptation to climate change in Latin American agriculture. World Bank Policy Res. Work. P. 4161.

Mendelsohn R, Christensen P, Arellano-Gonzalez J (2010). The impact of climate change on Mexican agriculture: a Ricardian analysis. Env. Dev. Econ. 15:153-171.

Mendelsohn R, Nordhaus WD, Shaw D (1994). The impact of global warming on agriculture: A Ricardian analysis. Am. Econ. Rev. 84(4):753-771.

Mendelsohn R, Basist A, Dinar A, Kurukulasuriya P, Williams C (2007). What explains agricultural performance: climate normals or climate variance. Clim. Ch. 81(1):85-99.

Molua E, Lambi CM (2007). The economic impact of climate change on agriculture in Cameroon. World Bank Development Research Group, Sustainable Rural and Urban Development Team. Policy Res. Work. P. 4364.

Polsky C, Easterling WE III (2001). Adaptation to climate variability and change in the US Great Plains: A multi-scale analysis of Ricardian climate sensitivities. Agric. Ecosyst. Env. 85:133-144.

Quiggin J, Horowitz JK (1999). The impact of global warming on agriculture: A Ricardian analysis. Am. Econ. Rev. 89(4):1044-1045.

Schlenker W, Hanemann M, Fischer A (2005). Will US agriculture really benefit from global warming?: accounting for irrigation in the hedonic approach. Am. Econ. Rev. 95(1):395-406.

Schlenker W, Hanemann M, Fisher A (2006). The impact of global warming on U.S. agriculture: An econometric analysis of optimal growing conditions. Rev. Econ. Stat. 88:113-125.

Seo SN (2008). A microeconomics analysis of climate change impacts on livestock management in African agriculture. MPRA Paper 6903, Yale University, New Haven, CT.

Seo SN, Mendelsohn R (2008). Measuring impacts and adaptations to climate change: a structural Ricardian model of African livestock management. Agric. Econ. 38(2):151-165.

Seo SN, Mendelsohn R, Munasinghe M (2005). Climate change impacts on agriculture in Sri Lanka. Env. Dev. Econ. 10:581-596.

Strzepek K, McCluskey A (2007). The impacts of climate change on regional water resources and agriculture in Africa. World Bank Development Research Group, Sustainable Rural and Urban Development Team. Policy Res. Work. P. 4290.

United Nations Framework Convention on Climate Change (UNFCCC) (2008). Compendium on methods and tools to evaluate impacts of, vulnerability and adaptation to climate change, available at http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/2674.php.

Van Passel S, Massetti E, Mendelsohn R (2012). A Ricardian analysis of the impact of climate change on European agriculture. FEEM nota di lavoro, 83/2012, available at http://www.oecd.org/tad/crp/VAN_PASSEL_WorkingPaper_RicardianAnalysis.pdf.

Wang J, Mendelsohn R, Dinar A, Huang J, Rozelle S (2008). Can China continue feeding itself?: The impact of climate change on agriculture. World Bank Development Research Group, Sustainable Rural and Urban Development Team. Policy Res. Work. P. 4470.

Weber M, Hauer G (2003). A regional analysis of climate change impacts on Canadian agriculture. Can. Pub. Pol. 29(2):163-180.