Forest fires and economic incentives: Impact of forest protection laws in Argentina

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This paper evaluates the potential impact of the recently enacted forest protection laws on the number of forest fires in Argentina. The forest protection laws (at a federal and provincial level) restricts the use of forestry land in several ways, and limit the expansion of the agricultural frontier. This restriction can make forest arson potentially profitable to clear land and to expand the agricultural frontier circumventing the laws. We present a conceptual model based in the economic theory of crime to analyze forest arson decisions, and to predict individual behavior. Using panel data from 2002 to 2014 at a provincial level we present empirical evidence of systematic effects in the occurrence of forest fire as a function of the new regulation and its sequential implementation. Fixed effects and difference-in-differences estimates show that the number of fires increased transitory some 100% -200% in the main crop producer provinces during the law implementation process (2009-2011).

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JEL classification codes: Q23, Q15, K32

Key words: forest fires, forest arson, forest protection laws, economic incentives for fire arson

I. INTRODUCTION

In recent years, policies related to environmental protection became increasingly prominent in Argentina, and the number of measures regulating the use of natural resources has increased. In year 2007 the "Minimum Standards for Environmental Protection of Native Forest" Act (henceforth, NF Act) established restrictions to the change in forestland use. After the passing of this federal law the argentine provinces (who are the regulatory authority on natural resources) enforced the legislation, designing a Native Forest Territorial Planning Map (NFTP). The time lapse between the beginning of the federal law regulation (2009) and the implementation of NFTP by provinces were different among provinces, but it took fa more than the 12 months stated originally by the federal law.

During this period, the provincial regulators were influenced by different interest groups which tried to affect forest land categorization. Also, during the time each province took to set NFTP permits for legal clear-cutting were suspended. However, this restriction was in some way broken by different illegal deforestation actions. Without legal permits for clearing and use the land in productive activities, there are two possible alternatives for a land owner: a) illegal forest clearance, b) to intentionally cause a fire and simulate it happened accidentally. This paper focuses on the second alternative: forest arson economically motivated.

In recent years, with high relative prices for agricultural production, people may perceive a high opportunity cost for preserving forests in their natural state and therefore they may favor the expansion of agricultural frontier (Zak et al, 2008, Viglizzo et al 2011). Even though there is an economic compensation established by law for forest conservation, the amount of money is relatively low, and landowners generally do not apply for it. On the other hand, the transaction costs associated to legally shifting from native forest conservation land use to an agricultural use are extremely high and this encourages illegal deforestation.

We analyze in this paper the change that the NF Act arose in the structure of economic incentives and evaluate the potential impact of this regulation on intentional forest fires. The main question to address is whether there is an increase in the number of forest fires due to the implementation of the native forest conservation law.

The NF Act was implemented sequentially, first at national level through a regulatory decree and afterwards at a provincial level through local laws. Despite the new regulations and controls there can be important incentives to generate intentional fires to avoid legal restrictions. A forest arson can be a mean to excluding the site from the scope of the regulations. The approach developed by Gary Becker (1968) is used as conceptual framework to analyze the economic incentives for fire forest arson.

We organized the paper as follows: first, we present a description of the regulatory and economic environment regarding native forest and agricultural production in Argentina. Section III, present a literature review related to forest arson and economic incentives. Section IV develops a conceptual model to capture the interplay between regulation and economic incentives to commit illegal activities. The next section describes the data and Section VI presents the empirical specification and the econometric techniques employed. Section VI reports the empirical results. Section VII concludes.

II. Institutions and Economic Incentives

In Argentina native forests are mainly placed on lands which have clearly defined property rights. Therefore, the restrictions over decisions on the use of resources have direct economic consequences on their owners. The main hypothesis in this study is that there are economic incentives which can motivate intentional forest fires crime if landowners perceive a high opportunity cost in conserving the forest in a legal manner. In the following section, we describe the transition towards greater restrictions in the use of forest lands after the NF Act enforcement at national and local level.

A. Institutions: Native Forest Legal Framework

National NF Act's main objective is to establish minimum standards for forestry environmental protection. It sets up minimum criteria for forest land categorization and it command the implementation through Native Forest Territorial Planning (NFTP) in the different provinces. Through this process the existing forest area was classified in three conservation categories (red, yellow and green). The two greater conservation categories (red and yellow) limit land use and comprise 70% to 90% of the forest area in the argentine provinces. Below, we describe the timing of the regulations and we characterize each stage and their main consequences.

The Native Forest National Act

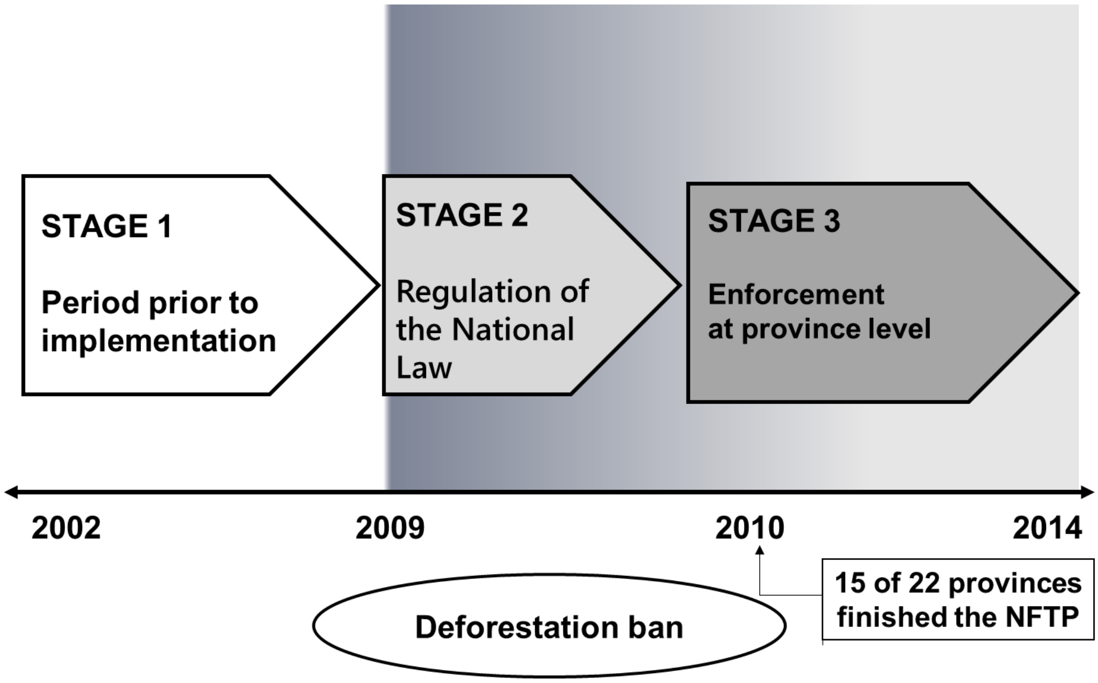
In November 2007, the Congress passed the Native Forest National Act, and later, in 2009, the Regulatory Decree for this law was enacted. It took several years for most of the provinces to comply with NFTP process. During those years, illegal activities which could affect forest conservation should be, according to the law, strictly controlled.

Figure 1 shows the timing of the regulatory process. We identify a sequence of three stages from 2002 to 2014: a) years before the federal law (stage I), b) transition period (stage II), and c) years after the NFTP (stage III).

The NF Act banned the deforestation, under any circumstance, of native forests until provincial NFTP enactment. We call this intermediate phase, stage II. If as from this provincial categorization a specific land site falls within the red or yellow category, legal deforesting to undertake any productive land use becomes banned in stage III. Consequently, we could expect an eventual increase in illegal deforestation during the stage II if individuals perceive potential economic gains changing the land categorization. Landowners with native forest areas in their lands, considering the deforestation ban and the uncertainty about the category in which the land will be classified, may consider profitable to deforest by simulating an accidental fire to avoid a potential economic restriction in future land use.

It is important to note that the transition time window may vary according to each province, depending on the year that each province completed the NFTP. By the end of 2010, almost 70% of the provinces had fulfilled the NFTP. The rest of the provinces enacted the provincial law between 2011 and 2014.

Figure 1. Timing of Regulations



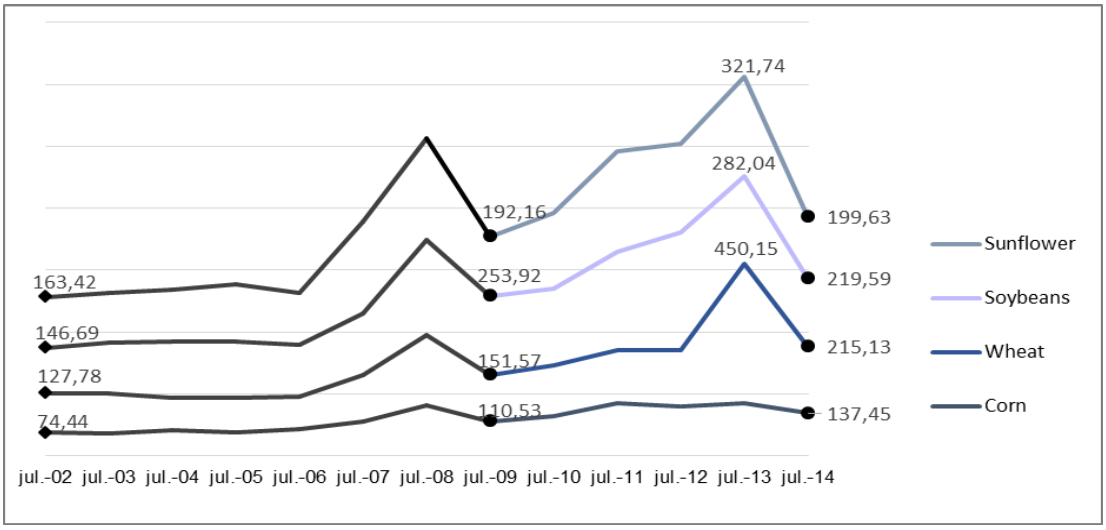
Source: Authors elaboration

B. Economic Incentives: Changes in Agricultural Profitability

During the initial years of the new regulation Argentina underwent an expansive phase of its agricultural frontier. In part due to important technological changes, but mostly due to favorable international agricultural prices. Figure 2 shows the evolution of prices for the four main exporting crops.

A recent study on agricultural frontier expansion in Argentina and its impact on environment (Viglizzo et al, 2011), explains how this expansion affected natural areas, highlighting that during 2000-2005 the most active advance areas were set in the central and northeastern region of the country where we can find an important concentration of native forest. Favorable agricultural prices and low compensation for conserving forests are factors added to weak law enforcement and control, and may motivate illegal deforestation as a rational decision considering the expected benefits.

Figure 2. Grain Prices in Argentina (current dollars / ton).



Source: Own elaboration based on data from Dirección de Información Agrícola y Forestal – Ministry of Agriculture, Argentina.

III. LITERATURE REVIEW: FOREST FIRES AND ECONOMIC INCENTIVES

The first studies which look for evidence on the correlation between intentionally set fires and economic variables were carried out by the insurance industry. In this context, Hershbarger and Miller (1978) made a key contribution with their study "The Impact of Economic Conditions on the Incidence of Arson". The authors analyzed the relationship between a group of economic indicators and losses due to intentionally set fires. They found a statistically significant relationship to explain some of the losses.

Some recent studies extended the analysis, specifically on intentionally set forest fires. Initially, there were studies that modelled the occurrence of forest fires according to the kind of land use, incorporating economic variables to evaluate if the fires were motivated by profits (Martinez, Chuvieco and Martin, 2004; Prestemon and Butry, 2005; Arima et al, 2007).

Michetti and Pinar (2003) use panel data econometric techniques to study causes of forest fire frequency and intensity in Italy. The authors define three geographical areas to control specific characteristics and they confirm differences among fire patterns in different regions. For example, in the south of Italy, the existence of illegal organizations correlates significantly with the number of forest fires.

In recent years, there have been several studies on economic incentives related to intentionally set fires in native forests. But, in general, emphasis was focused on finding a variable which would confirm the existence of intention in the setting of the fire and not only in economic incentives (Arima et al, 2007; Dogandjieva, 2008; Mothershead, 2012).

The conceptual approach presented in this paper follows the analysis proposed by Dogandjieva (2008). This author uses an economic model of criminal behavior to examine the relationship between land, grains, wood price and native forest fires incidence in the south of Europe. This author evaluated fire intentionality from a specific variable related to law enforcement. The author finds evidence of a relationship between economic incentives and forest fires, but he could not confirm that the fires had been intentional as from the variable used.

In Latin America Arima et al (2007), where they estimate the probability of agricultural and forest fire in the Amazonia, Brazil. The main conclusions of this study were first, that the increase in meat and soybean prices, together with roads paving, had a positive impact on forest fire ocurrence; second, that the creation of protected areas in some way reverted the impact, therefore reducing the possibility of fires to occur.

Finally, there are some studies examining the negative effects generated by policies. For example, inappropriate environmental control policies which lead to misrepresentation in individual incentives structure and impact on forest fire incidence. Pazienza y Beraldo (2004) analyzed the impact of a forest law on forest fires frequency variation in the south of Italy. They concluded that environment policies related to forest fire emergency management motivated unemployed people to carry out native forest intentional burning. This happened because they expected to be employed as firemen to fight fire (as it is so established by law).

IV. THEORETICAL FRAMEWORK

A. The Economics of Crime

The model developed by Gary Becker (1968) becomes the standard conceptual framework to analyze criminal behavior in economics. According to Becker’s model, rational choice results from maximizing individual utility and considers the criminal as a rational profit-maximizing individual who will only commit a crime (set off a fire) if the expected marginal utility is greater than zero. For criminal activities the agent faces uncertainty about the net profit derived from his actions, therefore the individual maximizes an expected utility function. The model assumes that an individual commits a crime only if its expected net benefits exceeds the benefit from using his time and other resources in an alternative activity. Formally, the expected utility of committing a crime for an individual is expressed as follows:

$$E(U_j) = p_j * U_j(y_j - f_j) + (1 - p_j) * U_j(y_j) \quad (1)$$

Where y_j represents the income obtained from the crime, p_j represents the probability of being caught and going to prison, f_j represents the punishment (equivalent in monetary terms) in case he is caught.

By taking partial derivatives with respect to the exogenous variables p_j and f_j we can predict individual behavior. Increasing the probability of being caught will diminish marginally the benefit and consequently, incentives for committing the crime will also be reduced. The analysis can be performed to a punishment increase:

$$\frac{dE(U_j)}{dp_j} = U_j(y_j - f_j) - U_j(f_j) < 0 \quad (2)$$

$$\frac{dE(U_j)}{df_j} = p_j * U'_j(y_j - f_j) < 0 \quad (3)$$

This way we can also expect that an increase in illegal activity income will also increase the expected utility of crime making it more attractive.

From this framework it is possible to propose a *crime supply equation* (O_j) that is function of the exogenous variables: *probability of being caught*, *punishment and income derived from the illegal activity*.

$$O_j = (p_j, f_j, y_j, u_j) \quad (4)$$

The variable u_j represents all the other factors which can influence an individual's decision to commit a crime. Changes in the exogenous variables affect expected benefit of committing a crime and the choice between legal and illegal activities. Variables f_j and p_j may be grouped in only one variable fp_j, which represents probability of being arrested as well as the punishment for committing the crime for individual j.

In our case, the *income* variable (y) is the potential profit from forest arson and it depends on several factors: land prices, the price of agricultural products, etc. An individual will set a forest fire to deforest if the expected benefit of this action is positive and greater than the benefit of conserving the natural forest o changing land use in a legal way.

This model allows us to explain general behavior during stages I and III (pre, and post NF Act). However, for the transition stage II it is necessary to consider the potential consequences of the forest arson over the future site categorization. In stage II, it must be considered that crime can also be motivated by future potential profits, since fire can increase the probability for the land to be excluded from extreme regulations in the future. Stage II is different from the others because it must be considered that the individual, through the forest arson, can influence NFTP process and making the lands not to be categorized as a yellow or red area. Therefore, incentives change for individuals according to the stage and the area where the land is. In the next section, we will describe the decision process for a landowner in each stage following the Becker's model and incorporating benefits derived from the potential influencing on regulations.

B. Individual Decision Process

Individuals must choose whether to: a) set a forest on fire intentionally (simulating an accident or natural causes) to modify forest land use and turn it into agricultural land b) request for permission to do it legally, or c) conserve NF. According to the defined stages, we present the different cases where a forest arson is optimal for a representative agent.

STAGE I: the individual compares benefits for replacing NF legally (using a deforesting permit)[1] or illegally (arson) by an economic activity (agriculture or livestock farming) as opposed to conserving the forest.

To cause an intentional fire the following condition must hold:

$$E(U_J) = p_j U_j\left(R_{aj} - f_j\right) + (1 - p_j)U_j(R_{aj}) \geq U_j(R_{aj} - C_{Lj}) \geq U_j(R_{Fj}) \qquad (5)$$

Where R_{aj} is the farm income obtained if forest land is replaced by agricultural land, C_{Lj} is the legal cost of land use change and R_{Fj} is the forest income obtained from conserving the forest. The first part of the condition (5) represents the expected benefit of illegal forest area replacement, the second part represents the expected benefit of legally changing land use, and the last part specifies NF conservation benefit. The other variables maintain the definition corresponding to the model presented in the above section.

STAGE II: the agent evaluates the expected benefit of intentionally setting fire to NF to influence NF categorization, trying to change the actual cover of the land to leave the area out of the future process of NFTP.

[1] During this period there is no legal categorization for forest land according to conservation degree.

In this phase before NFTP, we consider not only the actual benefits and costs of committing a crime, but also the future potential income in case the land is successfully excluded from NFTP.

To decide to replace NF by an agricultural activity, the forgone income of agricultural land must be higher than the discounted income of forest land.

$$R_{aj_{t=2}} + R_{aj} \sum_{t=3}^{\infty} \delta_t \geq R_{Fj_{t=2}} + R_{Fj} \sum_{t=3}^{\infty} \delta_t \qquad (6)$$

This condition compares the present profits (stage II) plus the discounted profits from periods after NFTP (where δ is the discount factor and *r* is the discount rate). To simplify, we assume that the income and the discount factor are constant over time, therefore income flows can be expressed as a perpetuity and condition (6) is:

$$\frac{R_{aj}}{r} \geq + \frac{R_{Fj}}{r} \qquad (7)$$

During this stage the landowner is obliged to conserve NF in their original natural state, until the province enacts the NFTP. In other words, land use for agricultural production is not a legal alternative.

The forest arson is an economic alternative if the following condition is met[2]:

$$E(Ui_j) = p_j \left[q' U_j\left(\frac{R_{aj}}{r} - f_j\right) + (1-q')U_j\left(\frac{R_{Fj}}{r} - f_j + S\right)\right] + (1-p_j)\left[q' U_j\left(\frac{R_{aj}}{r}\right) + (1-q')U_j\left(\frac{R_{Fj}}{r} + S\right)\right] \geq E(Uni_j) = qU_j\left(\frac{R_{aj}}{r}\right) + (1-q)U_j\left(\frac{R_{Fj}}{r} + S\right) \qquad (8)$$

Where q represents the subjective probability assigned for the area to be classified as green category according to NFTP, 1-q is the probability for land to be categorized as yellow or red. The q' represents the probability for converting forest land into agricultural land during stage II after a forest arson[3], and so excluding the land from NFTP process. And, 1-q represents the probability for the land to be categorized as yellow or red despite land use change (in this case the individual behavior does not influence the regulation).

The bigger the difference between the probability of excluding the land from regulation, relative to the probability of getting green category according to regulations, (Δ= q'- q), the more incentives the individual will have to commit the crime during the transition phase.

[2] See an illustration of the sequential decision process in the Appendix.
[3] It is assumed that q' is independent of the chance of being caught (p). That is to say, being caught committing arson does not affect land categorization probability.

Therefore, to obtain a net profit from committing the crime, the probability to "influence" the NFTP and succeed in turning forest land into agricultural land, must be higher than the probability of obtaining category III according to NF Act ($q'_j > q_j$). Thus, in this stage, crime is also motivated by the possibility of modifying endogenously the regulations to realize benefits in the future.

STAGE III: This stage is like stage I, with the only difference that land categorization is already decided, and landowners have the right to apply for a payment for conserving the NF according to the law.

Once the process is finished, the category designated to the specific area determines the potential land use. In this phase, individuals analyze costs and benefits associated to the category assigned to the land, as well as the probability of being caught if he commits forest arson. Two scenarios are possible here:

a) red or yellow categorization, which implies NF conservation and restrictions in land use:

$$E(U_J) = p_j U_j\left(R_{aj} - f_j\right) + (1 - p_j)U_j(R_{aj}) \geq U_j(R_{Fj} + S) \quad (9)$$

b) green categorization, under which permission for changing land use of NF into agricultural use can be asked for.

$$E(U_J) = p_j U_j\left(R_{aj} - f_j\right) + (1 - p_j)U_j(R_{aj}) \geq U_j(R_{aj} - C_{Lj}) \geq U_j(R_{Fj} + S) \quad (10)$$

Finally, considering these different economic conditions we propose a supply function of forest fires for each stage defined as a continuous function which arises from adding individual decisions. With this conceptual framework derived from Becker's basic model and following the conceptual proposition presented by Dogandjieva (2008), the *forest fire supply* may be defined as follows:

$$FF = f(y_j, fp_j, u_j) \quad (11)$$

Where FF represents the dependent variable *number of forest fires*, y_j represents income, fp_j represents costs and u_j contains other components which can explain natural fires and intentionally set forest fires.

V. DATA AND PRELIMINARY ANALYSIS

The dependent variable of interest is the number of forest fires observed in province *i* in year *t*[4] and we consider that is the relevant variable for modelling the representative agent behavior. An alternative variable can be the area affected by fires, but it does not only depend on an individual decision, but also on different natural factors which cannot be controlled by the agent that starts the forest fire (Dogandjieva, 2008; Michetti and Pinar, 2013).

Below, we present a descriptive analysis of the number of forest fires in Argentina in the 22[5] provinces included in the study. This variable is expressed in number of fires by province x 100.000 ha^{-1} of forest land in from year 2002 to year 2014[6].

Figures 3 and 4, show a slightly decreasing trend in the total number of forest fires between 2002 and 2014.

The data show that during stages II and III the total number of fires decreased on average from 3.8 in 2009 to 2.2 in 2014. Most part of the total fires are explained by "unknown causes" and "intentional causes", and a relative small number of fires are due to natural causes or negligence. It can be noted that the "negligence" cause for fires represented on average 27% until 2009, decreasing to 8% in 2014.

Even though it is complex to identify the real causes of this kind of events and the origin of changes, the decrease in the number of negligent fires is consistent with the information provided by the Federal System of Fire Management, which has been in force for more than 10 years[7].

The high percentage of fires due to unknown causes suggest that it is complex to identify the causes of this kind of events. This lack of information is part of the motivation for this study, since we suspect that unknown reasons can include disguised intentionally caused fires. Therefore, we use the total number of forest fires irrespective of their specific reported causes as dependent variable of interest.

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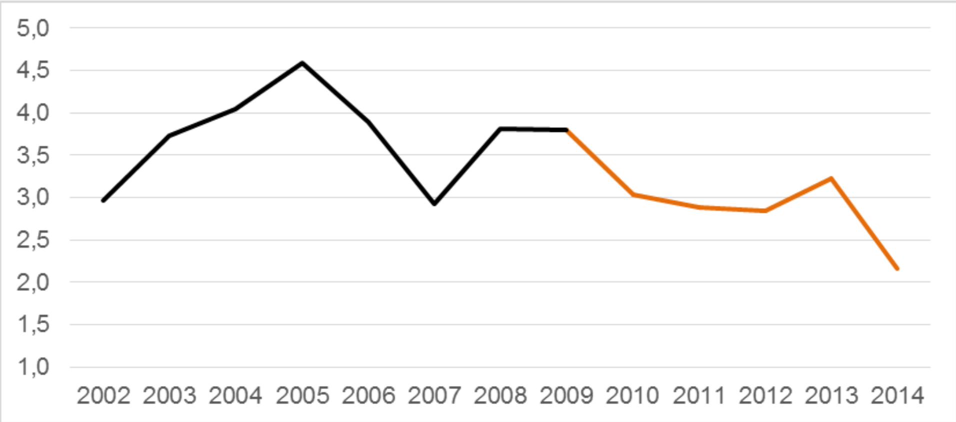
[4] Data source on forest fires is from the Argentina Forest Department. According to the definition a forest fire is every fire which spreads out of control over an area which was not supposed to burn; this area includes four types of vegetation: native forests, cultivated forests, pasture forests and shrub forests.

[5] The Federal District and Buenos Aires province were not included in the analysis. Buenos Aires was not included since NFTP has not been finished and NF area in this province is too small.

[6] The total area of forest land per province is based in estimates for year 2001. Data on the existing area between 1998 and 2001 is available from the first inventory on Natural Forests in Argentina. There is no available and updated information for the following years.

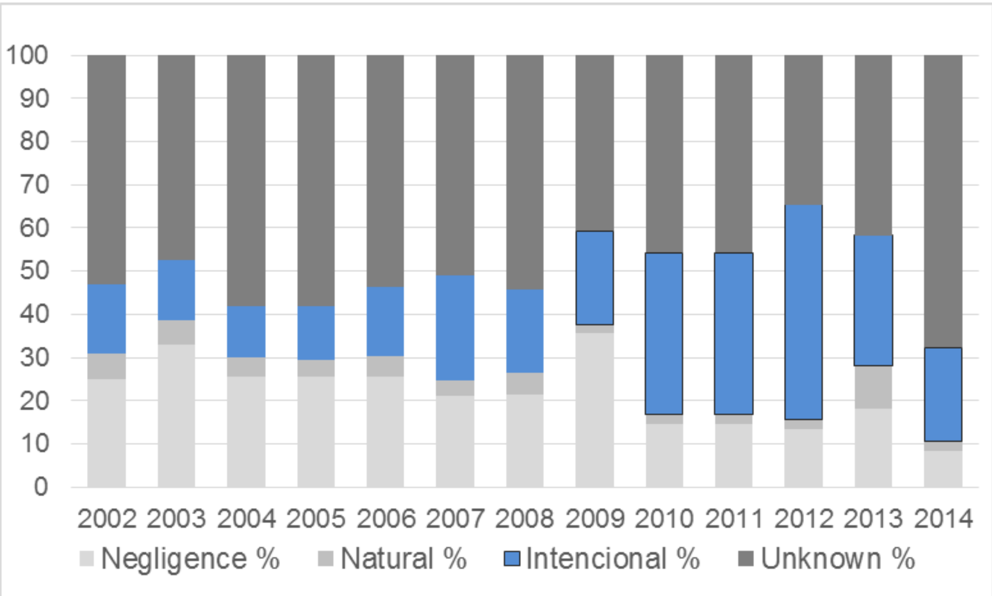
[7] One of the goals of this system is to make people aware of the impact of fire use, trying to induce a change in harmful actions for the environment.

Figure 3. Annual number of fires per 100,000ha of forest land in 22 provinces of Argentina. Years 2002-2014.



Source: authors own elaboration from the Forest Fires statistics published by the Secretariat of Environment and Development of Argentina.

Figure 4. Causes of forest fires in Argentina 2002-2014.

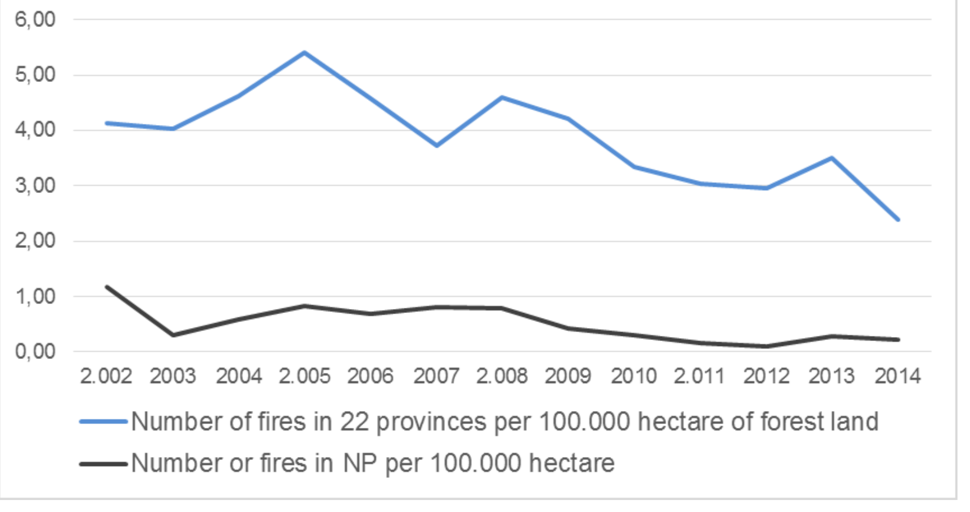


Source: authors own elaboration from the Forest Fires statistics published by the Secretariat of Environment and Development of Argentina.

In the original database it is possible to identify the forest fires occurred within National Parks. The identification of fires which occurred within National Parks allows us, first, to exclude these fires from the data used for the econometric estimations. Second, we were able to use this National Parks forest fire information to generate a control group suitable to be compared with other forest lands where economic incentives are relevant[8].

As a descriptive result, Figure 5 show that there is approximately 1 fire a year for every 100.000 ha. in National Parks lands compared to 4 fires a year for every 100.000 ha in the rest of forest lands. This can be taken as partial evidence that human activity and economic incentives have a significant impact on the number of fires which take place in forest areas.

Figure 5. Forest Fires Inside and Outside National Parks



Source: authors own elaboration from the Forest Fires statistics published by the Secretariat of Environment and Development of Argentina.

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Table 1 presents the average number of forest fires by stage of implementation of the NF Act and the result of a simple F test for difference in means.

Table 1. Average number of Forest Fires per Stage

		Nº of forest fires x 100.000 ha^{-1}
Stage I	t=1	4,58
Stage II	t=2	2,29
Stage III	t=3	2,85
F statistic		14,27
p-value		0

[8] It is probable that in this kind of lands there would not be economic incentives related to intentional fires since its productive use is almost forbidden even in the case of accidental deforestation.

Simple comparison of the average number of fires suggests a decrease in the number of fires after NF Act implementation. The F test result rejects the null hypothesis and we can assume that at least one of the means is different. Therefore, according to this non-conditional evidence, the average number of fires seems to decrease after the NF Act enforcement. The following section presents the econometric estimations where different results are obtained.

I. ECONOMETRIC SPECIFICATION

A. Model and variables

The *forest fires function* (FF) to be estimated is:

$$FF_{it} = f(NFAct_{it}, Prices_t, Stock_{it}, UE_{it}, LE_{it}, GDPgr_{it}, Precip_{it}, Temp_{it}) \quad (12)$$

Where FF_{it} is the dependent variable that represents forest fires, measured as the number of forest fires per 100.000 ha^{-1} of native forest in province i, in year t. We intend to capture the potential impact of the institutional change introduced by the law on the number of intentional forest fires. Our explanatory variable of interest is the variable *NFAct* that assumes value of 1 if the NF Act is in force. To estimate differential impacts, depending on the transitional time window, we incorporated binary variables which identify stages II and III defined in the section on institutions.

We include a set of additional variables to control for economic and weather conditions that can affect the occurrence of forest fires other than the NF Act. To identify the relevant control variables, we follow the existing literature that analyzes economic incentives and forest fires in several regions and countries[9]. In general proxy variables accounting for economic incentives and weather conditions may differ and they must be adapted to data availability.

We use the following set of control variables[10]:

a) Economic incentives variables selected to explain the potential income that would be obtained from ***intentional fires:***

   Index of crop *prices* (Prices) which consider the evolution of prices of the four main agricultural crops in Argentina (wheat, corn, soybeans and sunflower).

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[9] In chart A2 of the appendix we present the variables generally used in literature and the expected signs according to the correlation to forest fire dependent variable compiled by Michetti and Pinar (2003)
[10] For further details on variables and sources see the appendix.

Cattle stock (*Stock*), represents beef cattle stock measured in heads.

Unemployment rate (*UE*) as a proxy to capture the relationship between insufficient economic opportunities, lower income and greater chances to undertake illegal activities which have an impact on natural resources (forest fires).

Geographical Domestic Product growth rate (GDPgr), to control for provincial business cycles.

LE (law enforcement) represents the potential cost of committing crime. Two proxies for law enforcement were included, the number of prosecuted and the number of convicts for crimes by province.

b) Weather variables to control for ***natural causes***:

Rainfall (*Precip*), measured in mm/year per province

Temperature (*Temp*), two measures of temperature where considered. First, the maximum temperature observed in year t in each province (*TempMax*) and, second, the number of days in a year with temperature over 80°F in each province (*Temp80*).

The econometric specification for equation (12) is:

$$FF_{it} = \beta NFAct_{it} + \sum_{j=1}^{J} \gamma_j x_{jit} + \sum_{k=1}^{K} \gamma_k w_{kit} + \eta_i + \varepsilon_{it} \quad (13)$$ [11]

This specification represents a standard panel where the dependent variable number of forest fires (FF) for province i =1, ..., N in year t = 1, ..., T is a function of the institutional variable *NFAct*, a set of economic controls at the provincial level (x_{ijt}), a set of weather controls at the provincial level (w_{kit}), and a specific effect per province η_i. The term ε_{it} is a random error assumed to be independently and identically distributed. We control the specific effects using the panel data fixed effects (FE) estimator.

The coefficient β associated to the binary variable *NFAct* intend to capture the effect on forest fires of the stage II in the time window of the law implementation. Specifically, it assumes value equal one in years were the National Act suspended deforestation of native forests until provincial NFTP enactment. We assume that the institutional variable *NFAct*, is strictly exogenous.

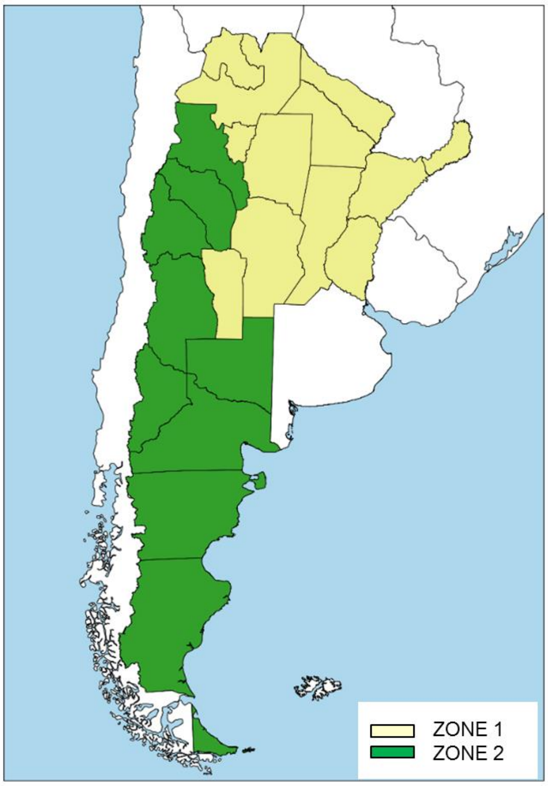
[11] J= regulatory decree (2009).

B. Results

We estimate different models which differ in the control variables included. First, Model I, is a basic specification that includes only the dummy variable which represents the transitional time window (stage II) without control variables. Afterwards in Models II and III, control variables related to economic incentives, socioeconomic and climatic conditions are incorporated. The difference between model II and III is that the last excludes the variable *Prices*, with the intention to keep a greater number of observations in the panel[12].

Finally, in model IV an additional dummy variable (*NFTP*) is included. This variable takes value one after *NFTP* (provincial territorial planning) is in force in each province. This variable detects possible incremental impacts of the provincial institutional change, related to increased controls and law enforcement, on the number of fires in stage III.

Figure 6. Zones



Source: Authors elaboration

[12] The exclusion of certain provinces results from the fact that they do not grow any of the crops included in the price index.

For each model, three estimates were performed according to the region considered, first a full sample which includes 22 provinces, and second a partition of the sample in two zones: 1) Crop Zone (CZ) and 2) the Rest of the Country (ROC) (see map in Figure 6).

Splitting of the total sample in two separate zones allows us to evaluate if the proposed "anticipation effect" happened in all the country, or if it only took place in provinces where competition between agricultural production and native forest conservation is relevant. Zones were defined considering the relevance of crops in the agricultural production. We define a "*Crop Zone" (CZ)* that includes the main grain producer provinces: Chaco, Corrientes, Cordoba, Entre Rios, Formosa, Jujuy, Misiones, Salta, Santa Fe, San Luis, Santiago del Estero and Tucuman. The rest of the country includes the following provinces that are more oriented to a variety of agricultural products, other than grain crops: Catamarca, Chubut, La Pampa, La Rioja, Mendoza, Neuquén, San Juan, Santa Cruz, Rio Negro and Tierra del Fuego.

Table 2 presents the mean values of the dependent and independent variables, by stage and Zone. Zone 1 represents provinces considered in the crop zone (CZ) and Zone 2 corresponds to the rest of the country (ROC). We can observe that, though in average there are no signs of relevant changes in climatic variables, there is a significant increase in the mean values of economic variables and, specially, in the number of fires in the CZ. But, we can remark that there is not an increase in the average number of forest fires in the rest of the country.

Table 2. Mean values of variables by stage and zone

Variable	**Stage I**		**Stage II**		**Stage III**	
	Zone 1	***Zone 2***	***Zone 1***	***Zone 2***	***Zone 1***	***Zone 2***
FF	4,51	4,07	11,45	3,19	3,33	2,92
Tempmax	29,72	29,85	30,60	30,43	31,04	29,72
Temp80	95,27	92,03	104,07	100,50	98,45	84,87
Precip	4,17	1,29	4,19	1,75	4,36	0,94
Prices	480,95	473,49	923,27	767,61	1149,63	1240,00
Stock	2659026	764444	3685390	535339	2049278	444181
GDPgr	0,13	0,17	0,05	-0,02	0,07	0,09
LEprosecuted	0,56	0,87	0,52	0,89	0,69	1,01
LEconvicts	0,51	0,55	0,36	0,42	0,48	0,45
UE	0,08	0,07	0,07	0,06	0,05	0,05

Table 3 presents the estimates of the basic model that includes only the NFAct dummy as explanatory variable. Estimates show that the coefficient associated to dummy variable NFAct is positive and statistically significant in the full sample and in the CZ estimation. This shows that during this specific time window, forest fires increased compared to previous and post stages. This result can be considered an evidence in favor for the hypothesis of a transitory increase of intentional fires, that were induced to avoid the restrictions imposed by NF Act after NFTP. In other words, there is some evidence of an "anticipation effect" during the time between year 2009 and the provincial law enactment. Our conjecture is that this effect could be motivated by the possibility of being able to affect the final NFTP. The forest arson increases the probability of excluding the burned forest from the regulation reach, and then use the land for agricultural production in the future.

Table 3. Forest Fires - Model I (Dependent variable: FF)

Variable	**Full Sample**	**Zone 1**	**Zone 2**
NF Act	2.559**	4.397**	.408
	(1.001)	(1.768)	(.581)
Constant	3.914***	4.226***	3.523***
	(.344)	(.607)	(.200)
Observations	286	156	130
Provinces	22	12	10
Estimation Method	Fixed Effects		

Notes: Standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

As expected, in the main grain production area the estimated coefficient of the dummy variable *NFAct*, presents the higher positive value. On the other hand, it is not possible to confirm an adverse effect of NF Act during transition phase in the rest of the country. As no evidence was found about law impact in the rest of the country, further analysis concentrates in the full sample, and in the CZ results.

Table 4. Forest Fires - Models II and IV ((Dependent variable: FF)

Variable	Model II		Model IV	
	Full Sample	Zone 1	Full Sample	Zone 1
NF Act	6.289**	7.056**	4.563**	6.475**
	(2.800)	(3.209)	(2.204)	(3.147)
NFTP	-	-	-.550	-.524
			(1.770)	(2.603)
Precip	-.114	-.682	-.785	-.690
	(.096)	(.970)	(.577)	(.860)
TempMax	-.841	.403	-.276	-.524
	(.819)	(2.041)	(.938)	(2.603)
Temp80	-.113	-.130	-.057	-.120
	(1.670)	(.109)	(.062)	(.103)
GDPgr	5.974	6.860	3.874	5.120
	(9.329)	(10.654)	(6.181)	(9.207)
UE	29.762	50.048	19.935	53.801
	(64.285)	(74.817)	(39.443)	(60.660)
Prices	-.904	-1.207	-	-
	(2.874)	(3.231)		
Stock	5.379	11.514	4.616	10.405
	(7.948)	(10.714)	(4.915)	(9.769)
LEprosecuted	-.329	-.986	.073	-.810
	(1.988)	(2.339)	(1.633)	(2.269)
LEconvicts	2.211	1.768	1.542	1.997
	(7.059)	(8.245)	(4.954)	(7.657)
Constant	-52.553	-152.850	-45.701	-141.906
	(146.7)	(191.811)	(77.629)	(170.828)
Observations	105	90	150	99
Provinces	12	10	16	10
Estimation Method	Fixed Effects			

Notes: Standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 4 presents the results of models II and IV that include economic and weather control variables[13]. The full sample estimate for model II does not include the following provinces: Chubut, La Rioja, Mendoza, Neuquén, Rio Negro, Salta, San Juan, Santa Cruz, Santiago del Estero and Tierra del Fuego[14], while estimates for agricultural Zone do not include Salta and Santiago del Estero.

Model II estimates, show that the dummy variable *NFAct* is still positive and statistically significant. Model IV incorporates the dummy variable *NFTP* and excludes the control variable *Prices*[15]. In both estimates, the full sample of provinces and the CZ, the dummy variable *NFTP* which captures the impact of regulation enforcement at provincial level (stage III) does not show statistical significance. This would indicate that there is no evidence of impact on forest fires after the final law enforcement at a local level, as compared to previous periods[16].

The full sample coefficient estimates for the dummy variable NFAct in models II an IV, shows a quantitative effect of 6.3 and 4.6 additional fires during the stage II. If we consider that the average annual fires per 100.000 ha of forest land from 2002 to 2014 was 4.23 annual fires, we can conclude that there was a significant quantitative increase in the number of forest fires (some100% to 200%) during the transition phase. As expected, in the agricultural Zone, the quantitative effect is larger than the full sample, with coefficients in the order of 6.5 to 7.0

Figure 7 shows a simplified representation of the impact on the number of forest fires during transition period. During the stage II the number of forest fires increases, relative to the average in stages I and III. According to our estimates the cyclical pattern is similar, but different in magnitude, for all sample specifications: number of forest fires increases during the transition period and returns to the mean after the NFTP implementation by the provinces.

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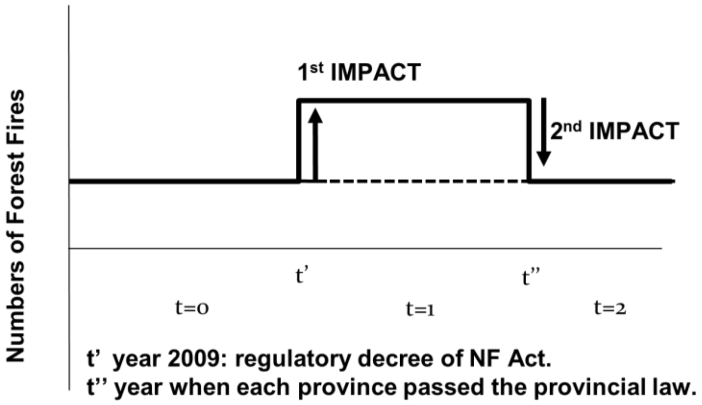
[13] Model III is presented in Table A3 in the appendix. Results are very similar to model II.

[14] Exclusion is due to missing data or, in the case of variable *Prices*, due to the absence of agricultural crop production in some provinces.

[15] The sample excludes the following provinces: La Rioja, Salta, San Juan, Santa Cruz, Santiago del Estero and Tierra del Fuego.

[16] Estimates were performed also by pooled OLS and Random Effects. Results preserve sign, significance and similar magnitude.

Figure 7. The NF Act impact



Source: Authors elaboration

This impact can be related to an adjustment in individual behavior caused by the changes in the institutional environment: economic agents anticipates future deforesting restrictions and decide, by forest arson, to avoid regulations and clear land which can have potential agricultural use. Also, it is possible to associate these actions to an intent of affecting the NFTP process. Indeed, the objective of the forest arson could be the increase in the exclusion´s probability of the burned site from the two greater conservation categories (red and yellow) that limit the agricultural land use in the NF Act. Therefore, the forest arson could have an impact over the regulation process influencing the categories assigned by the NFTP.

C. Robustness check: Difference-in-Differences Approach

In previous estimates the effect caused by NF Act on forest fires was statistically significant in the agricultural Zone but not in the rest of the country. Since information for pre- and post-intervention outcomes is available, in this section we use a difference-in-differences approach taking the area were the agricultural activity is not predominant as control group and the agricultural Zone as the treatment group. This approach assumes that NF Act enforcement has no impact in the rest of the country because restrictions established by the regulation are not operative in the provinces which belong to this Zone. To support this proposition, we note that: a) agricultural activities which had attractive prices during NF Act enforcement are not developed in these areas, b) land capacity differs from predominantly agricultural regions, they are generally arid and semiarid, and finally, c) the forest mass in this region is significantly smaller than forest mass in the Agricultural Region which includes *Parque*

Chaqueño, the *Selva Tucumano Boliviana*, the *Selva Misionera* and a great part of the *Espinal*.

The difference-in-differences methodology is widely used when treatment was not randomly assigned since the method allows to control for time-invariant unobservable heterogeneity. The difference-in-differences approach compares the trend in the outcome of interest for the treated group to the trend of the control group (i.e. the control group's trend is used as a counterfactual).

Formally, the difference-in-differences approach estimates the following regression model:

$$FF_{it} = \alpha_i + \beta T_{it} + \sum_{j=1}^{J} \gamma_j x_{jit} + \sum_{k=1}^{K} \gamma_k w_{kt} + \eta_t + \varepsilon_{it} \quad (14)$$

where FF_{it} is the outcome variable (number of forest fires per 100.000 ha^{-1}) of province i at time t, T_{it} is a dummy variable that is equal to one if province i is treated at time t and zero otherwise, α_i is the producer fixed effect, η_t is the time fixed effect common to all provinces, β is the parameter of interest, and ε_{it} is the error term. The vectors of x_{jit} and w_{kit} are economic and weather control variables as in equation (13)

The identification assumption of the difference-in-differences approach is that the trend of the control group is an unbiased estimator of the trend that the treated group would have followed had the intervention not taken place. The common trends assumption cannot be directly tested but, following Galiani et al. (2005), it is possible to test the similarity of the trends before the intervention.

Table 5 reports the estimates of a variation of equation (14) using only pre-treatment periods that includes a linear trend and, instead of the treatment variable, an interaction between the linear trend and a dummy variable that is equal to one if the province is eventually treated (crop Zone) and zero otherwise. Finding a statistically non-significant estimate for the interaction term provides evidence in favor of the parallel trends assumption. As shown in Table 5, we cannot reject the that pre-treatment linear trends are the same for the eventually treated and control provinces, providing confidence on the difference-in-differences assumption. This test confirms the previous evidence for the group of provinces which integrate the rest of the country region there are no evidences of any effect caused by law enforcement on forest fires.

Table 5. Test of pre-treatment trends. (Dependent variable FF)

Variables	Coefficients
Trend	0.51
	(0.82)
Interaction term	0.064
	(0.69)
Observations	67
Provinces	12
R^2	0.11

Notes: Control variables not reported: Precip, TempMax, Temp80, GDPgr, UE, Prices, Stock, LEprosecuted, LEconvicts. Standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

Table 6 presents the main results of the difference-in-differences estimation. The treatment variable is a dummy variable that is equal to one during the years of stage II for each province in the crops Zone and zero otherwise. The economic and weather variables are included as controls in the estimation.

The difference- in-difference coefficient estimate shows a positive impact of the NF Act on forest fires during the stage II. The treated provinces increased the number of forest fires during the implementation phase of the NF Act, and the magnitude of the impact (5.96), is close to the previous estimates presented in Table 3. These results indicate a robust effect on forest fires derived from the changes in the institutional environment and economic incentives after the NF Act enactment.

Table 6. Difference-in-differences model. (Dependent variable: FF)

Variables	Coefficients
Treatment	5.96**
	(2.69)
Observations	116
Provinces	12
R^2	0.08

Notes: Control variables not reported: Precip, TempMax, Temp80, GDPgr, UE, Prices, Stock, LEprosecuted, LEconvicts. Standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

VII. Final Remarks

This paper evaluates the impact of the implementation process of a new law that restricts the deforestation of native forests in Argentina. Our study has two main contributions. First, to the analysis of environmental regulation which can have unexpected negative impacts depending on the implementation strategy. Second, this paper contributes to the empirical literature on forest fires and the study of economic incentives for fire arson.

We propose that the crime of forest arson can be an economic response to the limitations to deforest lands due to the new environmental regulations. We present a conceptual model based in the economic theory of crime to describe the changes in institutions and economic incentives due to the new regulations, and to predict individual behavior.

We then present empirical evidence of systematic effects in the occurrence of forest fires in Argentine provinces as a function of the new regulation and its sequential implementation. We find more forest fires during a transition period, when the NF Act enforcement suspended deforestation of native forests until provincial NFTP enactment. (stage II).

Once we control for the regional specialization, dividing the sample of provinces according to agricultural production, estimates show that the number of forest fires tends to be larger in crop specialized provinces; the number of fires during the transition phase (2009-2011 approximately) in main crop producer provinces increases some 100%-200% relative to the national average. Using an alternative difference-in-differences approach, we confirm a significant increase in forest fires impact for the crop specialized provinces. This result reinforces the intuition of economic motivation behind the increase in the number of forest fires.

Our results suggest a transitory negative impact of the regulation on the number of forest fires, opposite to the conservation goal stated in the law. The conceptual model and the empirical results suggests that this adverse effect was a consequence both, of the potential benefits of agricultural activities that can be performed in deforested lands, as well as of poor law enforcement which turns arson more attractive.

We conjecture that there was also an important incentive due to the possibility of affecting the final setting of the native forest territorial planning during stage II. During the transition phase there was a low level of local law enforcement, high crop prices and a low economic compensation for forest preservation, practically not perceived by forest land owners. After the implementation of the provincial territorial planning we can presume, first, that the new restrictions and higher provincial law enforcement incremented the costs of committing crimes and reduced the net benefits of arson activities. Second, that the possibility of endogenously modifying regulations to obtain greater future benefits was no longer possible, explaining why in stage III results show a reversal in the number of forest fires.

Regarding institutions and NF Act enforcement, it can be noted that the law guidelines were designed mainly on a national level, with a poor participation of local stakeholders. Ostrom (1990, 2005) notes the importance of considering local conditions and agents' characteristics to obtain sustainable agreements in natural resources management. The number of agents and heterogeneity of interests proved to be serious disadvantages during NF Act formulation and implementation. In general, private actors were not involved in the process, and the low consensus between agents was important as a factor contributing to generate unexpected negative effects, as the described increase in forest fires. Finally, the present study intends to provide evidence about the relationship of forest conservation laws and economic incentives than can be useful for policy design in the field of natural resources.

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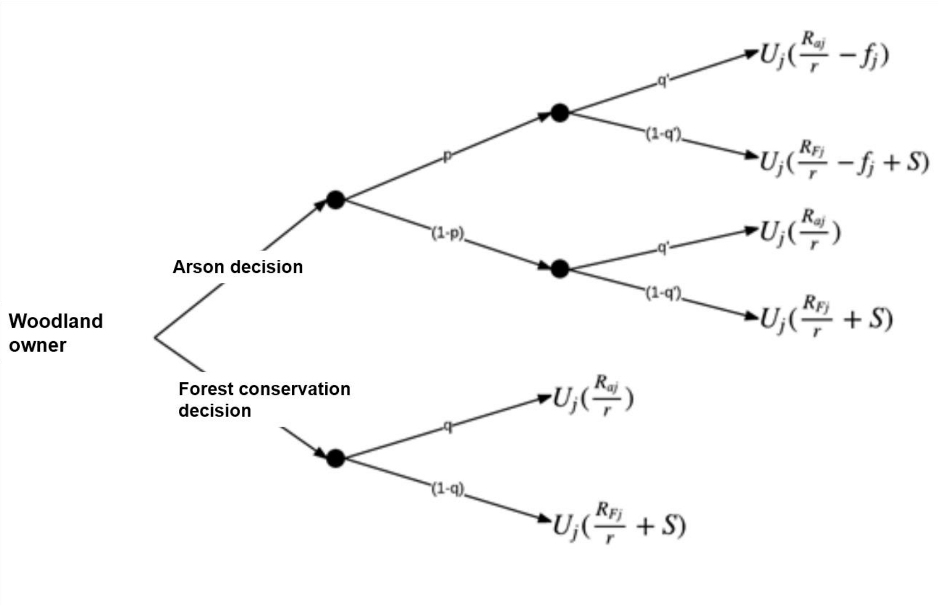
APPENDIX

1. Decision tree Stage II.



A2. Definition of variables and data sources

Variable	Description	Source
Dependent variable **Forest fires (FF)**	Number of annual fires in arbustal, native forest, implanting forest and pasture x 100,000ha^{-1} of forest lands per province.	Estadísticas de incendios forestales. Dirección de Bosques-Secretaría de Ambiente y Desarrollo de la Nación.
Explanatory variables		
NF Act	Binary variable. Equal to 1 from year 2009 until the end of the NFTP in the i-th province, and zero otherwise	Infoleg-Ministerio de Justicia y Derechos Humanos.
NFTP	Binary variable. Equal to 1 from the year that the i-th province enact the NFTP.	Infoleg-Ministerio de Justicia y Derechos Humanos.
Agricultural production (Prices)	Index that weights crop prices (soybean, corn, wheat and sunflower) by cultivated area per province. (natural logarithm) Prices = price sunflower * share S + price soybean * share S + price corn * share C + price wheat * shareW.	Series de *precios agrícolas* publicada por la Asociación Argentina de Consorcios Regionales de Experimentación Agrícola en base a datos disponibles en Dirección de Información Agrícola y Forestal-Minagri.
Beef Cattle Stock (stock)	Cattle stock, in number of heads (natural logarithm)	Agorseries de CREA, en base al Sistema Integrado de Gestión de Sanidad Animal (SIGSA)-SENASA.
Unemplyment (UE)	Unemployment rate	Encuesta Permanentes de Hogares continua (EPH-INDEC.

LE (Law Enforcment)	Bumber of prosecuted LEprosecuted) per thousand inhabitants and number of convicts (LE_convicts) per thousand inhabitants per year in each province.	Sistema Nacional de Estadística sobre Ejecución de la Pena-Dirección Nacional de Política Criminal
Growth rate (GDPgr)	Per capita Geographical Domestic Product annual growth rate by province	Dirección Nacional de Coordinación Fiscal con las Provincias- Ministerio de Hacienda y Finanzas Públicas.
Rainfall (Precip)	Annual average rainfall in millimeters, measured in rainfall days.	Sistema de Información y Gestión Agrometeorológico (SIGA) del Instituto Nacional de tecnología Agropecuaria (INTA)
Temperature (Temp)	• TempMax: annual maximum temperature per province. • Temp80_max: number of days in the year that exceed 80º Fahrenheit (26,66º C)	Sistema de Información y Gestión Agrometeorológico (SIGA) del Instituto Nacional de tecnología Agropecuaria (INTA)

A3. Forest Fires - Model III (Dependent variable: FF)

Variable	**Full Sample**	**Zone 1**	**Zone 2**
Constant	49.357 (76.454)	-145.510 (168.869)	Number of observations insufficient to estimate the model.
NF Act	**4.800**** **(2.060)**	**-**	
NFTP	-	6.681** (2.958)	
Precip	-.807 (.572)	-.718 (.843)	
TempMax	-.326 (.920)	.187 (1.774)	
Temp80	-.058 (.061)	-.122 (.102)	
GDPgr	3.849 (6.158)	5.251 (9.128)	
UE	26.983 (32.145)	60.695 (49.802)	
Stock	-.802 (.572)	10.775 (9.538)	
LEprosecuted	-.056 (1.573)	-.928 (2.179)	
LEconvicts	1.370 (4.905)	2.052 (7.606)	
Observations. / Provinces	150/ 16	99/ 10	
Estimation methods	Fixed Effect		

Notes: Standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.