Weather Impacts on Natural, Social and Economic Systems (WISE)
Part I: Sectoral Analysis of Climate Impacts in Italy

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Weather Impacts On Natural, Social And Economic Systems (WISE) Part I: Sectoral Analysis of Climate Impacts in Italy

Summary

This paper focuses on the results of the research work carried out by Fondazione Eni Enrico Mattei (FEEM) within the WISE project. This project aims at investigating the effects and the impacts of extreme weather events, particularly very warm summers, mild winters and storms, on the socio-economic systems of European countries. The output consists of a series of empirical studies, both of quantitative and qualitative-descriptive nature. The work of FEEM in the WISE project covers the quantitative analysis of the impacts of climate extremes on the socio-economic system in Italy and the analysis of individuals' perception of climate extremes based on results from individuals' surveys. In this paper is presented the statistical modelling of the impact of weather, through quantitative analysis of activity time series. In particular, the core sectors analysed include fires, health, energy use, tourism and agriculture.

Keywords: Climate change, Extreme events, Impacts

JEL Classification: Q2, Q250

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1. Introduction

1.1. Objectives

The paper focuses on the results of the research work carried out by Fondazione Eni Enrico Mattei (FEEM) within the WISE project. WISE (Weather Impacts on Natural, Social and Economic System) is a project financed by European Commission within the Environment and Climate Research Programme.
The FEEM's partners involved in the project are: the Climatic Research Unit (CRU), University of East Anglia, Norwich (UK); the Postdam Institute for Climate Impact Research (PIK), Postdam (Germany); the Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam (NL).

The WISE project aims at investigating the effects and the impacts of extreme weather events, particularly very warm summers, mild winters and storms, on the socio-economic systems of European countries.

The main objectives of WISE were:

- to examine the impacts of a recent hot summer and a recent mild winter on the natural environment and on national economies; in addition, and where possible, to set a monetary value on these impacts.
- To examine how the impacts of extreme seasons propagate between the national economies of the member countries of the EU. The sectors to be analysed were tourism and agricultural products.
- To examine the impact of climate 'shocks'. The selected shocks are wind storm and cold spells. The sectors to be examined are forestry and property insurance for wind storm, and health and energy supply for cold spells.
- To investigate the perceptions of the general public and management regarding climate extreme and shocks.

The output of the project consists of a series of empirical studies, both of quantitative and qualitative-descriptive nature.
The methodology adopted for the econometric analysis and the economic evaluation of the impact of weather extremes is homogenous across all partners. The agricultural variables on which the impacts of weather extremes are analysed in Italy slightly differ from those studied by our partners, both due to data availability and to features specific to the Italian economy, since Italy is the only Mediterranean country in the project.

The work of FEEM in the WISE project covered:

- the quantitative analysis of the impacts of climate extremes on the socio-economic system in Italy
- The analysis of individuals' perception of climate extremes based on results from individuals' surveys.
- Where possible, the economic evaluation of the impacts of weather extremes on the various sectors under analysis.

In this paper is presented the statistical modelling of the impact of weather, through quantitative analysis of activity time series.
In a subsequent paper will be considered the study of the perception of weather impacts, through questionnaire survey to the general public.

The core sectors analysed in the quantitative analysis include: fires, health, energy use, tourism and agriculture. For most of the data available, the statistical analysis exploits a time series covering the period between 1964 and 1995, and a spatial regional distribution, i.e. the 20 Italian regions. The data collected covers temperature, precipitation, heliophany, wind speed, production in the agricultural sector, gas and electricity consumption, bed-nights and arrivals of domestic and foreign tourists, number and area of fires and death rates.
FEEM's work after data collection focused on the descriptive analysis of the data, on the identification of the extreme seasons with regard to climate data and on the econometric analysis of the relationship between the climate variables, mainly temperature and precipitation, and variables on agricultural productivity, with regard to the domestic production of potatoes, wine, grapes, strawberries, oranges, pigs and poultry, variables on domestic gas and electricity consumption, death rates, bed-nights of domestic tourists and fires number.

1.2. Methodology for the Econometric Analysis

The general model that we use for annual and national observations is:

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 T + \alpha_3 W_t + \alpha_4 W_{t-1} + u_t$$

where t expresses the time-series dimension of the model, X denotes the index of interest (i.e. number of fires, death rates, per capita gas consumption, etc…). X depends on its lagged value to indicate that most influences other than weather (income, technology, institutions) are much the same now and in the past.

T denotes time: for annual observations T indicates the year of observation. Time is taken up as an explanatory variable to capture all unexplained trends.

W denotes the weather variable that is hypothesised to influence X. W is a vector including only those climate variables which are supposed to have an influence on X: the climate variables selected vary depending on the core sector under analysis.

The weather variable consists of the average value over the time dimension t of the climate variable under consideration; when yearly observations on X are available, the weather variable W generally consists of the yearly average of the climate variable. However, when specific seasons during the year are thought of having a stronger influence on the dependent variable, the average value of the climate variable over that season in each year will be used in the regressions. For instance summer temperature or rainfalls in each year are used as explanatory variables when the model is applied to estimate the yearly number of fires.

The lagged value of W is taken up to address a dynamic dimension in the model, and because past weather may influence current behaviour, particularly in some sectors, such as tourism and agricultural yields production.

When monthly observations on X are available, lagged values of X and W for both the month before and the corresponding month in the year before are used.

The monthly time series model to be estimated is:

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + + \alpha_2 X_{t-12} + \alpha_3 y + \alpha_4 W_t + \alpha_5 W_{t-1} + \alpha_6 W_{t-12} + u_t$$

u denotes the error term.

The intercept is included assuming that at least one of the variables is not expressed in deviations from its mean.

Under the assumption that u is i.i.d. and has normal distribution, we estimate the model by ordinary least squares (OLS) estimators.

We run a first estimation by OLS, and we check for the significance of the parameters' estimates; we then remove insignificant explanatory variables and re-estimate, checking whether the residuals are stationary.

When regional observations are available, the general model is applied to a panel data structure, covering the time series and cross-section regional data.

We perform fixed effects OLS estimation of the following model:

$$X_{it} = \alpha_0 + \alpha_1\ X_{i\,t-1} + \alpha_2\ T + \alpha_3\ W_{it} + \alpha_4\ W_{i\,t-1} + u_{it}$$

where the index i refers to the region observed and t expresses time, referring to annual observations.

When monthly observations are available, lagged values of X and W for both the month before and the corresponding month in the year before will be used.

The panel model estimated across regions and over a monthly time series is:

$$X_{it} = \alpha_0 + \alpha_1\ X_{i\,t-1} + \alpha_2\ X_{i\,t-12} + \alpha_3\ T + \alpha_4\ W_{it} + \alpha_5\ W_{i\ t-1} + + \alpha_6\ W_{i\,t-12} + u_{it}$$

As a further step in the econometric analysis, in both the time series and panel estimation of our general model we use dummies for the years showing patterns of extreme weather to capture the effect of extreme seasons on the dependent variables.

We use as well dummies for regions or macro-regions in order to identify specific regional effects on the dependent variables.

1.3. Methodology for the Economic Evaluation of Weather Extremes' Impacts

A direct cost evaluation method is used to assess the impact of climate sectors on some of the core sectors identified. The direct cost method assumes that the welfare change induced by the climate extremes can be approximated by the quantity change in the relevant variable times its price. The direct cost thus imputed would be a fair approximation of the change in consumer surplus if the price does not change much.

The use of dummy variables for extreme seasons in the time-series and panel estimations allows us to evaluate in monetary terms the relative impacts of those extreme seasons on the various sectors, exploiting estimates of quantity changes in those seasons and the corresponding seasonal prices.

When prices for the index of interest cannot be identified, the elasticity of the index of interest to the climate variable is estimated and illustrated. The elasticity measures the percentage change in the index of interest per marginal percentage change in the climate variable. Elasticity is computed as:

$$\varepsilon = (\Delta X/\Delta W)^* W/X$$

where :

ε is the elasticity, X is the index of interest, W is the weather variable

ΔX/ΔW is the estimated coefficient of the weather variable (a_3 in the general model previously described)

W/X is the ratio of the weather variable on the index of interest, both averaged over the whole period under analysis

Prices could be identified only in the agricultural sector and in the gas and electricity consumption sector, and costs were identified with regard to fires. Therefore the monetary evaluation of weather extremes' impacts applies only to agriculture and energy use.
The elasticity of the index of interest to the climate variable however will be illustrated for all sectors.

2. Sectorwise Analyses of Climate Impacts

Climate Data

Climate data is available for most variables on a monthly basis, at the regional level, from 1966 until 1995. Italy seems to show weather patterns which differ from the ones identified by northern and central European countries. The UK, the Netherlands and Germany identify respectively 1995 and 1992 as the most extreme summer seasons.

Italy in 1994 shows extremely high summer temperatures and anomalies with respect to the last three decades. A strong temperature anomaly during the '80s is recorded in the summer of 1982. 1994 is recorded as well as one of the most dry summers, together with the summer of 1985. The summer of 1985 is exposed as well to a very high sunshine rate, comparable only to the late '60s (in particular 1967) evidence.

With regard to extreme winter seasons, the 1989 winter is definitely the mildest winter recorded, showing strong anomalies in temperature, in exposure to sunshine and lack of precipitation. The winter of 1989 is followed by relatively mild winters, reaching very high peaks in temperature again in the year 1994.

Differently from the evidence collected by our partners, who record the 1990 winter as mild and wet, the 1990 winter season in Italy is mild and extremely dry all over the country.

Anomalies in yearly precipitation versus yearly temperature, as well as anomalies of winter precipitation versus winter sunshine rates show the highest negative correlation. Overall, the summers of 1994 and 1985, and the 1989 winter can be identified as the most extreme seasons in our country.

With regard to the regional variability of climate data, we generally observe a low variance of climate variables across regions in the extreme seasons with respect to the other seasons: this shows a relative homogeneity of weather extremes within the country.

2.1. Fires

Fires Data

Data on fires refer to the total number of forests' fires and to the area of forests burnt from 1964 until 1995 in each region. The number of fires shows a high variance over the whole period, and reaches two peaks in 1985 and 1993: 1985 in particular has been identified as one among the most dry summers, as well as most exposed to sunshine.

With regard to the regional distribution of fires, southern and coastal regions show the highest number of fires over the whole period. In particular one of the island, Sardinia, shows the highest area of forest burnt over all the years.

The annual number of fires is highly positively correlated with the summer national temperature (0.6067) and negatively correlated with the summer precipitation (-0.5876).
A very high correlation exists between the annual number of fires and the respective summer dryness index (0.7087), where the dryness index is built as the ratio between temperature and rainfall. The area of forests' burnt doesn't result to be highly correlated with any of the climate variables.

Results from the Econometric Analysis

Data on the number of forest fires is available for each region on a yearly basis, starting from 1964.

We first estimate the annual time series general model applied at the national level to predict the number of forest fires over the whole country. Then we perform a panel estimation using annual and regional observations, thus exploiting the full space and time dimension of the available sample.

The literature suggests that the number of fires increases with temperature in the summer months. However, rainfall and summer moisture are considered to be more important predictors of fire incidence. Higher temperatures associated with decreasing summer precipitation increase the risk of drought and fire. We test these hypotheses in Italy.

When the number of forest fires over the whole country is used as the dependent variable, we regress the number of fires over its value in the year before, the time trend, and the climate variables which are thought of having an influence on fires: summer national average temperature, average rainfalls, the dryness index, as well as their one-year lagged values. Following the methodological approach which has been previously described, we remove the variables showing insignificant coefficient estimates, and re-estimate the model.

The final regression's results are presented in Table 1-2.
The general model, estimated over a 29 years time series, is overall statistically significant and estimates are robust.
When a dryness index is used, the summer index and the yearly time trend are highly significant; the estimated coefficient of the dryness index shows a positive sign, indicating, as expected, that more dry weather definitely increases the number of fires. When summer precipitation is used, summer precipitation and the yearly time trend are highly significant; summer precipitation shows a negative sign, indicating that higher summer rainfalls tend to reduce the yearly number of forest fires.
In both estimates the residuals are stationary.

Table 1. OLS time-series estimation of the yearly number of forest fires in Italy, 1967-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
One-year lagged # of national forest fires	-.2964 *	-1.700
Time trend	10.1461 ***	3.308
Summer national dryness index	400.8691 ***	2.760
Constant	-19888.83 ***	-3.316
# of observations	28	
F test (3, 24)	16.78	
Adjusted R-squared	0.6368	
DW	2.1655	

* significant at 95% **significant at 97.5% *** significant at 99%

Table 2. OLS time-series estimation of the yearly number of forest fires in Italy, 1967-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
One-year lagged # of national forest fires	-.3079 *	-1.657
Time trend	11.8628 ***	3.858
Summer national precipitation	-3.1031 **	-1.973
Constant	-22945.47 ***	-3.769
# of observations	28	
F test (3, 25)	14.33 ***	
Adjusted R-squared	0.5882	
DW	2.2857	

* significant at 95% **significant at 97.5% *** significant at 99%

OLS fixed effects panel estimation regressions are performed as well, whereby the yearly regional number of forest fires is regressed over its one-year lagged value, the yearly time trend, the summer regional dryness index, as well as its lagged-values. The estimated coefficient on the lagged value of the summer regional dryness index is statistically non-significantly different from zero; based on the agreed methodology, we re-estimate the model without including lagged summer dryness index as an explanatory variable.

Final results are illustrated Table 3. All the explanatory variables included in the final regression are highly significant. The index of summer dryness by region has a strong positive impact on the number of regional forest fires. This result suggests the extremely relevant role that climate variables play on forest fires: during extremely hot and dry summers the number of forest fires tends to increase. When dummy variables for the extremely hot and dry summer seasons are introduced, they show statistically significant estimated coefficients. In particular those years showing extreme scarcity in rainfalls explain an increase in the number of fires.

Table 3. OLS panel estimation of the yearly regional number of forest fires across Italy, 1967-1995, using a dryness index climate predictor

Independent variables	**Coefficient Estimates from fixed effects panel estimation**	*t-statistics*	**Coefficient Estimates**	*t-statistics*
Constant	-13192.04 ***	-5.382	-12389.86 ***	-4.824
One-year lagged # of regional forest fires	.02076 ***	4.951	.2463 ***	6.052
Time trend	6.7564 ***	5.444	6.3505 ***	4.884
Regional summer dryness index	58.7140 ***	6.956	43.1502 ***	5.002
Dummy for 1982			-85.3652 *	-1.783
Dummy for 1985			278.6442 ***	5.281
Dummy for 1993			130.8809 **	2.276
Dummy for 1994			-165.0371 ***	-2.998
# of observations	531		531	
F test	51.36		30.76	
R-squared				
Within	0.2327		0.2993	
Between	0.5982		0.7500	
Overall	0.3572		0.4265	

* significant at 95% **significant at 97.5% *** significant at 99%

OLS panel estimation is then performed including dummy variables for macro-regions and for the extremely dry 1985 summer season. Variables showing insignificant estimated coefficients are excluded from the second stage estimation; in the final estimation the regional number of forest fires is regressed over its lagged value, summer average regional precipitation and temperature, its one-year lagged-value, dummies for macro-regions and for the extremely dry 1985 summer season.

The results are illustrated in Table4. All the explanatory variables show highly significant estimated coefficients; wet summers strongly and negatively influence the number of forest fires in each region, whereas hot summers have a considerable positive impact on the number of fires. Regional extreme weather summer effects result to be relevant in explaining regional fire numbers.

Table 4. OLS panel estimation of the yearly regional number of forest fires across Italy, 1967-1995

Independent variables	**Coefficient Estimates from fixed effects panel estimation**	*t-stat.*	**Coefficient Estimates**	*t-stat.*
Constant	-14145.44 ***	-4.653		
One-year lagged # of regional forest fires	.2115 ***	4.737	.644622***	20.926
Time trend	7.3350 ***	4.604		
Summer regional precipitation	-1.3727 ***	-2.371	-1.8860***	-4.120
Summer regional temperature	18.4345 *	1.736		
One-year lagged regional summer temperature	-21.6455 ***	-2.371		
Dummy for the North-West			240.2248***	5.674
Dummy for the North-East			190.3844***	4.158
Dummy for the Center			184.6965***	5.427
Dummy for the South			186.0877***	6.832
Dummy for the islands			149.492***	4.318
Dummy for 1985			328.6972***	5.836
# of observations	509		580	
F test	21.86***		187.35***	
R-squared			0.7238	
Within	0.1842			
Between	0.8292			
Overall	0.3797			

* significant at 95% **significant at 97.5% *** significant at 99%

Economic Evaluation of Climate Change Impacts on Fires

The model's estimates over the last three decades suggest that a 1° increase in summer regional temperature may explain 21 more fires in each region. A percentage increase in the summer regional dryness index instead may explain 59 more fires in each region.
In 1985, identified as an extremely hot summer season, estimates suggest that the summer dryness index may explain 328 more fires on average in each region.

The estimated elasticity of fire numbers to precipitation suggests a 4.9 percentage decrease in fire numbers per marginal percentage increase in summer precipitation.

During those years showing weather extremes, restoration costs from fire damages are considerably higher than in preceding years: in 1985 in Italy restoration costs from fire damages did amount to 103,5 billion it £ at current prices, compared to the restoration costs of 28.2 billion it £ beard in 1984.
In 1994, restoration costs from fire damages in Italy did amount to 85,9 billion it £ at current prices, and increased by 26,3% with respect to the costs beard in the previous season.

2.2. Health

Data on Death Rates

Death rates are available from 1964 onwards on a monthly basis for the country as a whole. Death rates are built as the ratio between the number of deaths in each month and the total population in the corresponding year, expressed in thousand units, for the country as a whole.

Summer death rates show an increasing trend over the three decades, in contrast with the winter death rates, which follow a decreasing trend over the thirty years. Both series are characterised by a high inter-annual variance. Looking at the monthly death rates averaged over the three decades, we observe a higher concentration of death rates over the winter months, and a lowest peak in the month of September.

Summer death rates, over July and August, and the respective summer temperature show a high positive correlation (0.7499).

Results from the Econometric Analysis

Data on death rates is available at the national level on a monthly basis, from 1960 onwards.

With regard to the influence of climate parameters on death rates, the literature suggests that mortality rates increase with an increase in temperature in the summer months; this relationship is supposed to be more evident in Southern Europe countries than in northern European countries, since the threshold temperature required to induce heat-stress strokes is more likely to be crossed.
Similarly, a temperature increase during winter months tends to decrease the number of cold-related deaths. We test these hypotheses across Italy, where we expect to observe some incidence of temperature on death rates, particularly in the South.

We perform a time-series OLS estimation using monthly and national observations, running separate estimations for winter and summer seasons. We regress monthly death rates over its value in the corresponding month during the year before, in the previous month, the time trend, and the climate variables which are thought of having an influence on death rates: average monthly temperature and its lagged values. Following the methodology previously described we first estimate the general model; we then remove the variables showing insignificant coefficient estimates, and re-estimate the model.

When we estimate the number of death rates over the winter season, i.e. the months of January, February and March, the only significant explanatory variable is temperature: warmer and milder winters tend to reduce death rates.

When we estimate the number of death rates during summer, mainly the months of June, July and August, we indeed observe that temperature has a positive and highly significant influence on death rates. As we expected, hotter summers seem to induce higher death rates. Estimated coefficients on lagged monthly death rates and temperature as well are highly significant.

The model is overall statistically significant and estimates are robust. The DW test in both estimations suggests that the residuals are stationary. The final regression estimation results for winter and summer death rates are shown in Table 5.

Table 5. OLS time-series estimation of the winter and summer death rates in Italy, 1965-1995

	Winter Death rates		*Summer Death rates*	
Independent variables	**Coefficient Estimates**	*t-statistics*	**Coefficient Estimates**	*t-statistics*
Constant	1.0437***	30.513	.26225***	4.233
One-month lagged regional death rates			.14192**	2.053
One-year lagged regional death rate in the corresponding month				
Time trend				
Monthly regional temperature	- .01914***	-3.919	.02734***	13.713
One-month lagged regional temperature			- .01124***	-8.750
One-year lagged regional temperature in the corresponding month				
# of observations	93		93	
R-squared	.1444		.6824	
F test	15.36		63.75	
DW test	1.9574		1.9241	

* significant at 95% **significant at 97.5% *** significant at 99%

As a further step in the analysis, we use the model to predict the incidence of climate factors on death rates in each calendar month over the period under consideration. We therefore carry out a time-series estimation for each month of the year, over a three decades time-series, using data at the national level.

Table 6 provides a qualitative synthesis of the results, reporting only the significant predictor variables of death rates in each month, as well as the direction of their impact, indicated by a positive or negative sign. The results illustrated apply to the estimation of overall statistically significant models.

Generally the results show that during the winter, spring and fall seasons a temperature increase tends to reduce death rates all over the country, whereas during summer months an increase in temperature explains higher death rates. In most of the estimates for which results are presented the Durbin-Watson (D-W) test suggests that there is no serial correlation.

When dummy variables for extreme seasons are used, it is estimated that the extremely hot weather during the1994 summer may be responsible for 63 more deaths on average in the country.

The estimated elasticity of death rates to climate suggests a 0.14 percentage decrease of winter death-rates per marginal percentage change in winter temperature, and a 0.76 percentage increase in summer death-rates per marginal percentage increase in summer temperature. Estimates suggest as well a 0.28 percentage decrease in summer death-rates per marginal percentage increase in temperature in the previous summer.

Table 6. Significant predictors of monthly death rates in Italy, 1965-1995

Death rates	Adj. R2	Predictor variables	D-W
JANUARY			
FEBRUARY	0.38	+JANUARY DEATH RATES – FEBRUARY TEMPERATURE	2.19
MARCH			
APRIL	0.20	+ MARCH DEATH RATES + YEARLY TREND – APRIL TEMPERATURE	1.75
MAY	0.62	+APRIL DEATH RATES +YEARLY TREND – MAY TEMPERATURE –FEBRUARY TEMPERATURE + LAST YEAR DECEMBER TEMPERATURE –LAST YEAR NOVEMBER TEMPERATURE – LAST YEAR MAY TEMPERATURE	2.08
JUNE	0.74	+ MAY DEATH RATES+JUNE TEMPERATURE – MAY TEMPERATURE –LAST YEAR OCTOBER TEMPERATURE +LAST YEAR JUNE TEMPERATURE	2.45
JULY	0.56	+ JULY TEMPERATURE – JUNE TEMPERATURE	2.05
AUGUST	0.69	+ AUGUST TEMPERATURE – JULY TEMPERATURE	1.56
SEPTEMBER	0.58	+AUGUST DEATH RATES + YEARLY TREND – AUGUST TEMPERATURE	2.09
OCTOBER	0.78	+ SEPTEMBER DEATH RATES + YEARLY TREND– OCTOBER TEMPERATURE	1.75
NOVEMBER	0.75	+OCTOBER DEATH RATES –YEARLY TREND – NOVEMBER TEMPERATURE + SEPTEMBER TEMPERATURE	1.97
DECEMBER			

Table 7-10 reports selected results from the estimation of death rates in specific months.

Table 7. OLS time-series estimation of death rates in February in Italy, 1965-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
Death-rates in January	.2922 ***	3.574
National temperature in February	-.0173 ***	-2.414
Constant	.6797 ***	7.096
# of observations	31	
F test (2, 28)	10.16	
Adjusted R-squared	0.3792	
DW	2.1932	

* significant at 95% **significant at 97.5% *** significant at 99%

Table 8. OLS time-series estimation of death-rates in April in Italy, 1965-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
Death-rates in March	0.1567 ***	2.515
Time trend	0.0012 **	2.173
National temperature in April	-.0133 ***	-2.911
National temperature in March	-.0050 *	-1.701
Constant	-1.5007	-1.432
# of observations	31	
F test (4, 26)	6.46	
Adjusted R-squared	0.4211	
DW	1.7591	

* significant at 95% **significant at 97.5% *** significant at 99%

Table 9. OLS time-series estimation of death-rates in July in Italy, 1965-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
National temperature in July	.0343 ***	7.226
National temperature in June	-.0157 ***	-2.524
Constant	.2985 ***	2.497
# of observations	31	
F test (2, 28)	26.59	
Adjusted R-squared	0.6304	
DW	2.0188	

* significant at 95% **significant at 97.5% *** significant at 99%

Table 10. OLS time-series estimation of death-rates in October in Italy, 1965-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
Death-rates in September	.6931 ***	4.936
Time trend	.0008 ***	2.805
National temperature in October	-.0117 ***	-7.094
Constant	-1.1353 **	-2.234
# of observations	31	
F test (3, 27)	47.82	
Adjusted R-squared	0.8240	
DW	2.2992	

* significant at 95% **significant at 97.5% *** significant at 99%

2.3. Energy

Gas Consumption Data

The data on gas consumption is available in a monthly time series at the national level, by sector, from 1980 until 1996. Gas consumption has gradually increased from the beginning of the ‘80s until 1996 in all sectors (civil, industrial and service), more than doubling in its total figures. The highest increase has occurred in the service sector.
It is interesting to note how gas consumption falls drastically in the month of August in the industrial sector, due to the vacation break which stops industrial production activities all over the country. The highest intra-annual variance of gas consumption occurs in the service sector. In the civil sector gas consumption gradually decreases during the spring and summer seasons, reaching its lowest bound in August. In 1995 and 1996 gas consumption in the civil sector reaches its highest variation with respect to the average trend over the previous decade.

The correlation between per capita monthly civil gas consumption and climate variables shows that a high negative correlation exists between monthly civil gas consumption and monthly temperature (-0.8651).

Results from the Econometric Analysis

Total and domestic per capita gas consumption data is available at the national level in a monthly time series, from 1980 onwards.

No specific evidence is available in the literature on the climate dimension of gas consumption. However we would expect the demand for gas to decrease in mild winters as less energy is required for space heating.

Looking at total gas consumption, the results are not satisfactory, due to serial correlation of the time series, and so results are not reported.

We perform a OLS estimation of the time series model regressing monthly domestic per capita gas consumption over its lagged values, the time trend, monthly temperature and its lagged values, as well as a dummy for the year 1994, which shows extreme weather patterns. As already mentioned, temperature is thought of being the climate variable which mostly affects domestic consumption of gas. In a second stage monthly temperature is used to estimate monthly and winter per capita domestic gas consumption.

Based on the agreed methodology, we first estimate the general model; then we remove the variables showing insignificant coefficient estimates, and re-estimate the model.

Final results are shown in Tables 11-12. The model is overall statistically significant and estimates are robust; the residuals are stationary and the independent variables show a very high explanatory power. It is interesting to observe that temperature has a strong influence on domestic gas consumption: the estimated coefficient on monthly average national temperature is highly significant and shows a negative sign. When only the winter months are analysed, the magnitude of the estimated coefficient on winter monthly temperature increases, showing that winter temperature has a strong effect on domestic gas consumption, and maintains a negative sign: as expected, milder winter tend to reduce per capita domestic consumption of gas. The estimated coefficient on the dummy for the extreme 1994 season is highly significant and shows a negative sign, explaining much of the variation in domestic per capita consumption of gas.

Table 11. OLS time-series estimation of per capita national domestic gas consumption in Italy, 1981-1995

	Monthly gas consumption		*Gas consumption over winter months*	
Independent variables	**Coefficient Estimates**	*t-statistics*	**Coefficient Estimates**	*t-statistics*
Constant	22.0967	1.611	15.467	0.614
One-month lagged gas consumption	.0755**	2.085		
One-year lagged gas consumption in the corresponding month	.9301***	25.362	1.0310***	26.057
Time trend				
Monthly national temperature	-16.9398***	-14.519	-29.0657***	-11.751
One-month lagged national temperature	1.6652*	1.807		
One-year lagged national temperature in the corresponding month	14.4325***	11.117	28.6607***	11.117
Dummy for the year 1994	-21.7709***	-2.753	-51.3575***	-2.973
# of observations	180		45	
R-squared	0.9776		0.9580	
F test	1258.65		228.29	
DW test	2.10548		2.3805	

*significant at 95% **significant at 97.5% *** significant at 99%

Table 12. OLS time-series estimation of per capita national domestic gas consumption in Italy over winter, 1981-1995

	Domestic gas consumption over winter months	
Independent variables	**Coefficient Estimates**	*t-statistics*
Constant	-15536.62 ***	-3.947
One-year lagged winter domestic gas consumption	.6798 ***	7.564
Time trend	7.8952 ***	3.940
Winter national temperature	-24.9380 ***	-12.625
One-year lagged national winter temperature	21.8357 ***	7.581
Dummy for the winter 1994	-46.8195 ***	-7.076
# of observations	15	
Adjusted R-squared	0.9970	
F test (5, 9)	947.30	
DW test	2.2872	

* significant at 95% **significant at 97.5% *** significant at 99%

Electricity Consumption Data

Electricity data is available on a yearly basis at the national level from 1981 until 1997 and at a regional level from 1987 onwards. Electricity consumption has gradually increased as well from the early ‘60s until 1995 both in agriculture, industry and in the service sector. In agriculture electricity consumption is more than 6 times higher in 1995 than in 1964; in the service sector is more than 4 times higher, in industry it has more than doubled and represents the highest share in total consumption. Per capita total electricity consumption decreases moving from North to South.

The correlation of the annual domestic electricity consumption over Italy with temperature is very high (0.9106 with the yearly national temperature, 0.8146 with the summer national temperature and 0.6863 with the winter national temperature).
An extremely low positive correlation exists between the annual regional domestic electricity consumption and the annual regional temperature (0.0351).

Results from the Econometric Analysis

Regional data on domestic electricity consumption is available on a yearly basis, from 1987 onwards.

Generally, the literature suggests that demand for electricity may increase with increasing temperatures due to the more intense use of air conditioning/fans. However the sensitivity of electricity demand to climate will be strongly influenced by regional characteristics, and it is not clear which effects of climate on electricity demand across Italy we may expect.

OLS fixed effects panel estimation is performed, using regional data, whereby the yearly regional domestic electricity consumption is regressed over its value in the year before, the yearly time trend and the regional average temperature over the whole year, as well as its one-year lagged value.

The final regression’s results are presented in Table 13. Only statistically significant estimated coefficients are reported. Overall, the model is highly statistically significant and estimates are robust. An increase in the average annual regional temperature is estimated to have a considerable negative effect on the regional domestic electricity consumption. As the literature suggests, the main reason for this effect could be the fact that higher temperature leads to less demand for heating services requiring electricity consumption; an increase in the use of air conditioning equipment, particularly during hot summers, is not likely to compensate for the previous effect given the little distribution of the air conditioning throughout the country.

Economic Evaluation of Climate Change Impacts on Energy

The welfare impacts of weather extremes on energy consumption appear to be positive.

Model estimates over the last two decades suggest that a 1° increase in winter temperature may have caused a decrease of 29 tep in per capita gas consumption on average across Italy.
In the extremely hot 1994 season, winter gas consumption in Italy is estimated to decrease by 51 tep per capita, equivalent to a small reduction in monetary expenditure equal to 4140,2 it £ per capita at current prices.

The estimated elasticity of per capita domestic gas consumption to climate suggests a 0.47 percentage decrease in per capita domestic gas consumption over winter months per marginal percentage increase in winter temperature.

Table 13. OLS regional fixed effects panel estimation of the regional domestic electricity consumption, 1987-1995

Independent variables	Coefficient Estimates from fixed effects panel estimation	*t-statistics*
Constant	589.2162 ***	7.230
One-year lagged # of regional domestic electricity consumption	.8638 ***	38.358
Yearly regional temperature	-8.6881 **	-2.230
# of observations	139	
F test (2, 119)	739.53	
R-squared		
Within	0.9255	
Between	0.9999	
Overall	0.9990	

* significant at 95% **significant at 97.5% *** significant at 99%

With regard to electricity consumption, it is estimated that a 1° increase in yearly temperature in Italy over the last two decades may have caused a reduction of 8 GWh (giga-watt/hour), equal to .09 tep, in domestic electricity consumption. We do not attempt to price the monetary gain from a reduction in expenditure for electricity due to tariffs.

The estimated elasticity of domestic electricity consumption to climate suggests a 0.026 percentage decrease per marginal percentage increase in yearly temperature.

2.4. Tourism

Data on Tourism

The data on tourism includes data on bed nights and number of arrivals for both domestic and foreign tourism. Data is available on a monthly basis at the national level over a two decades period, starting from 1976 for domestic tourism and from 1967 for foreign tourism, and at the regional level starting from 1983.

Since 1990 the data on tourism, due to a new legislation, refers only to accommodation facilities by enterprises, excluding accommodations provided by private individuals, and consequently we observe a structural break in both series. We run separate analysis for the two time periods. For both variables we generally observe an increasing trend over the three decades, and a seasonal peak during the summer season for both domestic and foreign tourism.

Focusing on the second period, a high positive correlation exists between the monthly number of tourists' bed-nights and the monthly temperature (0.7072), as well as the monthly temperature in the year before (0.6310), all measured at the national level.
The national number of tourists' bed nights during the summer is highly correlated with the summer national temperature (0.6838) and even more correlated with the summer national temperature in the year before (0.9486).

The regional number of tourists' bed nights over winter is highly and negatively correlated with the monthly regional temperature in the previous year.

The following tables illustrate the correlation between monthly bed-nights and monthly temperature in each month of the year in the two periods.

In the time-period between 1986 and 1995, temperature is positively correlated with monthly bed-nights during the month of May, and the summer months of June, July and August. A very high positive correlation exists between temperature and bed-nights in March: this evidence suggests a very sensitive demand for tourism in the spring intermediate season. A relatively strong negative correlation exists between temperatures and monthly tourism in December, perhaps due the negative effect of high temperatures on the skiing season in the Alps and in the Appennini.

Correlation between monthly bed nights and monthly temperature, 1986-1995

Reference month	**Correlation coefficients between monthly bed-nights and monthly temperature**
January	0.1378
February	-0.3102
March	0.7444
April	-0.1736
May	0.3299
June	0.1445
July	0.3263
August	0.2994
September	-0.1681
October	-0.1345
November	-0.0405
December	-0.4707

Data for the first period analysed, between 1976-1989, generally shows much higher correlation coefficients, certainly due to the fact that the data includes even accomodation provided by private individuals, which meet a high share of tourism demand.
A very high positive correlation exists between temperature and bed-nights in the months of January, August and December, which represent high peaks for the tourism season, thus denoting a strong sensitivity of tourism demand to climate related factors. A high negative correlation exists between temperature and bed-nights in November: this evidence suggests less sensitivity of tourism demand to temperature during fall.
When the correlation between monthly bed-nights and one-month lagged monthly temperature is investigated, the data shows that lagged temperature has a quite high positive correlation with monthly bed-nights during winter month. Temperature in May, July, October and November has a strong effect on tourism flows in the following months.

Results from the Econometric Analysis

The national monthly data on bed-nights of domestic tourism is non-stationary. We focus on the analysis of regional data on bed-nights of domestic tourism which is available on a monthly basis starting from 1983; due to a structural break in the data, we run separate analysis for the period 1983-1989 and for the period 1990-1995.

Correlation between monthly bed nights and monthly temperature, 1976-1989

Reference month	Correlation coefficients between monthly bed nights and monthly temperature	Correlation coefficients between monthly bed-nights and one-month lagged temperature
January	0.6245	0.4242
February	-0.1609	0.4577
March	0.1278	0.5564
April	0.3574	-0.2946
May	0.1306	0.2748
June	0.0843	0.5039
July	0.0510	-0.0276
August	0.6189	0.6544
September	0.0148	0.4084
October	-0.0606	-0.0747
November	-0.5770	-0.7097
December	0.6115	0.5185

During mild winters we may expect a decrease of domestic tourism to mountain regions due to the shortening of the skiing seasons and to a general increase of domestic tourism across the country due to warmer weather. The expected sign of the net outcome across the whole country could be slightly positive or uncertain. During extremely hot summer months we would expect a decrease in domestic tourism since domestic tourists may prefer to take their summer holidays abroad, particularly in Northern countries, where it is cooler than in Italy. We may also expect an increase in domestic tourism during summer months due to more weekend trips because of hotter weather. We intend to test whether the latter effect is stronger.

In both periods, we perform first OLS fixed effects panel estimation regressions, regressing the monthly regional number of bed-nights over its one-month lagged value, its twelve-months lagged value, the monthly time trend, the average temperature and precipitation in the corresponding month, as well as their one-month lagged value and their twelve-months lagged value. The panel analysis is first performed over all months in the year and then over selected summer and winter months. We then perform OLS fixed effects panel estimation regressions including dummy variables for the years which show extreme weather patterns and dummy variables for each region. In all stages, we follow the methodological approach of removing the variables which show insignificant coefficient estimates, and re-estimate the model.

The final results of the OLS fixed effects panel estimation for all the months of the year for both periods are presented in Table 14. The most interesting results can be summarised as follows. Confirming our hypothesis, in both periods higher monthly regional temperature is estimated to have a positive effect on domestic tourism flows; in the first period under analysis, even last year's temperature in the corresponding month appears to trigger monthly domestic tourism.
In the second period under analysis, last year's rainfall in the corresponding month appears to work as a deterrent for monthly domestic tourism flows, as we could expect. However, in the same period, monthly precipitation unexpectedly has a positive influence on domestic tourism. In both periods model estimates are robust.

The OLS panel estimation including the dummy variables for each region shows that in the period 1983-1989 the regions where Italian tourists spend the highest number of bed-nights are Emilia-Romagna, Trentino, Liguria and Lazio.

Table 14. OLS fixed effects panel estimation of the monthly regional number of bed-nights of domestic tourism across Italy all over the year

Independent variables	**Coefficient Estimates for the period 1983-1989**	*t-statistics*	**Coefficient Estimates For the period 1990-1995**	*t-statistics*
Constant	-203610.7***	-2.803	-118313**	-1.999
One-month lagged # of regional bed-nights	0.2545983***	12.248	0.3748518***	15.590
Twelve-months lagged # of regional bed-nights	0.5831289***	27.063	0.4085923***	16.741
Time trend				
Monthly regional temperature	84619.3***	4.454	44203.16***	8.207
One-month lagged regional temperature	-25735.59***	-3.285	-23126.96***	-4.224
Twelve-months lagged regional temperature	-32630.28*	-1.736		
Monthly regional precipitation			1150.442**	2.174
One-month lagged regional precipitation			1086.217***	2.662
Twelve-months lagged regional precipitation			-2865.918***	-5.541
# of observations	1364		1131	
F test	402.06		223.68	
R-squared				
Within	0.6002		0.5860	
Between	0.4652		0.6085	
Overall	0.5866		0.5922	

* significant at 95% **significant at 97.5% *** significant at 99%

We apply the same procedure to the estimation of climate predictors of domestic tourism during the summer months and individual months over the two periods under analysis.
Table 15 presents the final results of the OLS fixed-effects panel estimation for domestic tourism in the summer months of June, July and August.

In both periods the summer regional temperature has a high positive effect on the number of bed-nights and its twelve-months lagged value has even a stronger positive effect. In line with the hypotheses initially formulated, these results suggest the important role that temperatures play on the number of bed-nights: not only during hot summers the number of bed-nights tends to increase, but also a hot summer in the year before does influence the number of bed-nights that domestic tourists decide to take.

In the period 1990-1995, again the summer regional precipitation and its one-month lagged value have an unexpected smaller positive effect on the number of bed-nights of domestic tourists.

When we re-estimate the panel model including extreme seasons dummies, the dummy for the 1994 extreme season has a significant and negative effect on the number of bed-nights of domestic tourists during the summer months.

Table 15. OLS fixed effects panel estimation of the monthly regional number of bed-nights of domestic tourism across Italy during the summer months June, July and August.

Independent variables	**Coefficient estimates for the period 1983-1989**	*t-statistics*	**Coefficient estimates for the period 1990-1995**	*t-statistics*
Constant	-2853644***	-6.511	-1638962***	-6.746
One-month lagged # of regional bed-nights	1.011495***	27.607	1.123286***	39.348
Twelve-months lagged # of regional bed-nights	0.0881233***	2.791		
Time trend				
Monthly regional temperature	80178.66***	3.506	41022.48***	2.864
One-month lagged regional temperature				
Twelve-months lagged regional temperature	93467.5***	4.091	49305.5***	3.665
Monthly regional precipitation			1595.653**	2.269
One-month lagged regional precipitation			1698.946***	2.953
Twelve-months lagged regional precipitation				
# of observations	342			240
F test	507.90			510.92
R-squared *Within* *Between*	 0.8647 0.9234			 0.9210 0.9663
Overall	0.8408			0.9201

* significant at 95% **significant at 97.5% *** significant at 99%

Tables 16-20 report results from the estimation of the climate predictors of domestic tourism bed-nights across Italy in selected months, representative of the main seasons. It is interesting to note that tourism in February is strongly and negatively influenced by high temperatures in January: as it was initially formulated, this may be due to the negative influence of high temperatures on the skiing season, at least in the Alps and Appenini, or to anticipated winter trips or vacations due to good weather in the month of January. Higher temperatures in the intermediate seasons of spring and fall turn out to trigger domestic tourism flows; the results somehow suggest a relatively higher elasticity of domestic tourism to climate factors in the intermediate seasons. However, precipitation in July works as a deterrent for domestic tourists' flows in that month, and higher temperatures in July tend to reduce considerably domestic tourism in the month of August. Following our initial considerations, this result

may be partly due to a ‘substitution effect’ between domestic and foreign destinations in tourism demand due to climate variability.
Overall, domestic tourism demand seems to be quite sensitive to climate factors.

Table 16. OLS fixed-effects panel estimation of number of bed-nights of domestic tourism across Italy in February, 1983-1989

Independent variables	**Coefficient Estimates**	*t-statistics*
Constant	390832.9 ***	6.978
Regional bed-nights in January	.9285 ***	7.810
Regional bed-nights in February of the year before	-.6450 ***	-6.556
Regional temperature in January	-12887.39 ***	-2.959
Dummy for the winter 1988	57988.49 ***	2.989
# of observations	108	
F test (4, 86)	20.79	
R-squared		
Within	0.4916	
Between	0.9126	
Overall	0.8722	

* significant at 95% **significant at 97.5% *** significant at 99%

Table 17. OLS fixed-effects panel estimation of number of bed-nights of domestic tourism across Italy in May, 1986-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
Constant	372574.3 ***	4.299
Regional bed-nights in April	.3264 ***	2.672
Regional temperature in May	6135.286 **	2.246
Regional temperature in May of the year before	-9748.003 ***	-3.526
# of observations	98	
F test (3, 78)	8.85	
R-squared		
Within	0.2539	
Between	0.9454	
Overall	0.9224	

* significant at 95% **significant at 97.5% *** significant at 99%

Table 18. OLS fixed-effects panel estimation of number of bed-nights of domestic tourism across Italy in July, 1983-1989

Independent variables	**Coefficient Estimates**	*t-statistics*
Constant	7.34e+07 ***	2.680
Regional bed-nights in June	2.1685 ***	9.205
Regional bed-nights in July of the year before	.5816 ***	7.429
Time trend	-37375.1 ***	-2.705
Regional precipitation in July	-2014.282 ***	-3.029
# of observations	120	
F test (4, 96)	45.44	
R-squared		
Within	0.6544	
Between	0.8876	
Overall	0.8805	

* significant at 95% **significant at 97.5% *** significant at 99%

Table 19. OLS fixed-effects panel estimation of number of bed-nights of domestic tourism across Italy in August, 1983-1989

Independent variables	**Coefficient Estimates for the period 1983-1989**	*t-statistics*
Constant	1044081 **	2.074
Regional bed-nights in July	1.1424 ***	3.477
Regional bed-nights in August of the year before	.2119 **	-2.037
Regional temperature in July	-39493.91 **	-2.037
# of observations	107	
F test (3, 86)	148.18	
R-squared		
Within	0.8379	
Between	0.9919	
Overall	0.9885	

* significant at 95% **significant at 97.5% *** significant at 99%

Table 20. OLS fixed-effects panel estimation of number of bed-nights of domestic tourism across Italy in October, 1986-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
Constant	-271016.3 **	-2.150
Regional bed-nights in September	.1731 ***	2.468
Regional bed-nights in October of the year before	.2787 ***	2.741
Regional temperature in October	11540.6 ***	2.787
Regional temperature in October of the year before	14488.39 ***	4.108
# of observations	78	
F test (3, 78)	10.13	
R-squared *Within* *Between* Overall	 0.4112 0.7562 0.7496	

* significant at 95% **significant at 97.5% *** significant at 99%

To summarise some of the most interesting results, based on estimates over the last ten years, a 1° temperature increase in July in the coastal regions is estimated to increase by 24.783 the number of bed-nights in those regions. In the month of August a 1° temperature increase would imply an increase of 62.294 bed-nights. These effects are likely to increase welfare in those regions.

Focusing on winter temperatures and Alpine regions, over the same period the model instead estimates that a 1° increase in temperature would explain a decrease in local domestic tourism equal to 30.368 bed-nights, carrying out negative welfare changes.

On average across all regions the model estimates that anomalous hot weather in July would diminish domestic tourists' flows in the following month by 39.494 bed-nights. However in the intermediate seasons an increase in temperature is estimated to have a positive effect on domestic tourism: a 1° increase in temperature in May and October may explain an increase in domestic tourism in each region by 6.135 and 11.540 bed-nights respectively. Therefore the net welfare effect of climate extremes on tourism across regions and during the year is unclear.

The computed elasticity of domestic tourists' bed-nights, including accomodation provided by private individuals, to climate suggests a 0.071 percentage increase in tourism per marginal percentage increase in monthly temperature, and a 0.49 percentage increase per marginal percentage increase in summer monthly temperature.

When accomodation provided by private individuals is not included, the estimated elasticity suggests a 0.073 percentage increase in domestic tourism per marginal percentage increase in monthly temperature, and a 0.79 percentage increase per marginal percentage increase in summer monthly temperature.

2.5. Agriculture

Agricultural Data

The agricultural data mostly covers a thirty years time series, from 1964 to 1995, at the regional level, for the potatoes, strawberries, oranges and table grapes yields, wine, pigs and poultry production.

Most of the series show an increasing trend over the three decades, with a very low variability, except for the wine production, which has overall declined since the early '60s. Oranges and grapes yields, as well as wine production, show the highest variance.

We observe the regional distribution in agricultural production over the entire period. The production of wine shows the highest regional dispersion across the country. The other agricultural products identified seem to be more concentrated in specific regions, or macro-regions.

Results from the Econometric Analysis

The climate predictors of agricultural products are investigated with regard to the production of potatoes, strawberries, oranges, table grapes yields, wine, pigs and poultry production.
Generally for agricultural products it is difficult to predict the direction of the influence of temperature and precipitation, since:

- warmer temperatures and increased precipitation are often beneficial to agricultural yields.
- increased droughts resulting from the interaction of increased temperature and poor rainfall tend to reduce agriculture yields (in the absence of irrigation).

For each agricultural yield under analysis, expected results are formulated and further illustrated based on the hypotheses suggested by Italian agronomists.

Potato Yields

Data on potato yields is available at the regional level from 1964 to 1995.

According to agronomists, the climate variable which mostly influences potato yields is precipitation during the summer months. A positive correlation exists between regional potato yields and regional summer precipitation (0.3363), as well as with the one-year lagged regional summer precipitation (0.2225). The correlation of annual regional potato yields with the yearly regional precipitation is 0.21. The correlation of regional potato yields with the regional summer and yearly temperature instead is much lower .

OLS fixed effects panel estimation is performed using regional data, whereby yearly regional potato yield is regressed over its value in the year before, the yearly trend, the regional average temperature and precipitation over the summer months (June, July and August), as well as their one-year lagged value.
The final regression's results are presented in Table 21.
The model is highly statistically significant and robust.
In accordance with our expectations, summer precipitation is the only significant climate predictor of potato yields; the direction of the effect is estimated to be positive for the one-year lagged regional summer rainfall, indicating that higher summer precipitation in the year before tends to increase potato yields, whether it is negative for the current regional summer rainfall.

When extreme seasons dummies are introduced, the estimated coefficients show that the extremely dry summer of 1985 has a statistically significant strong and negative impact on potato yields.

Table 21. Fixed-effects OLS panel estimation of potato yields across Italian regions using summer climate variables, 1965-1995

Independent variables	**Coefficient Estimates from fixed effects panel estimation**	*t-statistics*
Constant	-2.722.188***	-8.529
One-year lagged # of regional potato yields	.5927***	16.702
Yearly time trend	1.4103***	8.658
Regional summer temperature		
Regional summer precipitation	.1920***	3.951
One-year lagged regional summer temperature		
One-year lagged regional summer precipitation	- .1904***	-3.787
# of observations	580	
F test	343.61***	
R-squared		
Within	.7120	
Between	.9990	
Overall	.8534	

* significant at 95% **significant at 97.5% *** significant at 99%

We repeat the same estimation procedure using the summer dryness index as climate predictor of potato yields. Estimated results are illustrated in Table 22.
The regional summer dryness index has a strong and statistically significant negative effect on regional potato yields: as expected, dry summers tend to have a negative impact on yearly potato yields. The direction of the impact of the one-year lagged summer dryness index is instead positive, consistent with the effect of summer precipitation.

Table 22. Fixed-effects OLS panel estimation of potato yields across Italian regions using the summer dryness index, 1965-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
One-year lagged # of regional potato production	.5757 ***	14.861
Time trend	1.5851 ***	8.736
Regional summer dryness index	-2.2520 ***	-2.574
One-year lagged summer regional index	1.6780 *	1.852
Constant	-3064.024 ***	-8.649
# of observations	506	
F test (4, 482)	297.24	
R-squared		
Within	0.7115	
Between	0.9909	
Overall	0.8485	

* significant at 95% **significant at 97.5% *** significant at 99%

Wheat Yields

Data on wheat yields is available at the regional level from 1964 to 1995.
According to agronomists, both temperature and precipitation in the months of April and May have an important impact on wheat yields.
A positive correlation exists between regional wheat yields and regional average precipitation over the months of April and May (0.3915), as well as its one-year lagged value (0.2339). The correlation with the regional yearly precipitation is also high (0.3190). Negative is the correlation between wheat yields and regional yearly temperature (-0.2637) and its one-year lagged value (-0.2306). The correlation with the regional average temperature in April and May and its one-year lagged value is much lower (-0.0639 and -0.1431 respectively).

OLS fixed effects panel estimation is performed using regional data, whereby the regional yearly wheat yield is regressed over its value in the year before, the yearly trend, the regional average temperature and precipitation over the months of April and May, as well as their one-year lagged value.

The final regression's results are presented in Table 23. Overall the model is highly statistically significant and estimates are robust. The regional average temperature during April and May has a significant negative impact on wheat yields. The estimated significant coefficient of the lagged average temperature and the lagged average precipitation over the months of April and May show a positive sign, indicating that higher temperature and precipitation during April and May in the year before tend to increase wheat yields. Extreme seasons dummies are not significant when introduced.

Table 23. OLS fixed effects panel estimation of wheat yields over climate variables in selected months across Italy, 1965-1995

Independent variables	**Coefficient Estimates from fixed effects panel estimation**	*t-statistics*
Constant	-570.6652***	-9.982
One-year lagged # of regional wheat yields	0.3721909***	8.679
Time trend	0.2956738***	9.987
Regional temperature over April and May	-0.370451***	-2.493
Regional precipitation over April and May		
One-year lagged regional temperature over April and May	0.5039184***	3.388
One-year lagged regional precipitation over April and May	0.0150665**	2.272
# of observations	519	
F test	144.58	
R-squared		
Within	0.5941	
Between	0.0319	
Overall	0.1610	

* significant at 95% **significant at 97.5% *** significant at 99%

In Table 24 we illustrate the results from the OLS panel estimation of wheat yields across Italian regions controlling for macro-regional effects.

Column two and three report results from estimation using climate predictors over April and May. Column four and five report results from estimates using climate predictors over monthly average regional climate.
When climate predictors in the months of April and May are used, precipitation is estimated to have a positive and significant impact on regional wheat yields.
When we measure the effect of climate variables during the whole year, using the monthly average of climate predictors, average rainfall in each region is estimated to have a positive and significant impact on yearly wheat yields.

Table 24. OLS panel estimation of wheat yields across Italian regions using climate variables in selected months, 1965-1995

Independent variables	Coefficient Estimates	*t-statistics*	Coefficient Estimates	*t-statistics*
One-year lagged # of regional wheat yields	.8289***	31.6121	.8459***	36.738
Time trend	.07481***	2.794	.0682***	2.905
Regional temperature over April and May	- .3635***	-2.465		
Regional precipitation over April and May				
One-year lagged regional temperature over April and May	.4180***	2.865		
One-year lagged regional precipitation over April and May	.0157***	2.228		
Monthly average regional temperature				
Monthly average regional precipitation			.0258***	2.248
One-year lagged monthly regional temp.				
One-year lagged monthly regional prec.			- .0223***	- 1.948
Dummy for the North-West	-144.064***	-2.761	-129.927***	-2.803
Dummy for the North-East	-142.855***	-2.740	-128.841***	-2.785
Dummy for the Center	-144.288***	-2.762	-130.298***	-2.810
Dummy for the South	-145.624***	-2.783	- 131.69***	-2.836
Dummy for the islands	-146.889***	-2.804	-132.806***	-2.858
# of observations	506		580	
F test	2800.89***		3730.46***	
R-squared	0.9826		0.9833	

* significant at 95% **significant at 97.5% *** significant at 99%

Orange Yields

Data on orange yields is available at the regional level from 1964 to 1995.
Ten out of the twenty Italian regions produce oranges. According to agronomists, both temperature and precipitation in the months of August, September and October have an important impact on orange yields. A high negative correlation exists between regional orange yields and regional average precipitation over the months of August, September and October in the previous year (-0.2203), as well as with regional yearly precipitation in the previous year (-0.1833). The correlation coefficient is negative with respect to regional yearly temperature (-0.1412), regional yearly temperature in the previous year (-0.1051) and average temperature over the months of August, September and October (0.1082). Correlation coefficients with the other climate variables are very low.

OLS fixed panel estimation is performed using regional data and controlling for macro-regional effects, whereby the regional yearly orange yield is regressed over its value in the year before, the yearly trend, the regional yearly temperature and precipitation averaged on a monthly basis, and their lagged values.
Results are illustrated in Table 25.
The model is overall statistically significant and robust.
Regional yearly precipitation is estimated to have a considerable positive effect on yearly regional orange yields. Looking at the estimated coefficients of the dummies for Italian macro-regions, it emerges that Italian islands and southern regions, where orange production concentrates, explain most of the variability of orange yields across the country and over time.

Table 26 illustrates the results from the OLS fixed effects panel estimation of orange yields using climate predictors averaged over selected months.
The regional average temperature over the months of August, September and October is the only significant climate predictor; its effect on the regional orange yield is estimated to be negative.

Table 25. OLS panel estimation of orange yields over yearly climate variables across Italy, 1965-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
Constant		
One-year lagged # of regional orange yields		
Time trend		
Regional yearly temperature		
Regional yearly precipitation	0.4101979**	2.296
One-year lagged regional yearly temperature		
One-year lagged regional yearly precipitation		
Dummy for the North-West	72.5122***	4.932
Dummy for the Center	90.74114***	6.647
Dummy for the South	128.7191***	10.630
Dummy for the islands	130.529***	13.155
# of observations	294	
F test	588.62	
R-squared *Within* *Between*	0.9106	
Overall		

* significant at 95% **significant at 97.5% *** significant at 99%

Table 26. Fixed effects OLS panel estimation of orange yields across Italy, 1965-1995, using climate variables in selected months

Independent variables	Coefficient Estimates	*t-statistics*
Constant	-2254.424***	-4.272
One-year lagged # of regional orange yields	.3753***	6.796
Time trend	1.2246***	4.438
Regional temperature over August, September and October	- 4.0645***	- 2.434
Regional precipitation over August, September and October		
One-year lagged regional temperature over August, September and October		
One-year lagged regional precipitation over August, September and October		
# of observations	285	
F test (3, 272)	31.33***	
R-squared		
Within	.2568	
Between	.7459	
Overall	.3873	

* significant at 95% **significant at 97.5% *** significant at 99%

Strawberry Yields

Data on strawberries yields is available at the regional level from 1964 to 1995.
According to the agronomists, temperature in the months of April and May has an important impact on strawberry yields. The correlation between regional strawberry yields and regional average temperature and precipitation over the months of April and May, as well as with their lagged values, is very low. The regional yearly precipitation in the year before is negatively correlated with the regional strawberry yields (-0.1835), while the correlation between regional strawberry yields and regional yearly temperature (0.1135), as well as with its one-year lagged value (0.1248), is positive.

We carry out OLS panel estimation of regional yearly strawberry yields using regional data and controlling for macro-regional effects, whereby the regional yearly strawberries yield is regressed over its value in the year before, the yearly trend, the regional average temperature and precipitation over the months April and May, as well as their one-year lagged value, and dummies for macro-regions.
The final regression's results are presented in Table 27.
The model is highly statistically significant and robust.
The average regional temperature over the months of April and May is the only significant climate predictor; it is estimated to have a considerable negative effect on annual yields.
Regions in the North-West explain most of the variability of yearly strawberry yields.

Table 27. OLS panel estimation of strawberry yields over climate variables in selected months across Italy, 1965-1995

Independent variables	**Coefficient Estimates**	**t-statistics**
Constant		
One-year lagged # of regional strawberries yields		
Time trend	3.929615***	17.414
Regional temperature over April and May	-5.090953***	-4.262
Regional precipitation over April and May		
One-year lagged regional temperature over April and May		
One-year lagged regional precipitation over April and May		
Dummy for the North-West	-7629.549***	-17.265
Dummy for the North-East	-7585.421***	-17.159
Dummy for the Center	-7573.864***	-17.139
Dummy for the South	-7549.821***	-17.095
Dummy for the islands	-7617.791***	-17.259
# of observations	569	
F test	609.13	
R-squared *Within* *Between*	0.8835	
Overall		

* significant at 95% **significant at 97.5% *** significant at 99%

The estimation procedure described above is repeated using the yearly regional temperature and precipitation averaged on a monthly basis. Results are illustrated in Table 28.

Estimates suggest that higher temperatures over the whole year tend to increase strawberry yields, while higher temperatures in the previous year tend to have a negative impact on current yields. North-Western regions again play a major role in explaining strawberry yields' variation.

Table 28. OLS panel estimation of strawberries yields across Italy using yearly climate variables, 1965-1995

Independent variables	Coefficient Estimates	*t-statistics*
One-year lagged # of regional strawberries yields	.8088***	29.851
Time trend	.5899***	3.119
Regional monthly temperature	3.511***	2.407
Regional monthly precipitation		
One-year lagged regional monthly temperature	- 3.3799***	-2.201
One-year lagged regional monthly precipitation		
Dummy for the North-West	- 1152.645***	- 3.124
Dummy for the North-East	- 1142.602***	- 3.100
Dummy for the Center	- 1140.087***	-3.100
Dummy for the South	- 1133.352***	- 3.087
Dummy for the islands	- 1152.308***	- 3.134
# of observations	532	
F test (9, 523)	1284.89***	
R-squared	0.9560	

* significant at 95% **significant at 97.5% *** significant at 99%

Table Grapes Yields

Data on table grapes yields is available at the regional level from 1964 to 1995. According to agronomists, the climate variable which mostly influences table grapes yields is precipitation during the summer months. A positive correlation exists between regional table grapes yields and regional summer precipitation (0.2678), its lagged value (0.2140), the regional yearly temperature (0.3529) averaged on a monthly basis and regional yearly temperature in the year before (0.2707). Negative is the correlation of regional table grapes yields with the regional summer temperature (-0.2634), its lagged value (-0.2354) and the regional yearly precipitation (-0.3356). The regional yearly precipitation in the year before is positively correlated with table grapes yields (0.1155).

OLS fixed effects panel estimation is performed using the regional data, whereby yearly regional table grapes yield is regressed over its value in the year before, the yearly trend, the regional average temperature and precipitation over the summer months (June, July and August), as well as their one-year lagged value.

The final regression's results are presented in the second and third column in Table 29. The model is statistically significant and robust. The estimated coefficient of the average summer temperature show a negative sign, indicating that higher summer precipitation tends to decrease table grapes yields.

OLS panel estimation is then performed controlling for macro-regional effects. The final results are presented in the fourth and fifth column in Table 29.

This time the estimated coefficient of the regional summer temperature in the year before is significant with a positive impact on table grapes yields. North-Eastern regions capture most of the variability of total grape yields.

Table 29. OLS panel estimation of table grapes yields over summer climate variables across Italy, 1965-1995

Independent variables	**Coefficient Estimates from fixed effects panel estimation**	*t-statistics*	**Coefficient Estimates**	*t-statistics*
Constant	-27862.06***	-5.119		
One-year lagged # of regional table grapes yields			-0.3502266***	-9.392
Time trend	14.88484***	5.219		
Regional summer temperature	-42.18027**	-2.187		
Regional summer precipitation				
One-year lagged regional summer temperature			145.5741***	4.959
One-year lagged regional summer precipitation				
Dummy for the North-West			-2970.612***	-4.781
Dummy for the North-East			-3027.557***	-4.840
Dummy for the Center			-2982.67***	-4.594
Dummy for the South				
Dummy for the islands			-1839.874***	-2.573
# of observations	577		564	
F test	13.77		51.88	
R-squared			0.3947	
Within	0.0473			
Between	0.1243			
Overall	0.0092			

* significant at 95% **significant at 97.5% *** significant at 99%

Columns two and three of Table 30 illustrate the final results of the OLS fixed-effects panel estimation carried out using yearly climate variables. The estimated coefficient of temperature in the current year is significant with a negative sign. This is in contrast with the expectation that temperature should have a positive impact on table grapes yields. When the extreme seasons dummies are introduced, the extreme dry year of 1983 has a statistically significant positive impact on table grapes yields.

The fourth and fifth columns in Table 30 illustrate the final results of the OLS panel estimation including dummy variable for macro-regions. In this case the estimated significant coefficients of the lagged value of the yearly temperature and of the yearly precipitation show a positive impact on table grapes yields and the estimated coefficient of yearly precipitation in the current year shows a negative impact. All the macro-regions except for the South turn out to be statistically significant. When introduced, none of the dummy variables for the extreme seasons turn out to be significant.

Table 30. OLS panel estimation of table grapes yields over yearly climate variables across Italy, 1965-1995

Independent variables	**Coefficient Estimates from fixed effects panel estimation**	*t-statistics*	**Coefficient Estimates**	*t-statistics*
Constant	-27344.52***	-4.870		
One-year lagged # of regional table grapes yields			-0.319283***	-8.124
Time trend	14.44641***	4.944		
Regional yearly temperature	-41.50018*	-1.784		
Regional yearly precipitation			-14.46951***	-3.934
One-year lagged regional yearly temperature			185.7837***	5.953
One-year lagged regional yearly precipitation			21.42883***	6.103
Dummy for the North-West			-2872.088***	-4.609
Dummy for the North-East			-2751.058***	-4.587
Dummy for the Center			-2747.553***	-4.554
Dummy for the South				
Dummy for the islands			-2097.905***	-3.166
# of observations	579		526	
F test	12.84		49.73	
R-squared			0.4640	
Within	0.0441			
Between	0.1424			
Overall	0.0252			

* significant at 95% **significant at 97.5% *** significant at 99%

Wine production

Data on wine production is available at the regional level from 1964 to 1995.

According to agronomists, the climate variable which mostly influences wine production is precipitation during the summer months. A negative correlation exists between regional wine production and regional summer precipitation (-0.1490), as well as with its lagged value (-0.1621). The correlation coefficient of regional wine production with the regional yearly precipitation is still negative and bigger in its magnitude (-0.2879). The correlation of regional wine production with the regional summer and yearly temperature is also quite high (0.2897 and 0.2626 respectively), while the correlation with the regional summer and yearly temperature one year lagged is lower (0.1154 and 0.1703 respectively).

We perform OLS panel estimation of regional wine production across Italy controlling for macro-regional effects and using regional yearly climate predictors averaged on the summer season and regional yearly climate predictors averaged on all months. Results are illustrated respectively in Tables 31 and 32.

Both model's estimations are overall statistically significant and robust.
When summer climate predictors are used, summer temperature is estimated to have a considerable and statistically significant positive effect on the regional production of wine. Contrary to our expectations, summer precipitation doesn't turn out to be significant.

When yearly climate predictors are used, regional yearly temperature is estimated to have a positive considerable and significant effect on regional wine production, whereas, in line with our expectations, regional yearly precipitation is estimated to have a negative and significant impact on the regional production of wine.

In both estimates, the macro-region which relatively explains most of the variation of wine production is the North-East, where vineyards are widespread.

Table 31. OLS panel estimation of wine production over summer climate variables across Italy, 1965-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
Constant		
One-year lagged # of regional wine production	-0.3774199***	-9.378
Time trend	-56.64789***	-3.217
Regional summer temperature	264.5953***	3.421
Regional summer precipitation		
One-year lagged regional summer temperature	160.4589**	2.060
One-year lagged regional summer precipitation	-17.68401***	-3.599
Dummy for the North-West	107179***	3.179
Dummy for the North-East	110792.9***	3.286
Dummy for the Center	108253***	3.214
Dummy for the South	107997.7***	3.210
Dummy for the Islands	110161.1***	3.280
# of observations	518	
F test	108.28	
R-squared *Within* *Between*	0.6807	
Overall		

* significant at 95% **significant at 97.5% *** significant at 99%

Table 32. OLS panel estimation of wine production over yearly climate variables across Italy, 1965-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
Constant		
One-year lagged # of regional wine production	-0.3433325***	-8.465
Time trend	-65.73414***	-3.891
Regional yearly temperature	317.4534***	3.999
Regional yearly precipitation	-30.98142***	-3.931
One-year lagged regional yearly temperature	301.6164***	4.445
One-year lagged regional yearly precipitation		
Dummy for the North-West	127348.1***	3.880
Dummy for the North-East	130972.6***	3.987
Dummy for the Center	128047***	3.908
Dummy for the South	127659.9***	3.903
Dummy for the islands	128682.6***	3.948
# of observations	521	
F test	113.51	
R-squared *Within* *Between*	0.6896	
Overall		

* significant at 95% **significant at 97.5% *** significant at 99%

Table 33 illustrates the results obtained from the OLS panel estimation of the yearly regional wine production using the summer regional dryness index.

Dryer summer seasons tend to have a considerable negative effect on the production of wine. The lagged effect of dry summer seasons however is positive. Again, the North-East captures most of the variation of wine production over time across the country.

Table 33. OLS panel estimation of the yearly regional wine production across Italy, 1965-1995

Independent variables	**Coefficient Estimates**	*t-statistics*
One-year lagged # of regional wine production	.9424 ***	70.334
Summer regional dryness index	-69.7353 *	-1.893
One-year lagged summer regional dryness index	81.9887 **	2.175
Dummy for the North-West	21.8261	0.209
Dummy for the North-East	229.0983 **	1.986
Dummy for the Center	94.1211	0.907
Dummy for the South	163.3575	1.550
Dummy for the islands	322.5013	1.366
# of observations	504	
F test (8, 496)	1625.75	
Adjusted R-squared	0.9627	

* significant at 95% **significant at 97.5% *** significant at 99%

Poultry production

Data on poultry production is available at the regional level from 1968 to 1995. A negative correlation exists between regional poultry production and regional summer temperature (-0.0671) and its lagged value (-0.1879). Negative is also the correlation of regional poultry production with the regional yearly temperature (-0.2848) and its lagged value (-0.1967).

OLS fixed effects panel estimation are performed using the regional data, whereby yearly regional poultry production is regressed over its value in the year before, the yearly trend, the regional average temperature over the summer months (June, July and August), as well as its one-year lagged value.

The final regression's results are presented in the second and third column in Table 34. The model is statistically significant and robust. The estimated significant coefficient of the average summer temperature in the year before show a negative sign, indicating that higher summer temperature tends to decrease poultry production. This is in accordance with our assumption that higher summer temperature decreases the poultry production.
When extreme seasons dummies are introduced they are not significant.

In the fourth and fifth column in Table 34 are presented the final results of the OLS panel estimation without the constant term is then performed including dummy variable for macro-regions. In this case, the estimated coefficient of the regional summer temperature, as well as its lagged value, are significant with a positive and a negative sign correspondingly. All the macro-regions are significant with a negative sign. The extreme seasons dummies are not significant when introduced.

Table 34. OLS panel estimation of poultry production over summer climate variables across Italy, 1969-1995

Independent variables	**Coefficient Estimates from fixed effects panel estimation**	*t-statistics*	**Coefficient Estimates**	*t-statistics*
Constant	-1404087***	-6.953		
One-year lagged # of regional poultry production	-0.210112***	-4.893	-0.4730416***	-14.075
Time trend	689.7703***	6.571	1063.008***	4.938
Regional summer temperature			2527.192***	2.805
One-year lagged regional summer temperature	3052.702***	5.719	-1901.436***	-2.426
Dummy for the North-West			-2060182***	-5.006
Dummy for the North-East			-2029814***	-4.932
Dummy for the Center			-2096387***	-5.098
Dummy for the South			-2111775***	-5.139
Dummy for the islands			-2115534***	-5.159
# of observations	439		426	
F test	52.66		103.02	
R-squared			0.6898	
Within	0.2752			
Between	0.0181			
Overall	0.0120			

* significant at 95% **significant at 97.5% *** significant at 99%

Columns two and three of Table 35 presents the final results of the OLS fixed-effects panel estimation using the average regional temperature over the whole year. The model is overall significant. The estimated coefficients of temperature and its lagged value are significant with a positive sign. When the extreme seasons dummies are introduced, they are not significant.

OLS panel estimation without the constant term is then performed including dummy variable for macro-regions. The final results are presented in the fourth and fifth column in Table 36. In this case the estimated coefficients of the lagged value of the yearly temperature show a significant positive impact on poultry production. All the macro-regions turn out to be significant. The extreme seasons dummy variables when introduced are not significant.

Table 35. OLS panel estimation of poultry production over yearly climate variables across Italy, 1969-1995

Independent variables	**Coefficient Estimates from fixed effects panel estimation**	*t-statistics*	**Coefficient Estimates**	*t-statistics*
Constant	-1177296***	-5.210		
One-year lagged # of regional poultry production	-0.220199***	-5.077	-0.4865052***	-14.467
Time trend	570.7953***	4.812	1298.747***	7.077
Regional yearly temperature	1799.817**	2.058		
One-year lagged regional yearly temperature	3662.296***	6.027	-1833.309***	-2.536
Dummy for the North-West			-2490495***	-6.928
Dummy for the North-East			-2459957***	-6.837
Dummy for the Center			-2524220***	-7.017
Dummy for the South			-2537625***	-7.057
Dummy for the islands			-2537317***	-7.069
# of observations	428		441	
F test	39.69		116.62	
R-squared			0.6830	
Within	0.2821			
Between	0.0636			
Overall	0.0000			

* significant at 95% **significant at 97.5% *** significant at 99%

Pigs production

Data on pigs production is available at the regional level from 1968 to 1995. A negative correlation exists between regional pigs production and regional summer temperature (-0.0163) and its lagged value (-0.1832). Negative is also the correlation of regional pigs production with the regional yearly temperature (-0.1633) and its lagged value (-0.0998).

OLS fixed effects panel estimation are performed using the regional data, whereby yearly regional pigs production is regressed over its value in the year before, the yearly trend, the regional average temperature over the summer months (June, July and August), as well as its one-year lagged value.

The final regression's results are presented in the second and third column in Table 36. The model is statistically significant and robust. The estimated significant coefficient of the average summer temperature show a negative sign, indicating what we are expecting: higher summer temperature tends to decrease pigs production. Its lagged value is also significant with a positive sign.

Moreover, the OLS panel estimation regressions including dummy variables for each region show that ten out of the twenty Italian regions are significant. When extreme seasons dummies are introduced the extremely warm and dry summer of 1994 is significant with a negative sign as it is expected.

OLS panel estimation without the constant term is then performed including dummy variable for macro-regions. The final results are presented in the fourth and fifth column in Table 36. Also in this case, the estimated coefficient of the regional summer temperature, as well as its lagged value, are significant . However the estimated coefficient of the regional summer temperature shows a positive sign and its lagged value a negative one. Only the North-East macro-region is significant with a positive sign. The extreme seasons dummies are not significant when introduced.

Table 36. OLS panel estimation of pigs production over summer climate variables across Italy, 1969-1995

Independent variables	**Coefficient Estimates from fixed effects panel estimation**	*t-statistics*	**Coefficient Estimates**	*t-statistics*
Constant	197.7902*	1.921		
One-year lagged # of regional pigs production	0.1005036***	3.311	-0.2514134***	-7.393
Time trend				
Regional summer temperature	-16.70935***	-3.275	31.89637***	3.112
One-year lagged regional summer temperature	23.05726***	4.887	-21.84212**	-2.232
Dummy for the North-West				
Dummy for the North-East			628.5152***	2.367
Dummy for the Center				
Dummy for the South				
Dummy for the islands				
# of observations	539		539	
F test	10.59		73.67	
R-squared			0.5261	
Within	0.0580			
Between	0.1094			
Overall	0.0471			

* significant at 95% **significant at 97.5% *** significant at 99%

Columns two and three of table 37 presents the final results of the OLS fixed-effects panel estimation using the average regional temperature over the whole year. The model is overall significant. The estimated coefficients of temperature and its lagged value are significant with a negative and a positive sign correspondingly. The OLS panel estimation regressions including dummy variables for each region show that nine out of the twenty Italian regions are significant. The dummy variable of the warm and dry summer of 1994 is statistically significant with a negative sign.

OLS panel estimation without the constant term is then performed including dummy variable for macro-regions. In this case none of the climate variables is significant.

Table 37. OLS panel estimation of pigs production over yearly climate variables across Italy, 1969-1995

Independent variables	**Coefficient Estimates from fixed effects panel estimation**	*t-statistics*
Constant	156.7428	1.894
One-year lagged # of regional pigs production	0.0899903***	2.933
Time trend		
Regional yearly temperature	-12.6756**	-2.064
One-year lagged regional yearly temperature	26.04135***	5.059
# of observations	541	
F test	10.92	
R-squared		
Within	0.0595	
Between	0.0586	
Overall	0.0166	

* significant at 95% **significant at 97.5% *** significant at 99%

Economic evaluation of climate change impacts on agriculture

Welfare impacts of weather extremes on agriculture can be measured with regard to potatoes and wine production.

The extremely hot and dry 1985 season explains a regional average reduction in potatoes production of 1300 kilos per hectare, which is equivalent to a monetary loss of 376.346 it £ per hectare, at current prices. Model's estimates over the last three decades suggest that the fall dryness index may explain a reduction of 200 kilos per hectare in the yearly regional production of potatoes due to a 1° increase in the average temperature.

The estimated elasticity of potato yields to climate suggests a 0.57 percentage increase in potato yields per marginal percentage increase in summer precipitation, and a 0.56 percentage decrease per marginal percentage increase in summer precipitation of the previous year.

With regard to wheat, the estimated elasticity suggests a 0.18 percentage decrease in wheat yields per marginal percentage increase in temperature in April and May, and a 0.24 percentage increase per marginal percentage increase in temperature in April and May of the previous year.

Model estimates suggest a monetary loss from orange production due to hot weather: a 1° temperature increase in autumn would cause a decrease of 400 kilos per hectare in the average production of oranges in the country.

The estimated elasticity of orange production to climate suggests a 1.73 percentage increase in orange yields per marginal percentage increase in yearly precipitation, and a 0.59 percentage decrease per marginal percentage increase in temperature in August, September and October.

The estimated elasticity of strawberries to climate indeed suggests a 0.39 percentage increase in strawberry yields per marginal percentage increase in yearly temperature, a 0.58 percentage decrease per marginal percentage increase in temperature in April and May, and a 0.37 percentage decrease per marginal percentage increase in temperature in the previous year.

With regard to wine production, the extreme 1994 season is estimated to cause an average regional reduction in wine production of 519.000 hectolitres, equivalent to a monetary loss of 44, 7 billion it £ at current values. It is estimated that, during the last three decades, a percentage increase in the summer dryness index may have caused a reduction in wine production of 48 thousand hectolitres on average across the country.

When only the effects of changes in temperature are considered, the estimated elasticity of wine production to temperature suggests a 1.60 percentage increase per marginal percentage change in summer temperature, a 0.97 percentage increase per marginal percentage change in summer temperature in the previous year, a 1.22 percentage increase per marginal percentage change in yearly temperature, and a 1.15 percentage increase per marginal percentage increase in temperature in the previous year.

Looking at table grapes instead the estimated elasticity suggests a 1.83 percentage decrease in table grapes per marginal percentage change in summer temperature.

3. CONCLUSIONS

The core sectors analysed in the quantitative analysis (see Table 1) slightly differ from those studied by the other European partners, due to specific features of the Italian economy, which is the only Mediterranean country in the project.
Overall, the projects' results suggest a significant sensitivity of most economic variables in the identified sectors to climate extremes.

It is important to note that Italy shows weather patterns which differ from the ones identified by northern and central European countries. The UK, the Netherlands and Germany identify respectively 1995 and 1992 as the most extreme summer seasons. Instead in Italy the summer of 1994 and 1985, and the 1989 winter can be identified as the most extreme seasons.

Looking at the weather impacts on **fires**, the model's estimates suggest that fires are extremely sensitive to precipitation: over the last three decades a 1° increase in summer regional temperature explains 21 more fires in each region. In 1985, identified as an extremely hot summer season, estimates suggest that the summer dryness index may explain 328 more fires on average in each region. The estimated elasticity of fire numbers to precipitation suggests a 4.9 percentage decrease in fire numbers per marginal percentage increase in summer precipitation.
Also in the other three countries investigated in WISE exist strong and significant relationships between summer temperature and rainfall and the occurrence of outdoor fires.

When weather impacts on **health** are considered, changes in temperature show significant effect on health. For instance it is estimated that the extremely hot weather during the 1994 summer may be responsible for 63 more deaths on average in the country. The estimated elasticity of death rates to climate suggests a 0.14 percentage decrease of winter death-rate per marginal percentage increase in winter temperature, and 0.76 percentage increase in summer death-rates per marginal percentage increase in summer temperature.

In Italy and in Germany both mild winters and hot summers have an impact. In the UK strong relationships with the weather could only be found in the winter months.

With regard to **energy use**, the model estimates over the last two decades suggest that a 1°increase in winter temperature may have caused a decrease of 29 tep in per capita gas consumption on average across Italy. In the extremely hot 1994 season, winter gas consumption in Italy is estimated to decrease by51 tep per capita, equivalent to a small reduction in monetary expenditure equal to 4140,2 it £ per capita at current prices. Therefore the welfare impacts of weather extremes on energy consumption can even be positive. The estimated elasticity of per capita domestic gas consumption to climate suggests a 0.47 percentage decrease in per capita domestic gas consumption over winter months per marginal percentage increase in winter temperature. With regard to electricity consumption, it is estimated that a 1° increase in yearly temperature in Italy over the last two decades may have caused a reduction of 8 GWh (giga-watt7hour), equal to .09 tep, in domestic electricity consumption. The estimated elasticity of domestic electricity consumption to climate suggests a 0.026 percentage decrease per marginal percentage increase in yearly temperature.
In all countries investigated the demand for energy falls in mild winters. The size of the perturbation due to weather events is much greater for gas than for electricity.

Focusing on **domestic tourism**, based on estimates over the last ten years, a 1° temperature increase in July in the coastal regions is estimated to increase by 24.783 the number of bed-nights in those regions. In the month of August a 1° temperature increase would imply an increase of 62.294 bed-nights. These effects are likely to increase welfare in those regions. Focusing on winter temperatures and Alpine regions, over the same period the model instead estimates that a 1° increase in temperature would explain a decrease in local domestic tourism equal to 30.368 bed-nights, carrying out negative welfare changes. The estimated elasticity of domestic tourists' bed-nights, including accomodation provided by private individuals, to climate suggests a 0.071 percentage increase in tourism per marginal percentage increase in monthly temperature, and a 0.49 percentage increase per marginal percentage increase in summer monthly temperature.
Analysing **international tourism** results that temperature has the greatest influence on international tourism. The optimal summer temperature for attracting tourists to a country is estimated to be about 21° C. A further result is that in hot years tourists tend to prefer domestic to foreign beach holidays.

Looking at weather impacts on **agricultural yields**, results differ considerably across the various crops and fruits studied. Welfare impacts of weather extremes on agriculture can be measured only with regard to potatoes and wine production, for which prices are available.
Potatoes. The extremely hot and dry 1985 season explains a regional average reduction in potatoes production of 1300 kilos per hectare, which is equivalent to a monetary loss of 376.346 it £ per hectare , at current prices. Model's estimates over the last three decades suggest that the fall dryness index may explain a reduction of 200 kilos per hectare in the yearly regional production of potatoes due to a 1° increase in the average temperature. The estimated elasticity of yields to climate suggests a 0.57 percentage increase in potato yields per marginal percentage increase in summer precipitation, and a 0.56 percentage decrease per marginal percentage increase in summer precipitation of the previous year.
Wheat. The estimated elasticity suggests a 0.18 percentage decrease in wheat yields per marginal percentage increase in temperature in April and May, and a 0.24 percentage increase per marginal percentage increase in temperature in April and May of the previous year.
Oranges. The estimated elasticity of orange production to climate suggests a 1.73 percentage increase in orange yields per marginal percentage increase in yearly precipitation, and a 0.59 percentage decrease per marginal percentage increase in temperature in August, September and October. Model estimates suggest a monetary loss from orange production due to hot weather: a 1° temperature increase in autumn would cause a decrease of 400 kilos per hectare in the average production of oranges in the country.

Strawberries. The estimated elasticity of strawberries to climate indeed suggests a 0.39 percentage increase in strawberry yields per marginal percentage increase in yearly temperature, a 0.58 percentage decrease per marginal percentage increase in temperature in April and May, and a 0.37 percentage decrease per marginal percentage increase in temperature in the previous year.
Wine production. The extremely dry 1994 season is estimated to cause an average regional reduction in wine production of 519.000 hectolitres, equivalent to a monetary loss of 44.7 billion it £ at current values. It is estimated that, during the last three decades, a percentage increase in the summer dryness index may have caused a reduction in wine production of 48 thousands hectoliters on average across the country. When only temperature's effects are considered however the estimated elasticity of wine production to temperature suggests a 1.60 percentage increase per marginal percentage change in summer temperature.
Table grapes. The estimated elasticity suggests a 1.83 percentage decrease in table grapes per marginal percentage change in summer temperature.

Table 38. Sectorwise weather impact analyses

Sector	Series considered	Positive impacts	Negative impacts	Valuation (elasticity of the index of interest to the climate variable, i.e. % change in the index of interest per marginal % change in the climate variable)
Fire	Total number of forest fires	Higher summer rainfalls tend to reduce the yearly number of forest fires	Peaks in total number of forest fires occurred in 1985 and 1993, identified as extremely dry summers. More dry weather definitely increases the number of forest fires	4.9% decrease per marginal % increase in summer precipitation
	Total area of forest burnt		Weather variable do not have any effect on the total area of forest burnt	
Health	All cause death-rate	Over the years, we observe decreasing winter death-rates. Warmer and milder winter, spring and fall seasons tend to reduce death-rates	Over the years, we observe increasing death-rates. Hotter summers induce higher death rates.	0.14% decrease of winter death-rates per marginal % change in winter temperature. 0.76% increase in summer death-rates per marginal % increase in summer temperature. 0.28% decrease in summer death-rates per marginal % increase in temperature in the previous summer..
Energy	Total gas consumption	Non significant results	Over the years, we observe increasing total gas consumption.	
	Per capita domestic gas consumption	Milder winter tend to reduce per capita domestic consumption of gas, due to reduced demand for space heating.	Over the years, we observe increasing per capita domestic gas consumption.	0.47% decrease in per capita domestic gas consumption over winter months per marginal % increase in winter temperature.
	Domestic electricity consumption	Electricity consumption is lower in warm years, because electricity is used for space heating more than for space cooling.	Over the years, we observe increasing domestic electricity consumption.	0.026% decrease per marginal % increase in yearly temperature.

Tourism	Bed-nights, including accommodation provided by private individuals	Decrease of domestic tourism demand due to higher temperatures in December. Domestic tourism in February is strongly and negative influence of high temperatures in January, probably due to negative influence of high temperatures on the skiing season or to anticipated winter trips or vacations due to good weather in January. Higher temperatures in July tend to reduce considerably domestic tourism in the month of August.	Increase of domestic tourism demand due to higher temperatures in the intermediate seasons of spring and fall. The summer regional temperature has a high positive effect on the number of domestic bed-nights.	0.071% increase per marginal % increase in monthly temperature. 0.49% increase per marginal % increase in summer monthly temperature.
	Bed-nights	The summer regional temperature has a high positive effect on the number of domestic bed-nights.	Temperature in the previous month has a negative impact on monthly domestic tourism.	0.073% increase per marginal % increase in monthly temperature. 0.79% increase per marginal % increase in summer monthly temperature.
Agricul-ture	**Potatoes**	Higher summer precipitation increase potato yields.	Higher summer precipitation in the year before tends to decrease potato yields in the current year. Dry summers tend to have a negative impact on yearly potato yields.	0.57% increase per marginal % increase in summer precipitation. 0.56% decrease per marginal % increase in summer precipitation of the previous year.
	Wheat	Higher temperature during April and May in the year before tends to increase wheat yields.	Higher temperature in April and May tends to decrease wheat yields.	0.18% decrease per marginal % increase in temperature in April and May. 0.24% increase per marginal % increase in temperature in April and May of the previous year.
	Oranges	Higher precipitation over the year increases orange yields.	Higher regional average temperature over the months of August, September and October decreases regional orange yields.	1.73% increase per marginal % increase in yearly precipitation. 0.59% decrease per marginal % increase in temperature in August, September and October.
	Strawberries	Higher temperature over the whole year tend to increase strawberry yields.	Higher regional temperature over the months of April and May decreases strawberry yields.	0.39% increase per marginal % increase in yearly temperature. 0.58% decrease per marginal % increase

			Higher temperature in the previous year tends to decrease current strawberry yields.	in temperature in April and May. 0.37% decrease per marginal % increase in temperature in the previous year.
	Table grapes		Higher summer temperature tends to decrease table grapes yields	1.83% decrease per marginal % change summer temperature.
	Wine	Higher temperature during the summer and all over the year increases the regional production of wine. The lagged effect of dry summer seasons is positive on the production of wine.	Higher precipitation all over the year decreases slightly the regional production of wine. Drier summer seasons tend to reduce the production of wine.	1.60% increase per marginal % change in summer temperature. 0.97% increase per marginal % change in summer temperature in the previous year. 1.22% increase per marginal % change in yearly temperature. 1.15% increase per marginal % increase in temperature in the previous year.
	Poultry	There is a slight evidence that higher temperature during summer and all over the year tends to increase poultry production.		
	Pigs	There is a slight evidence that higher temperature in the previous summer and in the previous year tends to increase pigs production.	There is a slight evidence that higher temperature during the summer and all over the year tends to decrease pigs population.	

Table 39. Integration of research results

Sector	
Agriculture	Statistical analyses and management study show that hot and dry weather negatively affect agricultural productivity except for wine production which increases with wet and hot summers.
Fire	More dry weather definitely increases the number of fire numbers as confirmed by the statistical analyses and the management survey.
Domestic electricity consumption	Management and population surveys suggest that domestic electricity consumption is lower in mild winters and higher in hot summer. The statistical analyses suggest that the overall outcome of warm years is lower electricity consumption, probably due to the fact that electricity is used for space heating more than for space cooling.
Domestic gas consumption	Results from the statistical analysis, management and population surveys suggest that mild winters tend to reduce domestic gas consumption. Results from both surveys suggest that domestic gas consumption increases during hot summers, while the statistical analysis does not provide significant results on the effect of hot summers on domestic consumption.
Tourism	Evidence from both the population and management surveys suggest that domestic tourism demand is very little sensitive to climate variability, while the statistical analysis shows that hot summers have a positive impact on the number of domestic bed-nights. The statistical analysis also suggests that mild winter tend to decrease domestic tourism, particularly in Alpine regions, but this impact is not very strong.

APPENDIX: DATA SOURCES FOR SECTORWISE ANALYSES

COLLECTED DATA

Sector	Variables	Unit measure	Time series	Spatial scale	Sources
Agriculture	**Wheat yield (soft and durum)**	0.1 tonnes/ha	Yearly 1964-1995	Regional	ISTAT
	Table table grapes and wine production	0.1 tonnes/ha	Yearly 1964-1995	Regional	ISTAT
	Strawberries and strawberry yields	0.1 tonnes/ha	Yearly 1964-1995	Regional	ISTAT
	Potato yield	0.1 tonnes/ha	Yearly 1964-1995	Regional	ISTAT
	Total population of pigs	Thousands	Yearly 1969-1995	Regional	ISTAT
	Produced population of poultry	Thousands	Yearly 1968-1995	Regional	ISTAT
	Selling and buying price indexes of agriculture products **Selling mean prices of agriculture products**		Yearly 1964-1995 Yearly 1964-1995	National National after 1973	ISTAT ISTAT
Energy	**Domestic gas consumption**	10^{14} KCal	Monthly 1980-1996	National	ENI BANK
	Domestic electricity consumption	GWH	Monthly 1981-1997 Yearly 1987-1996	National Regional	ENEL EUROSTAT
Water	**Domestic use: water supplied and abstracted**		Yearly in 1975 and 1987 Yearly in 1991 Yearly estimation in 1993	Regional Macro-Regions Regional	ISTAT in R&S Federgasacqua in R&S IRS in PROACQUA
	Irrigated agricul-tural land (surface and as a % of agricul-tural land)		Yearly almost every three years, 1967-1993	Macro-Regions	ISTAT

Fire	**Area of forest burnt**	Ha	Yearly 1964-1994	Regional	ISTAT
	Number of forest fires		Yearly 1964-1994	Regional	ISTAT
Tourism	**Number of bed nights and number of arrivals of domestic tourism at/in all means of accomodation**		Monthly	National 1976-1996 Regional 1983-1996 Regional 1986-1995	ISTAT EUROSTAT
	Number of bed nights and number of arrivals of foreign tourism at/in all means of accomodation		Monthly	National 1967-1996 Regional 1983-1996	ISTAT
Deaths	**Total number of deaths**		Monthly 1960-1995	National	EUROSTAT
Population	**Number of population**	Thousands	Yearly 1960-1996	National	EUROSTAT
Climate	**Mean daily temperature**	C degrees	Monthly 1964-1995	Regional	ISTAT
	Total precipitation	Mm	Monthly 1966-1995	Regional	UCEA
	Mean daily sunshine	Hours	Monthly 1966-1991	Six Regions	UCEA

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UCEA, Ministero per le Politiche Agricole, Ufficio Centrale di Ecologia Agraria, [Ministry of Agriculture Policies, Central Office of Agrarian Ecology]

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(lix) This paper was presented at the ENGIME Workshop on “Mapping Diversity”, Leuven, May 16-17, 2002
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(lxi) This paper was presented at the Eighth Meeting of the Coalition Theory Network organised by the GREQAM, Aix-en-Provence, France, January 24-25, 2003
(lxii) This paper was presented at the ENGIME Workshop on “Communication across Cultures in Multicultural Cities”, The Hague, November 7-8, 2002
(lxiii) This paper was presented at the ENGIME Workshop on “Social dynamics and conflicts in multicultural cities”, Milan, March 20-21, 2003
(lxiv) This paper was presented at the International Conference on “Theoretical Topics in Ecological Economics”, organised by the Abdus Salam International Centre for Theoretical Physics - ICTP, the Beijer International Institute of Ecological Economics, and Fondazione Eni Enrico Mattei – FEEM Trieste, February 10-21, 2003
(lxv) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications” organised by Fondazione Eni Enrico Mattei and sponsored by the EU, Milan, September 25-27, 2003
(lxvi) This paper has been presented at the 4th BioEcon Workshop on “Economic Analysis of Policies for Biodiversity Conservation” organised on behalf of the BIOECON Network by Fondazione Eni Enrico Mattei, Venice International University (VIU) and University College London (UCL) , Venice, August 28-29, 2003
(lxvii) This paper has been presented at the international conference on “Tourism and Sustainable Economic Development – Macro and Micro Economic Issues” jointly organised by CRENoS (Università di Cagliari e Sassari, Italy) and Fondazione Eni Enrico Mattei, and supported by the World Bank, Sardinia, September 19-20, 2003

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