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Forest fires in southern Europe : an econometric investigation of the existence of economic incentives for fire arson

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Forest Fires in Southern Europe: An Econometric Investigation of the Existence of Economic Incentives for Fire Arson

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Abstract

Devastating forest fires during the summer of 2007 resulted in an unprecedented level of destruction in the Mediterranean forests, prompting widespread speculation about profit-motivated arson as one of the principal causes of the fires. Forest protection laws essentially create a scarcity of land, making arson potentially profitable in several ways: the clearing of land for development and construction, expansion of farm size, and salvage logging (Economist 2007). This study seeks to evaluate the validity of these accusations by examining the relationship between land, wheat, and timber prices and incidence of forest fires in four countries: Spain, Greece, Italy, and Bulgaria. The fixed effects estimation yields mixed results, confirming the existence of a link between profit motives and forest fires, but failing to corroborate the arson allegations.

I. Introduction

The summer of 2007 was full of unpleasant surprises for Europe. While Britons saw their possessions float away in the immense floods that engulfed them after days of unabated torrential rains, Europeans along the Mediterranean directed countless prayers for rain toward the heavens as they fought some of the worst forest fires they had ever faced. As early as the end of July, the area of Europe's woodland lost to fires – 337,600 hectares – had already matched the losses of all of 2006 – 358,500 hectares. Just one month later, the total damage had already surpassed that of the previous year, over 80 people had perished in the flames, and damages in Greece alone were estimated at 3bn Euros, or about 0.7% of the country's GDP (Davidson 2007). Clearly, forest fires are a phenomenon of great impact.

In fact, southern Europeans have always feared droughts, not only for their adverse effects on agriculture and water supply, but also for being a harbinger of destructive forest fires. In a region where roughly a third of the total land area is covered by forest, more than 50,000 fires burn an estimated 600,000 - 800,000 hectares annually. This figure represents about 1,5% of total Mediterranean woodlands. The average total burnt area in the EU Mediterranean countries – Greece, Italy, Portugal, France, and Spain – has quadrupled since the 60's, largely as a result of land-use changes, socio-economic conflicts, and competing interests (WWF 2003). The gravity of these statistics and the tragic events of the summer of 2007 merit attention from researchers, policymakers, and the general public. (Consult Figure 1 for an illustration of the number of fires per Mediterranean country over the last 10 years, paying particular attention to the spike in Greece's data for 2007.)

The UN's Food and Agriculture Organization estimates that over 95% of forest fires in the Mediterranean are human induced (WWF 2003). While this may initially seem implausible, the fact that about three-fourths of Europe's forests have been influenced by humans, combined with the absence of certain climatic phenomena such as dry storms in the Mediterranean region, lends credibility to the claim. In addition, a large fraction of the total number of forest fires remains unexplained, allowing further investigation into the causes of woodland fires, which is precisely the intent of this study (Alexandrian et al. 1999).

The forest fires of 2007 prompted an avalanche of accusations in the media, as well as on the part of politicians and environmental groups; accusations that were largely made possible by the aforementioned ambiguity regarding the causes European forest fires. The claim was that most of the fires had been set off by arsonists seeking profit through various channels. An article titled, "A combustible mixture: Forest fires in Europe", is only one among many to point toward human activity as a cause of forest fires. Undoubtedly, fires started by farmers to burn stubble or clear land can unintentionally get out of control, but economically motivated arson, claims the article, poses a much more serious challenge to forest protection (*The Economist,* August 30, 2007).

The underlying issue is one of scarcity: since land is a scarce resource, there are alternative uses for forested land than merely allowing it to remain in its natural state. Each of these alternative uses is potentially more profitable, with three particular scenarios highlighted. One possibility, driven by rising incomes and the implied rise in the demand for property, is using the land for construction and development (e.g.

building vacation condos or accommodating urban sprawl). Rising property prices are likely to increase the profitability of such endeavors. The second alternative is planting crops on previously forested land, which results in increased revenue for farmers. In general, rising crop prices would likely encourage farmers to produce more (and with the world price of grain rising steadily over the last few years, there is no lack of incentive). The EU's Common Agricultural Policy might exacerbate the situation by encouraging larger farm size. Finally, harvesting the trees and selling them in the lumber market is another opportunity to earn income from the land, an opportunity whose appeal rises in tandem with rising timber prices.[1]

However, forest protection laws forbid all three of the abovementioned economic pursuits. Regardless of different trends in forest ownership (most forests in Greece and Bulgaria are public, while Spain and Italy have predominantly privately-owned woods), legislation prohibits any cultivation, construction, or logging on all forested areas.[2] Thus, the interested parties are likely to resort to arson as a way to circumvent forest protection laws. The perpetrators are not impeded by laws that forbid construction for a certain number of years on former forested areas, since weak law enforcement and corruption generally allows them to reclassify burned land as former farmland, which can then be used essentially for anything.[3] This is especially the case in Greece, which lacks a

[1] A fourth incentive emerges from the literature review in the form of compensation to volunteer firefighters: the unemployed are motivated to start fires knowing that they will get paid to put them out. However, this explanation has several drawbacks. It does not fit well within the framework of land scarcity and alternative uses of land, it proved impossible to confirm whether similar compensation is provided outside of Italy or how much the compensation actually is, and the media failed to mention this possibility in its criticism. Thus, while unemployment is tested in the model, its importance is inferior to that of the price variables, which are the principal focus of this study.

[2] Although very limited logging may be carried out in private forests with special permission from forest managing organs.

[3] In the case of logging, it may seem illogical to wish to set fire to potential lumber. However, of primary interest here is a practice referred to as "salvage logging." This is a scenario in which burned trees are

comprehensive registry of forested land. In contrast, a Greenpeace study conducted in Spain concluded that arsonists were only a minority (*The Economist,* August 30, 2007). These conditions imply that, assuming an ability to control for all other factors that may affect forest fires, it would be possible to isolate the arson effect, which would be observed in significantly different coefficients for each of the two countries.

The hypothesized economic incentives for forest arson are an application of Gary Becker's rational choice model of criminal behavior as the theoretical framework of this study (Becker 1968). Becker's model considers the criminal as a profit-maximizing individual who will only commit a crime (set off a fire) if the expected marginal utility is greater than zero. The study makes use of annual data for the time period 1991-2005 from a wide variety of sources including EuroStat, FAOStat, the ILO, and national banks. Thus, based on a sound theoretical model and eclectic data sources, and seeking to shed some light on a relatively unexplored topic, this paper seeks to determine whether it is possible to observe a positive relationship between the prices of land, timber, and agricultural products and the incidence of forest fires in a panel of southern European countries. The number of forest fires is regressed on the price variables while controlling for weather, law enforcement, macroeconomic conditions, tourism, and country fixed effects. The findings of this study are likely to have implications regarding the potential for certain types of legislation to create perverse incentives and how these can be corrected.

II. Literature Review

harvested for lumber since only their bark has been affected by the fire, while the heart of the tree remains intact (Black 2007). For instance, Alexandrian et al (1999) attest to the existence of an economy based on the cutting and the marketing of burnt woods. Thus, by setting off a fire, loggers would have more trees to harvest, which translates into higher income.

In order to clarify the issue at stake, identify the relevant variables, and assess the possible implications of any results, a large variety of sources must be consulted. While articles from popular news sources (cited in the Introduction) serve as a starting point by introducing the idea of forest arson and the legal elements involved, scholarly literature on the topics of arson, forest fires, and the Mediterranean region is crucial. First, it is necessary to ascertain that a connection does, indeed, exist between arson and economic factors. Perhaps the keystone study on this topic is by Hershbarger and Miller (1978), who examine the impact of economic conditions on the incidence of arson. In testing the null hypothesis that no statistically significant relationship exists between the movement of selected economic variables and fire losses, they find a statistically significant relationship between arson losses and several of the economic indicators. The relationship is particularly strong (and positive) between arson and bankruptcy filings, as well as the federal budget surplus. While this study has provoked various critiques, such as Spillman and Zak's (1979) claim that the relationship between the business cycle and incendiary activity is very weak, Murrey et al. (1992), in an updated economic arson model, confirms Hershbarger and Miller's findings. Among the independent variables tested, forgery bond loss ratios, the yield on long-term treasury bonds, and Canada's consumer price index are only a few of those that demonstrate a significant relationship with arson losses.

Once a generic link between economics and arson has been confirmed, a closer look is taken at the specific phenomenon of forest fires. Various studies have sought to model the occurrence of woodland fires. Prestemon and Butry (2005) set up wildland arson as an autoregressive crime function. The authors succeed in modeling the phenomenon in a way that accounts for temporal clustering, thus introducing annual variation in wildland arson, which may explain more accurately how arson is affected by variables that change slowly or that cannot be expressed precisely at the daily time scale. Keane et al. (2003) also try to model arson, but they do so through simulation, determining the relative importance of simulation time span, fire frequency parameters, and fire size parameters. In a curious small-scale project, Mees (1991) focuses on the phenomenon of arson weather, or the idea that as weather conditions raise the possibility of a forest fire, arsonists' propensity to start them also rises. His findings may have implications for the results of this study, in that if arson is a fairly small-scale phenomenon, weather variables may pick up its contribution to forest fires, thus masking any existing significance. None of these studies, however, considers economic incentives for arson.

Instead, a number of single-country case studies seeking to determine the causes of forest fires provide guidance regarding the profit incentive and the inclusion of certain variables in the supply model. Perhaps the case study most closely linked to the purpose of this paper is carried out by Arima et al. (2007) in the Brazilian Amazon. The authors use the prices of beef and soy as a predictor of forest fires, finding a significant positive relationship between the commodity prices and the incidence of fire. The results of their investigation indicate that commodity prices can, indeed, be an incentive for fire arson, thus justifying the inclusion of the price of wheat as an independent variable in the model.[4] Pazienza and Beraldo (2004) examine the effects of forestry legislation on the frequency of fires in Southern Italy. Compensation schemes for volunteer firefighters and

[4] Surprisingly, temperature was not included as a control variable in the model, indicating that it does not significantly affect the incidence of Amazon fires. This has implications for the model of European forest arson, as will be illustrated further.

the mechanism for distribution of federal funds to local governments based on incidence of forest fires encourage the unemployed or local officials to undertake incendiary activities. The study's findings of a significant, positive relationship between fires and unemployment demonstrate how legislation can provide perverse incentives for the setting off of forest fires and serve as the basis for the inclusion of unemployment in this model. Other studies yield a variety of results, from pointing to the burning of debris and incendiary activities as the primary causes of wildfires in Brazil (Soares et al. 2006), to indicating weather conditions as the main culprit in Poland (Ubysz et al. 2006), to promoting a theory of economically-motivated arson in a Mexican context (Aridjis 1998).

In considering specifically the Mediterranean region, Alexandrian et al. (1999) focus on the causes of forest fires, highlighting that these are predominantly human-induced rather than of natural origin. They argue that rising standards of living in the region are contributing to the growing incidence of woodland fires by spurring a transfer of population from rural to urban areas. This demographic change has resulted in a loss of inhabitants with a sense of responsibility for the forest and, more importantly, an increase in the amount of fuel,[5] both of which imply a rise in the number and intensity of forest fires. The growth of per capita GDP is included in this investigation (with an expected positive sign) to reflect Alexandrian et al.'s claims. Velez (1990) further develops the theory of tourist presence in Mediterranean forests as a significant contributing factor to fires. He blames the carelessness of smokers and excursionists who light cooking fires, as well as a secondary effect of their presence: the burning of large quantities of solid waste

[5] The accumulation of fuel refers to the gradual build up of biomass on the forest floor due to stagnation in forest activity. The presence of such highly flammable material raises the probability of a fire.

left by tourists and other recreational users of forest areas. Thus, it appears to be necessary to control for camper presence in the model.

Other studies related to the general topic of forest fires fall within the field of forensic economics, analyzing the costs, be they social or economic, of the burning of hundreds of hectares of forest. Ortuno-Perez and Martin-Fernandez (2004) explore the cost of forest fire in southern Spain, while Rella et al. (2005) investigate the economic impact of forest fires in Italy. Both investigations conclude that the costs of forest fires are enormous and show concern for the negative impact they have on frail domestic economies, which attests to the relevance of the current study. From the concern regarding costs stems the idea that fires must be prevented, but there exists a problem of who will bear the costs of prevention measures. Seemingly, they ought to be borne by the communities at risk – an idea that has spawned the trend of contingent valuation, or a sort of payment-in-kind measurement. This method has been applied to gauge communities' willingness to pay for forest fire prevention. For example, Hung et al. (2007) apply this in a Vietnamese context and conclude that CVM is a much more effective manner of persuading villagers to pay for fire prevention efforts. Their work may delineate a potential route for future government action.

All of the research outlined above, when grouped together, succeeds in portraying forest arson as an economic phenomenon. This study is unique in focusing precisely on the relation between prices of land, crops, and timber and the incidence of forest fires, something that has not been done before and that, if successfully modeled, may demonstrate a need for policy changes in forest fire prevention.

III. Theoretical Model

The nature of arson as a voluntary, illegal activity calls for a rational choice model of criminal behavior. The first of two theoretical models that were considered in relation to this topic was developed by Ehrlich (1973) and assumes that the gains from illegal activity depend solely on the amount of time devoted to that activity. It seems hardly applicable in the case of forest arson, which is neither a time-intensive activity, nor one that can replace legal activity as a source of income in the long term. Furthermore, the gains from forest arson do not depend directly on the amount of time dedicated to it, but rather on changes in the relative profitability of alternative land use and the probability of getting away with the crime. Arson, then, violates the basic assumptions of Ehrlich's model.

Hence, the preferred model is one developed by Gary Becker (1968) in which the arsonist is modeled as a utility-maximizing individual presented with the choice of whether or not to commit a crime. Economists generally agree that, when other variables are held constant, an increase in a person's probability of conviction or punishment would generally decrease his likelihood of committing the crime. Conversely, an increase in the utility of the illegal act would make it more appealing to the individual and hence raise the probability of its execution. However, neither the gain, nor the punishment is certain (the arsonist may or may not get caught), which calls for a model that focuses on expected utility. Becker illustrates this algebraically as

$$EU_j = p_j U_j(Y_j - f_j) + (1 - p_j) U_j(Y_j),$$

where Y_j is the individual's income, monetary plus psychic, from an offense; U_j is his utility function; f_j is the monetary equivalent of the punishment; and p_j is the probability of conviction. By taking the partial derivatives with respect to p_j or f_j it can be seen that an increase in either the probability of conviction or the cost of the penalty would decrease the marginal utility expected from committing the offence

$$\frac{\partial EU_j}{\partial p_j} = U_j(Y_j - f_j) - U_j(Y_j) < 0$$

and

$$\frac{\partial EU_j}{\partial f_j} = -p_j U_j'(Y_j - f_j) < 0 \quad .$$

In contrast, an increase in the income from engaging in the illegal activity (Y_j) would increase the expected marginal utility of the crime.

Logically, an individual will only break the law if the expected marginal utility of doing so is greater than zero. Thus, the expected marginal utility of a crime determines the number of offences, allowing Becker to expresses the crime supply function (with O_j as the number of offences an individual would commit) as

$$O_j = O_j(p_j, f_j, u_j),$$

where p_j and f_j retain their meaning from above, and u_j is a variable representing all the other factors (income available in other activities, nuisance arrests, etc.) that are likely to influence the marginal utility of committing a crime. A change in any one of these is expected to result in a change in the number of offences carried out. For instance, an increase in the probability of conviction reduces the utility expected from the crime and thus reduces the number of crimes supplied

$$O_{p_j} = \frac{\partial O_j}{\partial p_j} < 0 \quad .$$

In applying Becker's theory to arson, the probability of conviction and its cost are grouped into a single variable – law enforcement – due to unavailability of data. The simplified model is expressed as

$$EU_j = U_j(Y_j - fp_j),$$

so that the expected utility of setting off a fire depends on the extent to which law enforcement, fp_j, is likely to reduce the income, Y_j, from the crime.[6] Income itself consists of several components: the price of timber (*PT*), the price of land (*PL*), the price of wheat (*PW*), and unemployment (*UE*).[7] Taking the partial derivatives of the altered equation, first with respect to income, then with respect to law enforcement, illustrates that an increase in income (essentially, an increase in the profit incentive) raises the expected marginal utility of breaking the law

$$\frac{\partial EU_j}{\partial Y_j} = U_j'(Y_j - fp_j) > 0,$$

whereas an increase in fp_j lowers it

$$\frac{\partial EU_j}{\partial pf_j} = -U_j'(Y_j - fp_j) < 0.$$

As in the generic crime scenario, an individual will only start a fire if the expected marginal utility of doing so relative to a change in any one of the income components is greater than zero. To illustrate,

[6] The law enforcement variable (an index of corruption in the actual model) cannot be subtracted directly from the income that could be generated by a fire. Rather, the equation is only meant to illustrate the idea that better law enforcement and stricter punishment detracts from the potential profits.
[7] It is difficult to determine whether unemployment should be included in the income variable (*Y*) or grouped with the factors in *u*. While a greater number of unemployed implies more fires, being unemployed is not in and of itself a financial incentive to set off a fire. Rather, the incentive would be the actual compensation one would receive as a volunteer firefighter. Essentially, then, *UE* is included as a factor of income only in the theoretical sense; in terms of the actual modeling, this 'classification' is unimportant.

$$\frac{\partial Eu}{\partial Y} \cdot \frac{\partial Y}{\partial PT} > 0,$$

for a change in the price of timber, but *PT* could just as easily be replaced by *PL, PW,* etc. Thus, a change in the incentive structure or in the potential of getting caught alters the likelihood that the law is broken. Essentially, the expected marginal utility of arson determines the number of fires supplied intentionally, allowing the total supply of forest fires (*FF*) to be modeled as

$$FF_j = f(Y_j, fp_j, u_j),$$

where u_j stands for any factors that contribute to natural or accidental forest fires. Each of the variables in this model is then decomposed into its respective parts, so that the comprehensive supply model, derived largely from the media's allegations and the literature review, becomes

$$FF=f(PL, PT, PW, UE, LE, Precip, Temp, GDPgr, Tourism).$$

The first four variables have already been described as the profit incentive to forest arson; *LE* stands for law enforcement, or the potential cost to the perpetrator; and the remaining pieces are all factors that must be controlled for. Precipitation and temperature seek to offset weather effects, GDP growth ought to control for demographic and social changes, as well as the accumulation of fuel in the woods, and accounting for tourism siphons out the fires started by negligent people in close proximity to forested areas. [8] This selection of variables, while perhaps not exhaustive, realistically allows us to measure the effect of the proposed incentives for arson while controlling for alternative causes of forest fires

[8] It has been suggested that the supply of forest fires might be represented by a kinked supply curve of sorts. Basically, in natural or accidental conditions, the supply of fires is vertical, but as the potential returns to arson rise, the supply begins to slope upward.

such as weather conditions and unintended human intervention. The following section addresses the variables in greater detail.

IV. Model Variables and Data Sources[9]

The intended dataset for this study included six southern European countries – Spain, Portugal, Italy, Bulgaria, France, and Greece – over a 15-year time period, 1991-2005. These countries were originally selected because of their high incidence of forest fires,[10] the similarity of their climates, and coordination of their forest protection regulation under the European Union's Sixth Environment Action Program. Unfortunately, unavailability of data forced the exclusion of Portugal and France from the dataset and also limited the years with a complete set of observations to approximately 1995-2005. A table of summary statistics for this final dataset, categorized by country, is available in the Appendix (Table1).

The dependent variable, forest fires, could have taken on one of several distinct forms: number of forest fires started, total acres burned, or percentage of forest burned (over a one year period). The first of those is the best one for the model, since, to the extent that fires are a function of arson, their number depends directly on the individual's decision to start a fire, whereas he/she would have no control over the area burned. The number of fires is divided by the area of forested land in the country (measured in thousands of acres) and then scaled up by one hundred. Essentially, the final form of the depended variable is number of fires per one hundred thousand hectares of forested area, with country means that range from as low as 14 for Bulgaria to almost ten times more

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[9] Italics mark the use of exact variable names (e.g. *UE* rather than unemployment rate).

[10] A report on Wildfire 2007, the 4th International Wildfire Conference, explains that Spain, Portugal, Italy, France and Greece are worst affected due to their geographical position and climate conditions. They are the EU member states with the highest forest fire risk index, and where the largest amount of burnt forestland is recorded (Rego, May. 10, 2007).

for Spain. This variable exhibits a great deal of variation both over time and across countries. The source is the *Timber Bulletin,* an annual publication of the United Nations Economic Commission for Europe (UNECE).

The UNECE is also the source of data on one of the profit incentive variables: timber prices *(Price Timber)*. These are calculated as a weighted average of the export prices per cubic meter of roundwood, plywood, and sawnwood – the three principal wood products of the panel countries – and then transformed from real dollar prices, to real Euro prices (UNECE).[11] Much like the dependent variable, the price of timber exhibits a great deal of variation, with Italy having average prices approximately ten times greater than Bulgaria. Variations in the price of land (*Chng Price Land*) are captured in a variable that measures annual change in the real price of a square meter of residential property which is compiled from several different publications. Data on Greece is from an OECD report on real estate price indexes (Eiglsperger 2006); statistics on Spain are from the Bank of Spain (Bank of Spain), Italian prices are published by Nomisma, an economic research institute (Nomisma); and the value of Bulgaria's property is made available by the National Statistical Institute (NSI).[12] The mean change in housing prices for Bulgaria stands out with its large magnitude and negative sign. This is largely the effect of hyperinflation and economic problems during the transition period. Next, producer wheat prices (*Price Wheat*) from the UN's Food and Agriculture Organization are used as a proxy for farmers' profit incentive (FAOSTAT). Wheat was chosen because

[11] Since the Euro was only introduced in 1999, the Federal Reserve's "Euro Community" exchange rate is used for data prior to that year. It forms a continuous series with the ensuing Euro exchange rate. In addition, although Bulgaria has a distinct national currency, it is pegged to the Euro (and previously the German mark), which makes the use of Euro prices suitable (FRED).

[12] An alternative variable, the European Central Bank's Residential Property Price Index for the Euro Area, was tried in the model, but it performed poorly, most likely due to its failure to capture fluctuations within each country.

it is a principal crop grown in each of the countries in the model and enjoys steady demand.[13] It was lagged in order to account for the seasonal nature of agriculture: arguably, a farmer cannot expand the area under cultivation until the next planting season.[14] Lags of the other two price variables were also tried, but they proved to have less explanatory power than non-lagged values, which indicates that loggers and contractors are able to react to price changes quickly. Figure 3 graphs the prices of timber and wheat alongside the average number of forest fires in an effort to illustrate the fluctuations in all of them over time. The final variable related to economically motivated arson – unemployment (*UE*) – is reported as total, civilian unemployment rates from the International Labor Organization (ILO). The coefficients on all four of the variables just described are expected to have positive signs based on the profit-motivated arson theory.

The law enforcement variable is represented by Transparency International's Corruption Perceptions Index (*CPI*), which is reported on a scale from 1 to 10, with 1 indicating the lowest level of corruption and 10, the highest (Transparency International).[15] The expected sign on the corruption index is positive, since higher levels of corruption arguably lower the costs of arson, raising the supply of fires. Several alternatives to the CPI were considered, such as number of crimes committed per capita and two of the World Bank's aggregate governance indicators – control of corruption and government effectiveness – but none improved the explanatory capacity of the model.

[13] According to FAOSTAT, a producer price is "the amount receivable by the producer from the purchaser for a unit of a good or service produced as output minus any VAT, or similar deductible tax, invoiced to the purchaser" (FAOSTAT). Seemingly, this measure does not account for any subsidies.

[14] Lags were also tried with the other two price variables, but

[15] Normally, the scale goes the other way around: 1 is most corrupt, 10 is least corrupt. However, the measurement was "flipped" in order to make for easier interpretation of the coefficient. TI defines the CPI thus: "The Transparency International Corruption Perceptions Index ranks countries in terms of the degree to which corruption is perceived to exist among public officials and politicians. It is a composite index, a poll of polls, drawing on corruption-related data from expert and business surveys carried out by a variety of independent and reputable institutions" (TI).

Although it is easy to note that Bulgaria, for instance, is more corrupt than Spain, *CPI* exhibits very little within-country variation (standard deviations ranging between .4 and 1), which might deprive it of significant descriptive power.

Turning to the accidental and natural factors, weather in the model is accounted for in two ways: a measure of precipitation (*Precip*), which is predicted negative, and a measure of temperature (*Days80up*), predicted positive. National meteorological institutes provide monthly precipitation data, with the precipitation variable an average of rainfall (in millimeters) over the three summer months – June, July, and August – in the most affected regions.[16] Bulgaria is the country that receives the greatest amount of rainfall (50mm per month), which partially explains its significantly lower number of forest fires. The University of Dayton is the source of daily temperature data for each of the four countries, data which is converted into a variable indicating the number of days during which the country experienced temperatures above 80 degrees Fahrenheit over the four hottest months, June through September (U of Dayton). The temperature variable fares better in this particular format than as average temperature or maximum temperature, although Greece appears to have an unusually high number of hot days.[17] Real GDP per capita growth (*GDPgr*), made available by the USDA's Economic Research Service, is expected to be positive for reasons laid out in the literature review, as well as on the assumption that economic growth is an indication of more development and construction, which raises the demand for land (USDA). Finally, tourism (*Campers*)

[16] For Spain, precipitation data was from Barcelona, Salamanca, Madrid, and Seville; for Italy, the Ciampino weather station, located in the middle of the peninsula; for Greece, Kalamata, Mikra, and Alexadroupoli; and for Bulgaria, Haskovo, Pleven, Pazardzhik, and Kazanlyk. These locations are marked with red dots on the map of forest fire risk in the Appendix.

[17] An interaction variable between precipitation and temperature was also tried, since weather that is both hot and dry would likely result in more fires, but it was found to be insignificant.

data comes from EUROSTAT – the European Union's statistics database – and is calculated as the number of nights (in hundreds) spent by campers divided by the number of campsites (EUROSTAT). Essentially, it represents a density of campers in the woods and as such, the anticipated sign of its coefficient is positive, as greater human presence increases the chances of fires caused by negligence.

V. Econometric Estimation

When using panel data, the general expectation is that because of country-specific factors, the averages of the dependent variable (number of forest fires) are different for each cross-section unit (country) but the variance of the errors is not. Indeed, as can be seen from the summary statistics (Table1), there is significant variation in the mean number of fires. Spain, for instance, has roughly 140 forest fires annually per one hundred thousand hectares of forested land, in contrast to Bulgaria, which can expect less than 15. In contrast, the difference in the standard deviations is not nearly as pronounced (27 versus 12). Such peculiarities in the data tend to result in inconsistent coefficients on the independent variables with random effects estimation. The technique most commonly used to eliminate the inconsistency is fixed effects estimation. By creating country binaries and including them in an ordinary least squares model, country-specific characteristics are controlled for, leaving only time-dependent variation in the data. In order to avoid perfect multicollinearity, the country binary for Spain is left out of the estimation models. Thus, the coefficients on the other countries indicate how the number of forest fires in Italy, Greece, or Bulgaria compares to the number of fires in Spain.[18]

[18] At early stages of modeling, year binaries were also tried in an effort to control for year-specific idiosyncrasies, but they were found to be insignificant.

Expectations regarding the coefficient signs on these binaries are uncertain for several reasons. First of all, if the Greenpeace study carried out in Spain is correct in its conclusion that arson is not a significant cause of forest fires in the country then Spain should, arguably, have fewer fires than its Mediterranean neighbors if the model successfully controls for all other factors (positive signs on all three country binaries). Second, Greece's lack of forest records presumably makes arson much easier to carry out and get away with, resulting in a greater incidence of fires in Greece (positive coefficient on country binary), other things held constant. Finally, Spain traditionally has suffered from more forest fires than any of the other countries, so if arson is too small of a phenomenon, the country binaries are not likely to reflect its impact unless all other causes are perfectly controlled for. Given this ambiguity, the significance of the binary variables is evaluated with a two-tailed test, while one-tailed tests are used for all other variables.

The regression analysis begins with a very simple model, which includes only unemployment, GDP growth, precipitation, temperature, and campers. The profit incentive is added in the second model in the form of the three price variables. The Corruption Perceptions Index – the law enforcement factor – is included in the third regression. Adding the profit incentives and the potential cost of arson to the model at separate stages provides a better illustration of the impact of each than would be obtaining by testing an all-inclusive model from the very beginning. However, that benefit aside, the results of these three initial models are hardly relevant, since it is absolutely crucial that fixed effects be included. The fourth model does, indeed, contain the country binaries, and is the most comprehensive estimation possible. Finally, the "best" model is chosen based on a combination of adjusted R-squared optimization, the strength of the theoretical justification for the inclusion of a variable, and the significance and sign of the coefficient. Standardized coefficients are calculated to demonstrate the relative importance of each independent variable in, while variance inflation factors are monitored to ensure that multicollinearity is not a problem.

VI. Results and Interpretation

Table 2 displays the results of the five regressions, and it can be seen immediately that the first two models are very similar in their results. The variables account for approximately four-fifths of the variation in number of forest fires (the second model has a higher adjusted R-squared than the first model, indicating that including the profit incentive in the model improves it). Such high explanatory power initially seems spurious, but it is easily explained by the presence of a precipitation variable, which is the largest natural determinant of fires, as well the inclusion of a tourism statistic. This latter measure is highly correlated with the country binaries, meaning that because of their absence from the model, *Campers* picks up much of the country-specific significance. Indeed, the standardized coefficient (0.890 in the initial model, 0.817 in the second) on the variable is far too high to account only for negligent tourists' contribution to forest fires. Aside from the tourism variable, the coefficients on GDP growth, unemployment, and weather have the expected sign and are significant at least at a 5% confidence level in the initial model and at least at 10% in the second one. However, only one of the price variables, the lagged price of wheat, is significant (at 5%) and of the correct sign. A negative sign on the price of timber contradicts expectations, but its lack of significance makes this less disconcerting.

In the next step, the law enforcement variable, *CPI*, is added to the model. This is a variable with very little within-country variation (Table1 indicates that standard deviations range between .4 and 1 depending on the country). As such, it is highly correlated with several of the country binaries (thus picking up their effect) and with the tourism variable (itself highly dependent on country), which explains the appearance of multicollinearity in the model. *CPI* itself has a variance inflation factor slightly above 5 (the usual cut-off point for economists), while a VIF surpassing 10 on the camper statistic indicates that multicollinearity is, indeed, a problem. GDP growth is stripped of its significance, as are temperature and the price of wheat, while the price of timber becomes borderline significant (10%) and positive. The unemployment rate and tourism remain as the strongest predictors of forest fires. Contrary to all expectations, the coefficient on the law enforcement variable has a negative significant sign, which indicates that as corruption increases, there are fewer fires. However, attempting to interpret this variable without controlling for country-specific effects reveals very little information.

When the model is finally run with fixed effects, the R-squared indicates that over 90% of the variation in forest fires is now explained. The adjusted R-squared is also notably higher than that of the previous model. These measures are viable in spite of the severe multicollinearity (VIFs around 40 for *Campers* and *Greece,* notably above 5 for another six variables) that has appeared, since multicollinearity does not affect the overall reliability of the model but rather the accuracy of the individual coefficients.[19] As could be anticipated based on their close association to the country variables, the tourism, unemployment, and corruption variables all lose their significance. GDP growth regains

[19] In case these are of interest, and seeing as they are not included in the results table: *UE* has a VIF slightly over 9, *Days80up* over 7, *CPI* close to 7, *Price Timber* around 8, and the remaining country binaries, over 10.

it, remaining positive, as weather remains almost unchanged. Unfortunately, none of the price variables is significant, but the multicollinearity in the model might be partially responsible. All of the country binaries are negative and significant at least at 5%, which means that Italy, Greece, and Bulgaria all have fewer fires relative to Spain even after controlling for all of the profit-related, accidental, and natural causes of fires possible. This will be addressed in greater detail in section VII.

The last column in Table2 displays the results of the final, and preferred, model. While this model does have a lower R-squared and adjusted R-squared than the previous one, both measures are still very high, indicating that the model has considerable explanatory power and is better than the first three models.[20] It also uses a greater number of observations – 49 as compared to 39 in the previous model. All of the variables removed are ones that were insignificant in the previous model, except for the price measures, which are retained as the focal point of this study. However, insignificance is not the only justification for the elimination of *UE, Campers, CPI* and *Days80up*. Perhaps the principal reason for the elimination of the first one was the impossibility of finding out whether or not the other three countries in the dataset have the same policies for the compensation of volunteer firefighters as Italy. Thus, if such legislation exists only in one small area, the unemployment rate is unlikely to have a large impact on the number of forest fires. Tourism was removed because it was not significant in any one of numerous fixed effects regressions, it was highly multicollinear with many of the variables, and its coefficient was of the wrong sign when controlling for fixed effects.

[20] Naturally, the 5 models included in the results table are only a small representation of the total number of regressions that have been run on the dataset. The 'preferred' model is better than many of them if adjusted R-squared is considered to be the only criterion. It is better than all of them if adj. R-squared is considered alongside theoretical justification and the simplicity principle.

While the theoretical justification for including it into the model might be strong, it appears that the variable itself fails to capture the desired tourist effect as increased presence of people in close proximity to forested lands. Corruption was discarded because not only does the index not offer significant within-country variation over time, but it might also be failing to capture the exact phenomenon of interest to this study. An optimal variable would have been percent convicted of forest arson out of total arrests for it, but such data is not publicly available. Finally, the absence of a temperature variable in the Pazienza and Beraldo study (2004) of Amazon fires, coupled with the generally moderate Mediterranean climate and the relatively larger contribution of other weather phenomena to forest fires are the reasons for the exclusion of the temperature variable.[21]

Focusing on the results of this final regression, the only insignificant variable is the change in land prices, which has actually remained insignificant all along. Aside from the obvious explanation of property prices having no effect on the number of forest fires, other possibilities include the variable's ineffectiveness as a proxy for the price of land that is likely to be a target for arson or the incomplete information given by a "change in price" variable rather than an actual measure of price. All of the other variables have the predicted sign and are significant at least at 10%. In comparing standardized coefficients, country has the largest impact, followed by the prices of wheat and timber, precipitation, and finally GDP growth. Multicollinearity is reduced significantly by taking out the abovementioned variables: it now only slightly (VIF of roughly 6.5) affects *Italy* and *Price Timber,* which is understandable since Italy is characterized by an unusually high price of timber relative to the other countries. In the interest of interpretation, it appears

[21] The insignificance of temperature makes sense. If the weather is hot but wet, the chances of fire are miniscule, but if conditions are extremely dry, a spark will set of a fire regardless of whether temperature is in the 60s, 70s, or anything over that.

that a one percent increase in GDP per capita growth results in over two additional fires annually; two additional millimeter of precipitation decrease the number of fires by one; a 100 euro increase in the price of timber leads to three additional fires; and a similar increase in the previous year's price of wheat would increase the number of fires by almost 24. In terms of country binaries, other things held constant, Italy has 60 fewer fires than Spain, Greece – 95, and Bulgaria – 90. Overall, the model appears to be capturing the variation in number of forest fires quite well, while adhering to the basic economic principle of parsimony.

VII. Discussion and Implications

Before the results of the study are evaluated, it ought to be noted that a bold assumption had to be made regarding the dependent variable. It is assumed that all forest fires are reported with equal accuracy and based on identical criteria as to what constitutes a forest fire in terms of magnitude and surrounding vegetation. However, although the data comes from a uniform source, it is reported to the UNECE by the individual countries. Differences in the accuracy of monitoring systems, in definitions of a forest fires, or in the presence (or absence) of incentives to report more fires or conceal a number of them could all affect the consistency of the data.

Assuming the validity of the data, the fixed effects estimation of forest fires in southern Europe yields mixed results. On the one hand, there is strong evidence that human induced changes have an effect on the number of forest fires. This is seen in the positive, significant coefficient on GDP per capita growth, a coefficient which captures demographic relocation, incentives for development, and the accumulation of fuel. It also appears that a profit incentive to arson does, indeed, exist and is manifested in the positive, significant coefficients on the price of timber and price of wheat variables. However, in the absence of a law enforcement variable, these prices do not reflect the true expected returns from a forest fire. In addition, there may be alternative explanations for their significance which are not controlled for in the model. For instance, in the case of higher grain prices, farmers might be starting fires to clear land that is simply abandoned farmland in order to expand the total area they cultivate. If they lose control of the fire and it spreads to a nearby forest, that forest is, practically, the victim of economic incentive, but arson has no part in the scenario. Along the same lines, a rise in the price of timber would likely implicate increased activity in the logging industry, which raises the probability of accidental fires. On the flip side, if producer prices from the FAO do not account for subsidies, which are generous in the European Union, the price of wheat variable is unable to capture the profit motives in their entirety. Furthermore, ‘arson weather’ behavior (Mees 1991) might be masking the arson effect (which is relatively small to begin with), since weather variables such as precipitation would pick up most of the explanatory power.

Another important consideration revolves around the significance of the country binaries, which include a variety of factors not controlled for in the model. One possibility is climate and geographical distinctions, such as the frequency of storms (that generate lightning, thus sparking fires), wind (which can carry sparks to new patches of forest), or the location of forests (how far removed are they from cities and human activity). Another potentially important factor is the amount of resources dedicated to forest protection and educational campaigns, which can directly decrease the number of fires. Finally, country binaries represent an aggregate of cultural factors that are impossible to isolate – mindsets, attitudes, peculiarities. Perhaps a certain culture has a stronger sense of responsibility for the state of the world's forests or is less likely to throw a cigarette stub out the window. In the exclusion of the *CPI*, corruption is one of those 'cultural' factors. The fact that the coefficients on Italy, Greece, and Bulgaria are negative, indicating that all three countries have relatively fewer fires than Spain, could mean one of several things: first of all, the study that claims that most fires in Spain are not arson is wrong (the other countries are more corrupt, so they should have had a greater incidence of arson/fires); second, Greece's lack of forestry records does not make it significantly easier to profit from arson than in the countries with forest records (otherwise Greece would have had a positive coefficient); finally (and most likely), the incidence of arson is too small to capture without a very precise model. Since the country binaries carry so much other information, it is very likely that the arson phenomenon is not pronounced enough to alter the overall country effect.

However, since there is some evidence as to the connection between economic incentives and forest fires, this might have implications for government policy regarding forest regulation. One approach would be for governments to bolster their law enforcement efforts for the protection of forested areas by increasing monitoring and the severity of punishment. An alternative approach would be to adopt positive incentives. Ehrlich (1996) argues in favor of a similar course of action, arguing that decreasing the disparity between potential profits from legal and illegal activities can be an effective deterrent of crime. Thus, a program offering subsidies to property owners for the maintenance of their forests in a healthy condition may be an effective solution. Indeed, Mayer and Tikka (2006) investigate similar initiatives in North America and several northern European countries and find that an incentive-based approach is effective in maintaining biodiversity in privately owned forests.[22] Whichever approach is chosen, policymakers must be aware of the potential consequences of their actions, of the possible adverse incentives certain forms of legislation might be creating.

VIII. Conclusion

It ought to be conceded that this study leaves many questions unanswered. While human actions clearly affect the number of forest fires, there is little certainty as to the exact motivation (legal or illegal, accidental or intentional). The interpretation of country-specific effects is complicated by the comprehensive nature of the country binaries. Essentially, the study leaves abundant room for further investigation: expanding the data set to include Portugal, France, and perhaps Turkey, as well as a greater number of years; fine-tuning some of the independent variables, particularly in terms of prices; collecting data on expenditure for forest protection; and investigating the impact of EU agricultural subsidies on forest fires.

However, one thing is undeniable: forest fires deserve the attention of scholars, policymakers, and the public worldwide. They are a devastating force that annually annihilates millions of trees, releases tons of carbon dioxide into the atmosphere, and destroys hundreds of thousands of euro of private property in the countries of southern Europe (as well as around the world). The fixed effects estimation undertaken in this study indicates that humans are responsible for more damages than can be offset by natural factors such as precipitation. Thus, it is every government and every individual's

[22] According to another study, another possible course of action is to encourage cooperation between small forest owners: "Twelve countries reported that the fragmentation of private holdings represents a hindrance to sustainable forest management. Small-scale owners may find it more difficult to draw profits than larger entities, and transfer of knowledge and access to infrastructure can be complicated when owners are many. Local and regional cooperation among owners is thus crucial."

responsibility to ensure the adoption of measures to prevent forest fires resulting from negligence, deter arsonists through better law enforcement and positive incentives, and improve the efficiency of firefighting techniques. Keeping in mind the importance of the Mediterranean forests for biodiversity and the rising threat of global warming, it is imperative that humans cease to exacerbate a phenomenon that is already so destructive in its natural state and work to diminish its deleterious effects.

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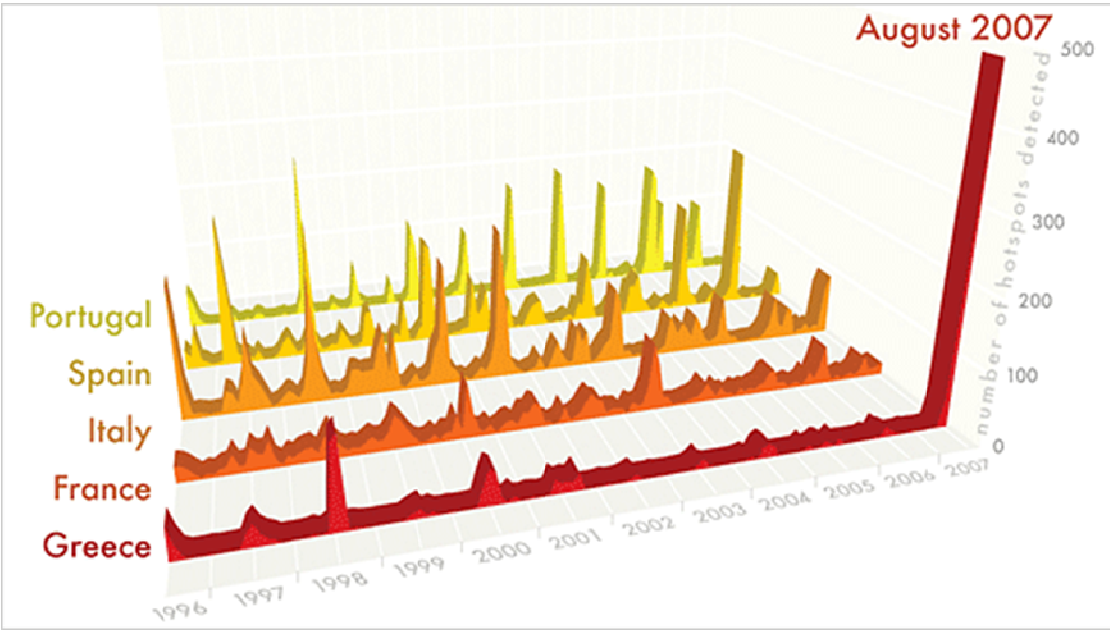
Appendix

Figure 1: Number of Hot Spots* Detected in Mediterranean Countries (1996-2007)

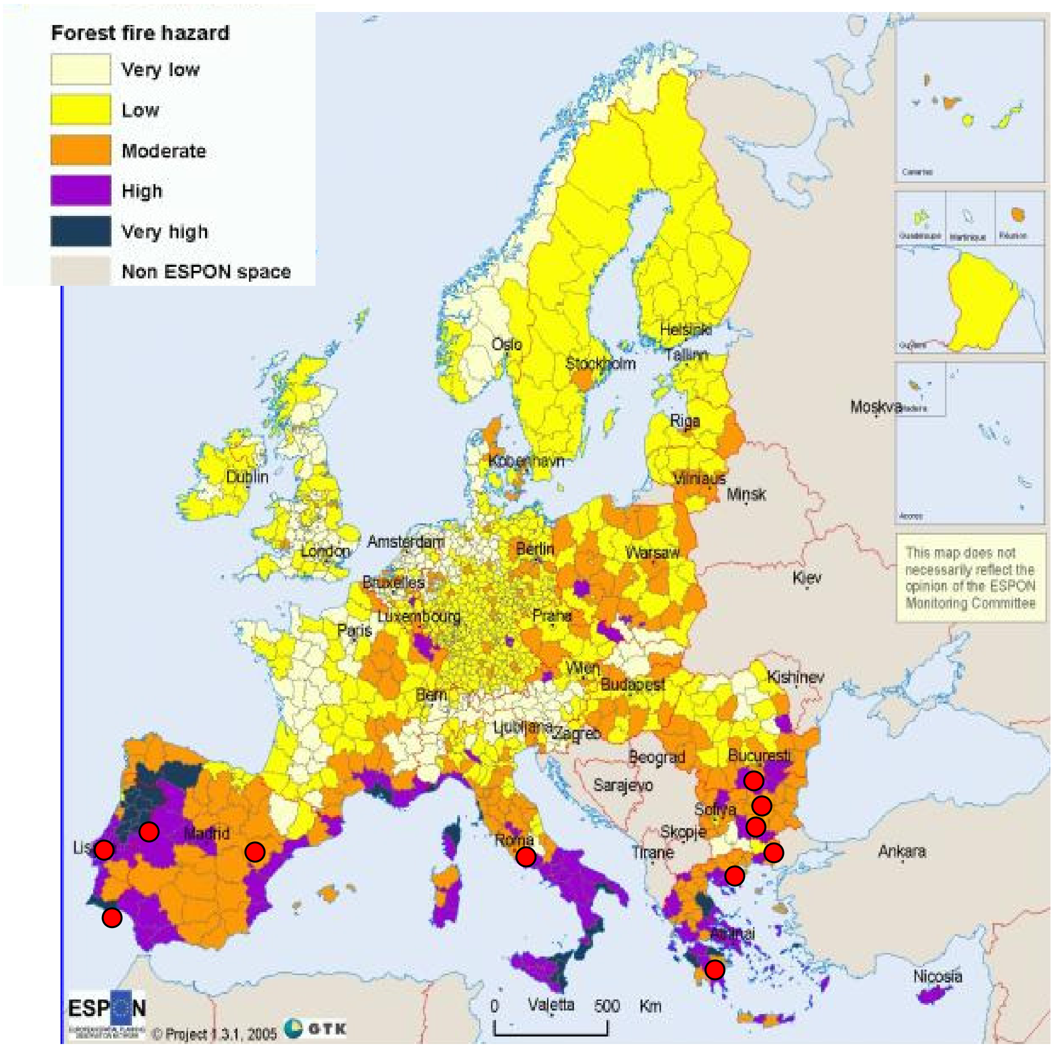


** A hotspot is a mark on an infrared satellite image indicating a heat source typical of burning vegetation.*

Source: ATSR World Fire Atlas

http://dup.esrin.esa.int/ionia/wfa/index.asp

Figure 2: Mapping Levels of Forest Fire Hazard
(Based on: forest fire data for the period 1997-2003 and biogeographic factors)



Source: ESPON (European Spatial Observation Network) Data Base, 2005
http://www.gtk.fi/projects/espon/ForestFires_files/image002.jpg

Figure 3: Time Trends in 4-Country Average Prices and Number of Fires (1991-2005)

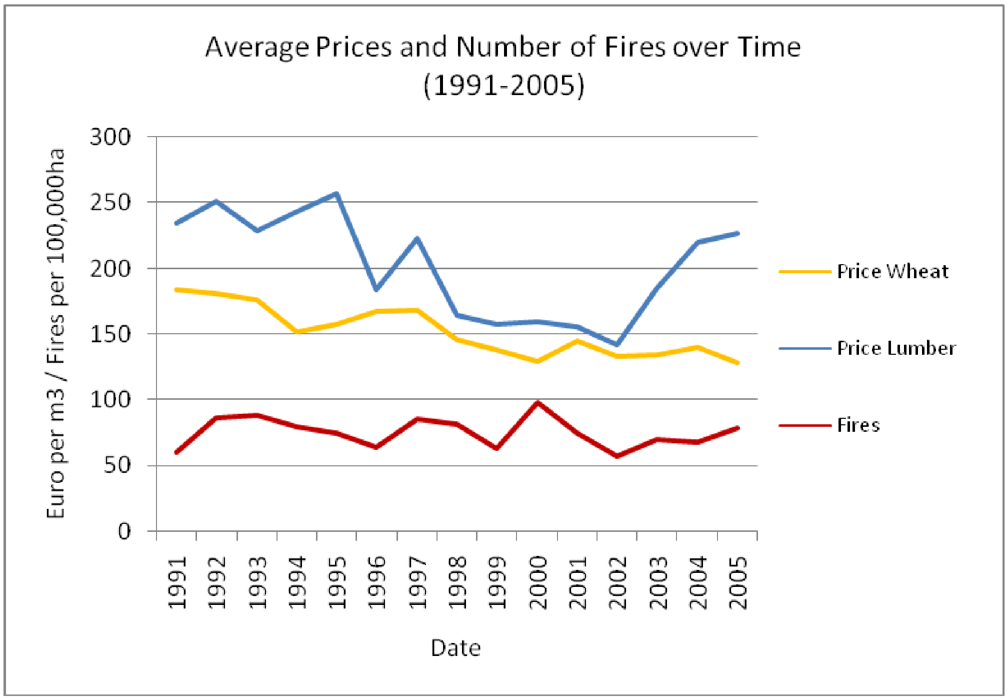


TABLE 1: Summary Statistics for Model Variables (1991-2005)*

	Spain	Italy	Greece	Bulgaria
	Mean (Std Dev)	Mean (Std Dev)	Mean (Std Dev)	Mean (Std Dev)
Fires	138.26 (27.03)	96.96 (30.27)	50.30 (15.18)	14.31 (11.96)
GDPgr	2.85 (1.93)	1.15 (1.07)	2.51 (1.85)	1.76 (5.43)
UE	16.60 (5.13)	10.23 (1.36)	9.97 (1.00)	15.36 (3.41)
Timber Price	228.06 (81.15)	871.10 (223.09)	231.72 (118.57)	77.30 (36.35)
Price Land (Δ)	8.36 (7.44)	1.87 (6.19)	9.58 (3.99)	-34.04 (137.17)
Price Wheat	157.36 (25.89)	183.14 (32.31)	185.64 (41.39)	80.91 (29.23)
Campers	82.03 (28.86)	94.18 (17.73)	21.20 (3.86)	26.46 (12.28)
Days80up	10.36 (18.73)	5.27 (8.92)	62.09 (7.16)	1.90 (2.51)
Precipitation	15.98 (10.19)	30.27 (23.24)	17.07 (8.69)	52.31 (26.25)
CPI	3.69 (1.06)	5.35 (.78)	5.43 (.43)	6.30 (.42)

*For certain variables, the available data does not span the entire period. *Days80up* and *CPI* are limited to 1995-2005.

TABLE 2: Ordinary Least Squares Regression Results: With and Without Fixed Effects Estimation[a]

Dependent Variable = Number of Fires per 100,000 Hectares of Forest

Variable[b]	**Basic Model**	**With Prices**	**With CPI**	**Fixed Effects**	**"Best" Model**
R-squared	0.7947	0.8309	0.8571	0.9282	0.8803
Adj. R-squared	0.7677	0.7899	0.8127	0.8951	0.8564
n	*44*	*42*	*39*	*39*	*49*
Intercept[c]	-84.041**	-108.068***	-35.411	163.581*	93.872***
	(-2.69)	(-3.56)	(-0.50)	(2.06)	(5.28)
GDPGr (+)[d]	4.301***	3.458**	2.956	4.847**	2.355**
	0.221	0.188	0.112	0.183	0.124
	(2.88)	(2.26)	(0.88)	(1.75)	(1.92)
UE (+)	6.097***	6.297***	7.489***	0.217	
	0.424	0.455	0.575	0.017	
	(4.47)	(4.59)	(5.08)	(0.10)	
Precip (-)	-0.559***	-.485**	-0.421**	-0.250*	-0.425***
	-0.261	-0.237	-0.214	-0.127	-0.198
	(-2.60)	(-2.41)	(-2.20)	(-1.63)	(-2.72)
Days80up (+)	0.581**	0.356*	0.227	0.050	
	0.295	1.33	0.125	0.027	
	(2.29)	(0.187)	(0.85)	(0.19)	
Campers (+)	1.193***	1.071***	0.626**	-0.346	
	0.890	0.817	0.508	-0.281	
	(7.98)	(6.70)	(2.25)	(-0.86)	
Price Timber (+)		-0.009	0.034*	0.017	0.032*
		-0.059	0.230	0.117	0.217
		(-0.57)	(1.65)	0.77	(1.56)
Chng Price Land (+)		0.038	0.600	-0.451	-0.012
		0.054	0.124	-0.093	-0.016
		(0.67)	(1.21)	-0.95	(-0.26)
Lag(Price Wheat) (+)		0.240**	0.179	0.134	0.238**
		0.200	0.137	0.102	0.220
		(2.06)	(1.26)	0.95	(2.32)
CPI (+)			-13.086**	-6.084	
			-0.304	-0.141	
			(-1.89)	-1.02	

Italy (?)	-48.552**	-59.750***
	-0.444	-0.523
	-2.36	(-3.72)
Greece (?)	-114.814***	-95.413***
	-1.018	-0.745
	-2.92	(-11.04)
Bulgaria (?)	-127.420***	-89.353***
	-1.044	-0.744
	-4.36	(-6.68)

a. The layout of results for each variable is Coefficient, Standardized Coefficient, (t-value).
b. Significance at 1% is reported as ***, 5% as **, and 10% as *.
c. All tests are one-tailed except for country binaries.
d. The sign in parentheses immediately following the variable name is the anticipated sign of the coefficient.