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Decentralization Effects in Ecological Fiscal Transfers: A Bayesian Structural Time Series Analysis for Portugal

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Abstract Portugal has a unitary system in which the central government transfers funds to lower government levels for their public functions. In 2007, Portugal introduced Ecological Fiscal Transfers (EFT), where municipalities receive transfers for hosting protected areas (PA). We study whether introducing EFT in Portugal incentivized municipalities to designate PA and has led to a decentralization of conservation decisions. We employ a Bayesian structural time series approach to estimate the effect of introducing EFT in comparison to a simulated counterfactual time series. Quantitative results show a significant increase in the ratio of municipal and national PA designations following Portugal's EFT introduction—which we infer to be a causal consequence. The analysis furthermore places emphasis on the importance of relevant municipal conservation competencies for the functioning of the instrument. Results have important implications for conservation policy-making in terms of allocating budgets and competencies in multi-level governments.

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Abbreviations

AR	Autoregressive
CI	Confidence interval
EFT	Ecological Fiscal Transfers
EU	European Union
GDP	Gross domestic product
GMF	General Municipal Fund
ICNF	Instituto da Conservação da Natureza e das Florestas
IUCN	International Union for Conservation of Nature
MCMC	Markov chain Monte Carlo
NGO	Non-governmental organization
PA	Protected area
RNAP	Rede Nacional de Áreas Protegidas
SAC	Special Areas of Conservation
SD	Standard deviation
SPA	Special Protection Areas

1 Introduction

In the face of a rapid biodiversity loss (MEA 2005) and the increasingly recognized importance of ecosystem services for human well-being (MEA 2005; TEEB 2010), the role of public conservation becomes by no means less crucial. Particularly, the designation of protected areas (PA) can be considered an (ecological) public function (Ring 2002). Regarding this context, an innovative instrument has gained attention in recent years: Ecological Fiscal Transfers (EFT) change the redistribution of tax revenue by incorporating ecological indicators, for example, the existence of PA, into the fiscal transfer scheme. EFT have first been introduced in the Brazilian federal state of Paraná in 1992 and subsequently in 17 out of 27 Brazilian states (Vogel 1997; Grieg-Gran 2000; Loureiro 2002; May et al. 2002; Loureiro 2008; Ring 2008b; Droste et al. 2017). Portugal has been the first state to introduce an EFT scheme on a national level in 2007 (Santos et al. 2012, 2015). From a theoretical perspective, EFT schemes have been proposed and simulated for Switzerland (Köllner et al. 2002), India (Kumar and Managi 2009), Indonesia (Mumbunan 2011; Irawan et al. 2014), Germany (Schröter-Schlaack et al. 2014), and France (Borie et al. 2014). In this paper, we study the effects of EFT on the degree of centrality in conservation decisions through a novel implementation of a Bayesian Structural Time Series analysis (Brodersen et al. 2015).

As such, EFT have a range of interesting features (Droste et al. 2017): (i) they may not require additional budget but change the existing fiscal revenue redistribution (Grieg-Gran 2000; May et al. 2002; Ring 2008b); (ii) they can incentivize nature conservation and thereby increase the supply of an underprovided public good (Grieg-Gran 2000; May et al. 2002; Ring 2008b; Droste et al. 2017); (iii) they take local preferences and local knowledge into account since both in Brazil and Portugal they are general purpose transfer and responses are the choice of local decision makers;[1] (iv) transaction costs for the introduction of EFT are relatively low because they constitute a rather marginal change in existing fiscal transfer schemes (Ring 2008b; Vogel 1997); and (v) in the pioneering state of Paraná in Brazil, EFT even include criteria for the quality of PA management in the fiscal transfer scheme which may enhance not just quantity but also quality of conservation areas and measures (Loureiro 2008). Regarding the outcomes of EFT, so far few studies have studied the effect of EFT on the designation of PA econometrically (see for example Sauquet et al. 2014).

Analyzing EFT in Brazil with an econometric panel data approach for 1991–2009, Droste et al. (2017) find evidence that introducing EFT creates an incentive effect for an additional designation of PA. They furthermore find indications for a decentralizing effect in the introduction of EFT since especially municipalities respond by designating additional PA. In general, decentralization provides means to incorporate local needs and preferences in polycentric and multilevel governance systems (Rubinchik-Pessach 2005; Andersson and Ostrom 2008; Faguet 2014). In particular, decentralized conservation decisions can take into account relevant ecosystems that provide goods and benefits mainly to the local level but also conserve local habitat with endemic species and thus contribute to national and global conservation goals (Smith et al. 2009; Butchart et al. 2015). Hence, there are spill-over effects associated with local conservation action which can be internalized through a respective fiscal remuneration (Ring 2008a). Given budgetary constraints for local governments, recognizing such spill-overs can change relative costs of provision and thus induce an incentive for an increased provision of local conservation. Focusing on the decentralization effect of introducing ecological indicators within fiscal transfers systems, we analyze the Portuguese EFT scheme as a case study for the first implementation of EFT that consider local governments' conservation policies within national level fiscal transfer schemes. The Portuguese case may serve as a model for other countries and its effects on municipal PA designations thus embody policy relevance beyond the national scope.

Since 1993 municipalities in Portugal are formally permitted to designate their own PA and in 2008 a reform widened the range of municipal conservation competencies. In this context, we study whether the 2007 introduction of EFT in Portugal has incentivized municipalities to make use of their (enlarged) conservation competencies to designate PA, and in this sense, led to a decentralization of the decisions where to protect nature. Our research question therefore is: *Did the introduction of EFT in Portugal support the decentralization of conservation decisions, namely increase municipal PA designations in relation to national PA designations*? To this end, we employ the means of a Bayesian structural time series approach (Brodersen et al. 2015), which has the benefit of providing an estimated counterfactual time series for Portugal—simulating what would have happened without the intervention of introducing EFT; controlling for the simultaneous shift in nature conservation law. We are the first to assess the effect of a change in a fiscal governance regime on conservation planning outcomes through a Bayesian simulation of a counterfactual time series.[2]

The structure of the paper is as follows: Sect. 2 introduces relevant literature on the theory of decentralization and fiscal federalism in relation to conservation governance; Sect. 3 introduces a theoretical model of conservation decisions; Sect. 4 provides background information on the relevant institutions in Portugal, namely the 2007 reform of the Local Finances Law that introduced the EFT scheme, and the conservation competencies of different

[1] For an analysis of strategic interactions at the local level in the Brazilian state Paraná see Sauquet et al. (2014).

[2] For an application of voter behaviour with web search data see Street et al. (2015).

governments to designate a range of PA categories, including the 2008 reform; Sect. 5 gives the data sources and introduces the Bayesian structural time series approach; Sect. 6 provides the results of our analysis; Sect. 7 gives the outcomes of robustness checks; in Sect. 8 we provide methodological remarks on the quantitative approach; we discuss implications of results in Sect. 9 and conclude briefly in Sect. 10.

2 Literature Review: Decentralization and Conservation

The economic theory of fiscal federalism has its origins in the field of public finance (Musgrave 1959; Oates 1972, 2005). As an early scholar on the subject Hayek (1945) argued that decentralized systems provide informational advantages since local actors have more precise information of the needs, preferences and conditions of their 'immediate surroundings' than a central actor. According to Qian and Weingast (1997) this assumption refers to both consumers and local governments. Another important contribution was provided by Samuelson's theory of pure public goods and public expenditure (Samuelson 1954, 1955). For public goods where consumption is below national scale, say local public goods, local governments are assumed more efficient in providing the locally desirable level of output (Tiebout 1956; Inman and Rubinfeld 1997; Qian and Weingast 1997)—given the absence of economies of scale (Olson 1969). Because local constituencies may have different preferences and opportunity costs a local provision of regionally differentiable public goods maximizes welfare in comparison to a reference scenario of a central government providing an equal output level for all municipalities. Furthermore, the optimal level of provision of (local) public goods is also determined by the distribution of costs and benefits. Matching costs, benefits, and decision-making competencies was called the principle of 'fiscal equivalence', basically stating that for an optimal supply those who benefit from a provision of a public good should also bear the costs of provision, and therefore hold the competencies to decide on it (Olson 1969).

These theoretical models have been generalized into a proposition known as the 'decentralization theorem' (Oates 1972). However, since governmental structures cannot in every case coincide with the spatial coverage of the public good in question, interjurisdictional spillover effects may occur, e.g. by roads or clean rivers (Oates 2005) or species conservation (List et al. 2002). In such cases a fiscal transfer from a more central to a decentral governmental level can internalize such positive spillovers in the sense of a Pigouvian subsidy (Oates 2005, see also Zodrow and Mieszkowski 1986). Furthermore, it has been shown that even in the absence of informational asymmetries and a cheaper provision of particular public goods at a central government, decentralization can be beneficial in terms of welfare since projects of only local importance are realized (Rubinchik-Pessach 2005).

These contributions on optimal allocations of costs and benefits among government levels assume, to a greater or a lesser extent, a welfare maximizing governmental behavior (Brennan and Buchanan 1980; Feld 2014). Thus, at all government levels the respective actors assumingly seek to promote the interest of their people (Oates 2005). Such theory of optimal fiscal revenue allocation has been called the first generation fiscal federalism (Oates 2005). Since the assumption of a welfare maximizing government might not always be fulfilled, a second generation fiscal federalism has been developed in order to analyze the 'black box' of governmental behavior (Qian and Weingast 1997). Drawing upon the theory of the firm (Coase 1937), its updates, and public choice theory, Qian and Weingast (1997) develop a theory of how governmental actors react upon institutional incentives and informational constraints.

Oates (2005) extends the second generation theory of fiscal federalism to budget constraints, risk-sharing insurances and self-enforcing mechanisms in intergovernmental settings. Latest works include analyses of incentives and (de-)centralization tendencies (Weingast 2009, 2014), decentral governance quality in general (Faguet 2014), and in particular, the responsiveness of government spending to local needs (Faguet 2004; Borge et al. 2014). Local municipal actor involvement in national policy formulation has been analyzed regarding corresponding effects on successful implementation of those policies (Terman and Feiock 2014), and in terms of causal relations of municipal spending and taxing behaviors to either locality bound micro incentives or institutional macro-level structures (Smith and Revell 2016).

Observations of state-federal conflicts regarding environmental public functions have led to a general analysis and comparison of command and control, taxes and tradeable permits (Williams 2012). Boadway and Tremblay (2012) identify environmental federalism and the governance of natural resource as unsolved challenges for future research and particularly name the organization of regulatory competencies, intergovernmental fiscal relations and incentive structures within multi-level governments as knowledge gaps. In this context, urban conservation behavior under budget constraints and the fiscal implications have been modeled from a micro-economic perspective (Wu 2014) but without considering a multi-level structure.

We draw upon this body of literature, study municipal behavioral responses to fiscal incentives within multi-level government structures, and extend it into the direction of the provision of those public goods that are eminently supplied by protected areas (PA)—such as biodiversity conservation (Ring 2002; Perrings and Gadgil 2003; Ring 2008a). PA are mostly designated at higher levels of government but management and opportunity costs related to these areas mostly occur at local levels. EFT compensate for foregone income, thus lower opportunity costs of hosting PA for local jurisdictions and potentially incentivize PA designations. Our argument is thus twofold. Firstly, EFT may compensate for management and/or opportunity costs at the local level that are incurred through the realization of (supra-) national conservation interests. Secondly, EFT may create an incentive for the designation of decentral PA through a change in conservation costs by a per area transfer for PA. This two-sided argument reads as follows.

On the one hand, there are national conservation interests, such as providing a high connectivity habitat network across the nation or the protection of large and nationally important sites through national parks. Furthermore, there even are supra-national interests such as the European Natura 2000 network that ensures a protection of important habitats and species across Europe. For these cases of overarching interests a central planning is better suited than a decentral implementation, since local decision makers are unlikely to consider these (supra-) national interests in their rationale unless fully internalized. Such internalization is difficult to realize since both opportunity and management costs of a habitat network may well differ across sites and regions and would thus require a spatially differentiated scheme in order to fully internalize the overarching interests in local decision making. EFT however, are generally lump-sum transfers that are not regionally differentiated. Through a uniform per area rate they may only (partially) compensate for opportunity costs incurred to the local level. Such a (partial) compensation may nevertheless lower the resistance of local jurisdictions to PA planned and designated at higher levels of government.

On the other hand, most of the benefits from PA are of a regional nature, such as health, recreation and amenity services (Brink et al. 2013). Additionally, there are the positive spillover effects to the state, national and even the global level which originate from those services with a long spatial (and temporal) range such as climate regulation, biodiversity maintenance or water regulation (Brink et al. 2013). We assume that those services may not just be provided by national PA but also by local ones, but spatial spill-over benefits are often not internalized in local decisions. Since costs and also benefits differ among location and conserved habitats, a uniform EFT scheme would not internalize these positive external effects in a targeted manner but still create an incentive to increase decentral provision of PA. The incentive effect lies in the change in the relative prices (see Sect. 3). If, for example, every per cent of a local jurisdictions territory that is put under protection receives a transfer quota, this reduces the price of providing local PA and therefore, likely yields additional local PA. Furthermore, this incentive effect would be greatest where the preferences for a local PA are largest and thus a change towards a positive net gain is most likely.

Considering these two sides of EFT, theoretically they lead to welfare gains by: (a) reducing local costs through compensation for burdens incurred by centrally planned PAs, and (b) better taking into account both local preferences and positive spatial externalities in the designation of smaller scale, local conservation areas.

3 Theoretical Model: Local Public Conservation Decisions

There can be a range of factors ultimately determining local decision maker's conservation spending and regulatory decisions. Starting from a neoclassical textbook definition, local decision makers could be considered as rational actors optimizing pay-offs corresponding to their preferences (or arguments of their utility function). It has been noted that such rationality is bounded by cognitive capacities (Simon 1955), that commitment is a fundamental part of decision making (Sen 1977) and that institutions define actions at least as much as intrinsic motivation (Ostrom 1990; Vatn 2007). Furthermore, local governments are no unitary actor but consist of multiple actors that all have their own agenda beyond the collectively defined one (Olson 1965).

There is, however, no doubt that local governments face budget constraints. Let us consider a situation where a local decision maker has to decide between spending public budget on either conservation policy or some other public good out of all possible ones. The outmost boundary is given by the budget constraint, such that all available money income M is spent on either conservation action X at price p_x or a composite public good Y at price p_y (Eq. 1).

$$M = p_x X + p_y Y \tag{1}$$

Canonically, the optimal choice regarding quantities of X and Y is determined by both relative prices and marginal utilities U'_x and U'_y, such that $\frac{p_x}{p_y} = \frac{U'_x}{U'_y}$. A policy that induces a price change, such a per unit fiscal transfer for PA, say from p_x to p'_x, may lead to a greater quantity of conservation action, ceteris paribus (see Sect. 4 for institutional details). For the sake of simplicity, let us assume that both goods are normal goods, and that there is some degree of substitutability between the two public goods. Then, $\Delta X = X(p'_x, M) - X(p_x, M) > 0$ if $p'_x < p_x$.

From this simplistic model we would thus hypothesize that introducing fiscal transfers for PA leads to an increase in PA, given that PA spending leads to PA designations. There are, however, many more factors that determine the decision making of local government agents including various, right-based considerations, attitudinal beliefs and other intrinsic motivations beyond just monetary considerations (cf. works on factors determining willigness-to-pay for conservation: Kotchen and Reiling 2000; Spash 2006; Ojea and Loureiro 2007; Spash et al. 2009. While such motivations may also alter the degree to which monetary considerations are taken into account in public administration and political conservation decision making, we would nevertheless base our analysis on the following simplifying hypothesis:

Hypothesis 1 If designating PA becomes a source of income for local governments there will be an increase in corresponding conservation action.

4 Institutions: Ecological Fiscal Transfers and Conservation Competencies in Portugal

While Portugal has a unitary government, there are some municipal and regional (fiscal) competencies, regarding e.g. taxation (Costa and Carvalho 2013) or water management (Thiel 2015). In this section we elaborate on the institutional context in Portugal concerning (i) the introduction and functioning of EFT (Sect. 4.1) and (ii) the municipal and regional competencies in nature conservation, focusing on the designation of PA (Sect. 4.2).

4.1 Ecological Fiscal Transfers

The Portuguese EFT were introduced through the Portuguese Local Finances Law (*Lei das Finanas Locais no. 2/2007*) reform in 2007 (Santos et al. 2012). The law establishes new rules for revenue distribution and fiscal transfers from central government funds to the local level, and was reformed again in 2013 but without a change in the EFT component (*Lei no. 73/2013 do regime financeiro das autarquias locais e das entidades intermunicipais*). On average total transfers account for about 44 per cent of total municipal income during 2007–2014 (Direção-Geral das Autarquias Locais 2015) while the rest is levied by municipal taxes on e.g. property, income and business (Santos et al. 2012, see also Costa and Carvalho 2013).

There are three main national funds for disbursement of public revenue among municipalities. The Financial Equilibrium Fund (*Fundo de Equilbrio Financeiro*) is a general grant with a value of 19.5 per cent of the arithmetic mean of income tax, corporate tax, and value added tax revenues (in 2007 it was 25.3 per cent). The Financial Equilibrium Fund is divided into two sub-funds with 50 per cent each, the General Municipal Fund (*Fundo Geral Municipal*) and the Municipal Cohesion Fund (*Fundo de Coeso Municipal*) for fiscal imbalances (Santos et al. 2012; Direção-Geral das Autarquias Locais 2015). Moreover, there also is the Municipal Social Fund (*Fundo Social Municipal*) for expenditures on social public functions such as education, health and welfare. Additionally, a 5 per cent share of the income tax also goes directly to the municipalities (Santos et al. 2012; Direção-Geral das Autarquias Locais 2015). Beyond those national funds, there are also transfers from the European Union to municipalities (Direção-Geral das Autarquias Locais 2015).

With regard to EFT the funds' allocation works the following way. Among other criteria, 5 per cent of the General Municipal Fund (GMF) are allocated in proportion to the area under protection (Natura 2000 and other PA). In case more than 70 per cent of the municipal area is under protection the ecological component portion becomes 10 per cent—which reduces the otherwise 25 per cent of the GMF redistributed according to area to 20 per cent (*Lei no. 2/2007* and *Lei no. 73/2013*). This makes EFT 2.5 to 5 per cent of the Financial Equilibrium Fund. It is important to note, however, that the EFT are general purpose transfers without any earmarking. While the allocation of EFT in Portugal is based on the existence (and expanse) of PA, the municipalities can spend the respective income on whatever public function they

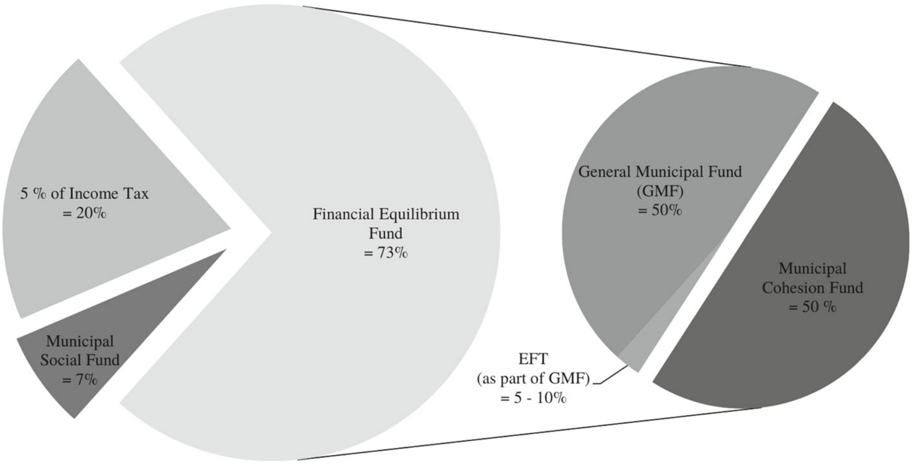

Fig. 1 Fiscal transfer funds and EFT in Portugal. *Source*: authors' elaboration based on data from DireGeral das Autarquias Locais (2015). The left bubble represents the 2015 distribution funds (taxe income varies). The right bubble is defined by law (both general and cohesion fund are always 50 per cent of the equilibrium fund)

consider necessary. Figure 1 gives an overview of the structure of fiscal transfers in general and the EFT in particular.

Analyzing the transfers based on the 2007 reform (Santos et al. 2012, p. 271) compare the reform to a simulated computation that excludes the ecological component. They derive that EFT have an average unit value of 50 €/ha PA for municipalities with more than 70% of PA on their territory and 25 €/ha for those municipalities with less PA. Calculating the EFT proportion of total municipal revenues and fiscal transfers they find a range of 4 to 38% for the group with at least 70% PA and on average less than 8% for the remainder. This is to say, the average EFT unit values are rather small over all but incentives for some municipalities can be quite strong.

4.2 Nature Conservation Competencies

The competencies regarding the designation of PA in Portugal are divided between the national, the local, and the private level. In Table 1 there is an overview of different PA categories per government level. We briefly introduce each in turn.

The European Natura 2000 network site selection is based on lists of ecologically important natural habitats and species, known as Sites of (European) Community Importance (Evans 2012). Based on these lists the Portuguese national authorities decide upon the designation of Special Areas of Conservation (SAC) under the Habitat Directive and the Special Protection Areas (SPA) under the Birds Directive.

The national authorities (i.e. the Environmental Ministry and its agency, the Institute for Nature Conservation and Forests (Instituto da Conservao da Natureza e das Florestas—ICNF) can designate all IUCN (International Union for the Conservation of Nature) PA categories such as national parks, nature parks, nature reserves, protected landscapes areas and nature monuments (*Decreto Lei no. 142/2008*).

The municipalities or regional associations of several municipalities may designate all these PA categories except national parks. It is important to note that while the law decree

Table 1 PA designation competencies and their legal foundation. *Source*: authors' elaboration based on ICNF (2015), see also Santos et al. (2012)

Designating body	PA categories	Legal foundation
National authorities	Special Area of Conservation	EU Habitats Directive
	Special Protection Area	EU Birds Directive
	National Park	Decreto-Lei n.o 19/93
	Nature Park	Decreto-Lei n.o 142/2008
	Nature Reserve	
	Protected Landscape Area	
	Nature Monument	
Regional and local	Nature Park	Decreto-Lei n.o 19/93
municipal authorities	Nature Reserve	Decreto-Lei n.o 142/2008
	Protected Landscape Area	
	Nature Monument	
Private landusers	Private PA	Decreto-Lei n.o 142/2008

19/1993 defined that municipalities and municipal associations can *propose* the designation of only a regional protected landscape area to the ministry, the law decree 142/2008 widened their competencies and authorizes them to directly *designate* all PA categories but a national park. However, out of the eight regional and local PA designated on basis of law decree 142/2008 only three are not protected landscapes areas, meaning there are relatively few responses to the 2008 widening of municipal PA designation competencies regarding the type of designated PA (see Table 3 in the appendix for some detail). In practice, the change from proposing a local PA and designating it at the local level can be considered a fairly slight change since even under the 2008 regime, official recognition of municipal PA designations is subject to Ministerial decision. Furthermore, the 2008 reform allowed explicitly for the designation of private protected areas. So far, there is one private PA (Faia Brava). With the exception of Natura 2000 sites, these protected sites altogether constitute the national network of protected areas (Rede Nacional de reas Protegidas—RNAP).[3]

5 Empirics: Bayesian Structural Time Series Analysis

5.1 Data

Focusing on the PA designated under Portuguese law, we collected data on designated protected areas from the Institute for Nature Conservation and Forests (ICNF) that account for the national network of protected areas but do not include Natura 2000 areas except those parts that are spatially overlapping with the national PA (ICNF 2015), socio-economic controls representing the general structure of the economy such as GDP per capita, population

[3] In this context, it is worth noting, that the Natura 2000 network (including most other PA) covered 18.8 per cent of continental Portugal in 2010, while the RNAP only accounted for 7.9 per cent (INE 2015) and in 2013 Natura 2000 covered 20.7 per cent of entire Portugal (EU 2015) while the RNAP accounted for 8.5 per cent of Portugal (ICNF 2015). This is due to the special nature of Natura 2000 sites which are not necessarily to be designated as PA under national law but managed according to EU law. The EFT mechanism, however, accounts for both Natura 2000 and RNAP sites.

density, value added by the agricultural, industrial, and service sectors from the World Bank (2015), and controls representing conservation preference proxies such as data on members of environmental NGO per 1000 inhabitants, municipal spending and income related to the environment (regarding climate and air quality, waste water treatment, residual waste treatment, water protection, noise reduction, biodiversity and landscape protection, radiation control, research and development and other environmental protection) from the National Statistics Institute (INE 2015). All monetary values are given in constant €2005 prices.[4] This way, we constructed a multivariate time series for Portugal from 1995 to 2014 with yearly observations. Summary statistics and time series of PA data can be found in the appendix, and the compiled raw data and code for reproducing results is provided in a personal github repository at https://github.com/NilsDroste/EFT-PT).

5.2 Econometric Model

Since we want to estimate the effect of the 2007 EFT introduction on the degree of centrality in conservation decisions, measured by the ratio of municipal and national PA designations, we employ a model constructing an appropriate counterfactual via a synthetic control. The *CausalImpact* package (Brodersen et al. 2015) within **R** (R Development Core Team 2016) provides such an implementation by employing a Bayesian structural time series approach. Originally designed to infer effects of online marketing interventions, *Causal Impact* estimates the post intervention difference between the observed time series of the response variable and a simulated (synthetic) time series that would have occurred without the intervention (Brodersen et al. 2015). The posterior causal inference functions the following way: The model is first estimated with the pre-intervention data. Then the dependent variable is predicted over the post-intervention period using the observed value of the explanatory variables. The difference between the prediction and the observed values of the dependent variable during the post-intervention period is interpreted as the impact of the policy intervention. The counterfactual post-intervention prediction is thus basically built through three sources of information: (i) the dependent time series behavior prior to invention, (ii) covariate time series pre-intervention behavior with predictive power for the response variable time series, and (iii) if existent, available prior knowledge about the model parameters since it is a Bayesian framework (Brodersen et al. 2015).

The employed Bayesian structural time series model is a state-space model for time series data which can generally be defined as a pair of equations:

$$y_t = Z_t^T \alpha_t + \epsilon_t \tag{2}$$

$$\alpha_{t+1} = T_t \alpha_t + R_t \eta_t \tag{3}$$

where $\epsilon_t \sim N(0, \sigma_t^2)$ and $\eta_t \sim N(0, Q_t)$ are error terms independent of all other unknowns (Brodersen et al. 2015). Equation 2 is the *observation equation* where the response variable y_t is linked to a d-dimensional state vector α_t and an independent and identically, normally distributed error term ϵ_t. $Z_t \in \mathbb{R}^d$ denotes an output vector. Equation 3 is the *state equation* that covers the behavior of state vector α_t. Here, the matrices $T_t \in \mathbb{R}^{d \times d}$ and $R_t \in \mathbb{R}^{d \times q}$ are transition and control matrix respectively, where $q \leq d$, and $Q_t \in \mathbb{R}^{q \times q}$ denotes the state-diffusion matrix of the above mentioned system error $\eta_t \in \mathbb{R}^q$, see Brodersen et al. (2015, p. 252). In our case, we estimate the basic local level model with contemporaneous covariates and with static, that is time-invariant coefficients. This can be achieved by setting

[4] Monetary values were deflated based on the World Bank GDP deflator for Portugal or calculated in Euro with average US dollar exchange rates for 2005.

$Z_t = \beta^T x_t$ and $\alpha_t = 1$ (Brodersen et al. 2015). In order to account for local variation in time series we also specify a local linear trend model (see Eqs. 4, 5) for the robustness tests (see Sect. 7). The local linear trend can be be defined by the pair of equations:

$$\mu_{t+1} = \mu_t + \delta_t + \eta_{\mu,t} \tag{4}$$
$$\delta_{t+1} = \delta_t + \eta_{\delta,t} \tag{5}$$

where $\eta_{\mu,t} \sim N(0, \sigma_\mu^2)$ and $\eta_{\delta,t} \sim N(0, \sigma_\delta^2)$ (Brodersen et al. 2015). Parameter μ_t represents the local trend of the response variable at time t, and δ_t corresponds to the change in μ between t and $t + 1$ or, in other words, the slope at time t exhibits a random walk (Brodersen et al. 2015). Parameters μ_t and δ_t enter Eq. 2 as in $y_t = Z_t^T \alpha_t + \mu_t + \delta_t + \epsilon_t$ (cf. Commandeur and Koopman 2007, chapter3).

Semi-local trend models (which we also use as a robustness check in Sect. 7) are more useful for estimating long-term predictions since the slope is modeled as stationary AR(1) process instead of a random walk which makes it less variable (Brodersen et al. 2015). The model can be expressed as

$$\mu_{t+1} = \mu_t + \delta_t + \eta_{\mu,t} \tag{6}$$
$$\delta_{t+1} = D + \rho(\delta_t - D) + \eta_{\delta,t}, \tag{7}$$

where $\eta_{\mu,t}$ and $\eta_{\delta,t}$ are independent, the slope of the time trend varies with an AR(1) process around the long-term slope of D which is estimated with a a Gaussian prior, and $|\rho| < 1$ is the learning rate of the local trend updates which is estimated with a Gaussian prior truncated to (− 1, 1) (cf. Brodersen et al. 2015).

We employ this Bayesian structural time series framework to estimate the effect of EFT introduction (our intervention starting in 2007) on the ratio of municipal and national PA. We have chosen the ratio of municipal and national PA in order to account for the degree of decentrality in conservation decisions. The higher the ratio, the more municipal PA there are in relation to national PA. If the ratio significantly increases after EFT were introduced, this would indicate a decentralizing effect of transfers (for PA provisions) from state to the municipal level. For the robustness checks (see Sect. 7), however, we also account for the area covered by PA in order to account for area-wise decentralization effects in PA designations.

The socio-economic covariates' time series, namely GDP per capita, population density, value added by each the agricultural, industrial, and service sectors, members of environmental NGOs per 1000 inhabitants, and municipal spending and income related to the environment (for data sources see Sect. 5.1) are included according to a spike-and-slab prior of the predictors. The spike places a positive probability mass at zero for the coefficients, the slab poses a weakly informative prior parameter distribution through a close to flat Gaussian with large variance, and the models include nonzero predictors (Scott and Varian 2014). The spike-and-slab prior ensures that sparse models with few but powerful predictors are estimated. The model algorithm chooses an appropriate set of covariates within a forward-filtering, backward-sampling framework, based on a Kalman filter. The filter recursively computes the predictive distribution $p(\alpha_{t+1}|y_{1:t})$ moving forward through the time series, while the Kalman smoother moves backward through time updating the output of the Kalman filter (Scott and Varian 2014). The algorithm averages the final model over parameter value results of a Markov chain Monte Carlo (MCMC) simulation of several model draws that are each based on the spike-and-slab prior and thereby include different (sub-)sets of controls (George and McCulloch 1997; Scott and Varian 2014; Brodersen et al. 2015). In our case we set the number of MCMC model draws to 10,000. The model structure with a Bayesian model averaging over models based on a spike-and-slab prior allows for uncertainty in model-selection while we can report both the marginal probability with which particular co-variates were included, thus on their predictive power, and the marginal probability of e.g. a positive coefficient.

6 Results: Decentralization effects in Portuguese Ecological Fiscal Transfers

During the post-intervention period, namely after the introduction of the EFT, the response variable, that is to say the ratio of municipal and national PA, had an average value of approximately 0.30. By contrast, in the absence of the intervention, we would have expected an average response of 0.14 with a 0.02 standard deviation (SD). The 95% confidence interval (CI) of this counterfactual prediction is (0.10, 0.18). Subtracting this prediction from the observed response yields an estimate of the causal effect the intervention had on the response variable. This effect is 0.17 with a 0.02 SD and 95% CI of (0.13, 0.21). This means that if we predict the development of the ratio of municipal and national PA numbers during the postintervention period, given the pre-intervention period correlations of the control variables and the post-intervention development of these variables, the observed ratio is about 0.17 higher than we would have expected.

Summing up the individual data points during the post-intervention period, estimating a cumulative impact, the response variable of the ratio of municipal and national PA counts had an overall value of 2.10. By contrast, had the intervention not taken place, we would have expected a sum of 0.97 with a SD of 0.15 and a 95% CI of (0.69, 1.25). The above results are given in terms of absolute numbers. In relative terms, the response variable showed an increase of +119% with a SD of 15% . The 95% CI of this percentage is (+91%, +148%). The probability of obtaining this effect by chance is very small (Bayesian tail-area probability $p = 0.0001$). This means that the positive effect observed during the intervention period is statistically significant and unlikely to be due to random fluctuations. Summarizing, our estimation shows that the ratio of municipal and national PA numbers has significantly increased after EFT were introduced in Portugal, which we infer to be a consequence of the fiscal incentive effect that is inherent in designating a percentage of tax income transfers to municipalities according to ecological criteria (see Sect. 9.1 for a further comment on causal inference). For a graphical illustration of our analysis see Fig. 2.

Figure 3 displays the marginal posterior inclusion probability of control variables. This gives insight into how the different model draws are structured and about the average probability of the sign of coefficients. It shows that GDP per capita is by far the most predictive covariate with regard to the ratio of municipal and national PA numbers and has a positive sign on average. With less predictive power and a slightly lower probability of a positive sign, follow population density and value added by the service sector (which accounts for a large portion of GDP per capita) and even less so value added by the industry sector. Members of environmental NGO per 1000 inhabitants most probably has a negative sign. The other covariates have a low probability of a positive sign and a relatively low predictive power since they are rarely included in models drawn from 10,000 simulated models. The Monte Carlo Standard Errors of the estimated coefficients can be found in Table 4 in the appendix.

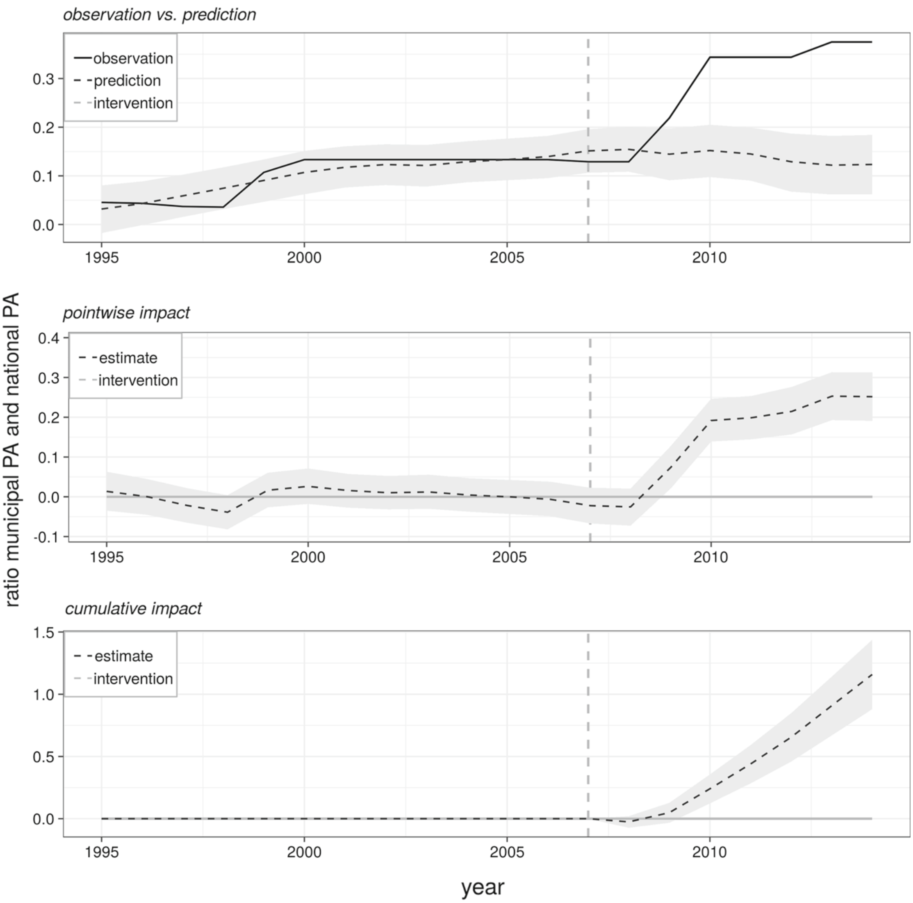

Fig. 2 Graphical illustration of Bayesian Structural Time Series model results: (i) observation versus prediction, (ii) pointwise impact and (iii) cumulative impact estimates, all with grey shade as uncertainty range between upper and lower limit estimates. Note that the uncertainty range in the post-intervention period slowly increases from 2008 to 2014: for the prediction from (0.108, 0.201) in 2008 to (0.061, 0.185) in 2014, for the pointwise impact from (−0.072, 0.021) in 2008 to (0.190, 0.314) in 2014, and for the cumulative impact from from (−0.072, 0.021) in 2008 to (0.877, 1.448) in 2014. *Source*: authors' computation

7 Robustness Checks

Because there was a reform of the PA designation competencies in 2008, just after the introduction of EFT in 2007, we conduct a robustness check for this second and almost simultaneous regime shift. This first check consists in excluding those three municipal, respectively regional municipal association, PA designations (in terms of the number of PA designated) from our data set that have only been possible with the reform of the nature conservation competencies (the regional Natural Park Vale do Tua, the local Natural Reserve Esturio do Douro, and the local Natural Reserve Paul de Tornada). The result shows that the estimated causal effect would be lower than in our initial analysis but it would still be significant. The difference between observed post-intervention average of the response (0.24) and the prediction without an effect [0.14 with a 0.02 SD and a 95% CI of (0.09, 0.18)] would be

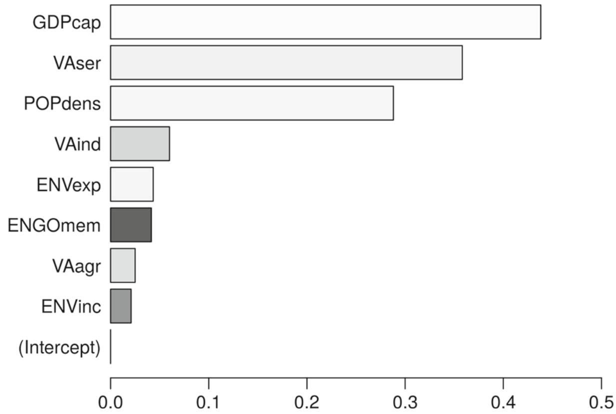

Fig. 3 Marginal posterior inclusion probability of variables in 10,000 model draws. Color shades are in proportion to the probability of a positive coefficient on a continuous (0, 1) scale: negative coefficients are black, positive coefficients are white, and gray indicates an indeterminate sign, of a probability of a positive coefficient around 0.50) (Scott and Varian 2014). Variables are (with probability of a positive coefficient in parentheses): *GDPcap* is GDP per capita (0.98), *POPdens* is population density (0.96), *VAser* is value added by the service sector (0.84) *VAind* is value added by industrial sector (0.79), *ENVexp* is the environmental municipal expenditure (0.95), *ENGOmem* are members of environmental NGOs per 1000 inhabitants (0.29), *VAagr* is the value added by agricultural sector (0.84), and *ENVinc* is the environmental municipal income (0.51). *Source*: authors' computation

0.10. In relative terms, the response variable showed an increase of 75% (16% SD). The 95% interval of this percentage is (+45%, +105%). The Bayesian tail-area probability is $p = 0.0001$. Hence, even when excluding those above mentioned PA designations, that have only been possible with the law decree 142/2008 reform of municipal nature conservation competencies, we consistently estimate a significant causal effect with this model.

Since national-level PA are on average larger in size than municipal PA and we are interested in the decentralization effect regarding PA designations we measured the dependent variable as the ratio of municipal and national PA. However, conservation is not just about the number of PA but also about their expanse. Therefore, as another robustness check, we repeat the analysis with the respective ratio of the area in hectares of municipal and national PA (see Table 3 in the appendix for some detail). The results show a similar but weaker effect—which is due to the difference in sizes of municipal and national PA. The observed post-intervention average of the response is 0.027 and the counterfactual prediction 0.015 with a 0.002 SD and a 95% CI of (0.009, 0.019) which means an estimated effect of 0.012 [SD 0.002, CI (0.008, 0.018)]. In relative terms, the results are comparable to the analysis of PA numbers: the response variable showed an increase of +82% [SD 16% and a 95% CI of (+52%, +123%)]. The Bayesian tail-area probability is $p = 0.0001$.

However, if we proceed to estimate the EFT effect on the ratio of municipal and national PA in terms of area covered and also exclude those municipal PA that have only been possible with the 2008 reform of municipal conservation competencies, there is no longer a significant effect. Predicting a counterfactual response of 0.015 [SD 0.002, 95% CI (0.009, 0.019)] we fail to reject the null hypothesis of a significant difference to the observed ratio of 0.017. This is due to the fact that the area-related effect is mainly driven by one singular municipal PA, namely the regional Natural Park Vale do Tua. This regional park has been designated in 2013 and, with a size of about 24, 767 ha, is comparable to the size of national PA. It has furthermore been designated by a regional association of the municipalities of Alij, Mura, Vila Flor, Carrazeda de Ansies, and Mirandela (ICNF 2015). This means that in terms of PA area, the introduction of EFT in Portugal had no significant effect *without* the widening of municipal conservation competencies (see Sect. 9.2 for a discussion of the relevance of compentencies for the functioning of the instrument).

Furthermore, we also computed (semi-)local trend models in order to account for local variation in time series. The local trend model is based on a random walk slope and the semi-local trend model is based on a stationary AR(1) process around a long-term trend (see Sect. 5.2 for details). The local trend model has a strong variability which means long-term predictions may suffer from wide uncertainty intervals but the semi-local trend model balances short-term information with longer-term information from the past (Brodersen et al. 2015). As expected, the significance in the local trend model ceases: the predicted counterfactual response of 0.014 [SD 0.097, 95% CI (−0.08, 0.32)] is not significantly different to the observed ratio of 0.3. This means that, although the intervention appears to have caused a positive effect, this effect is not statistically significant when considering the entire post-intervention period as a whole. There appears to be significant effect for about a three year period after the intervention. However, the apparent effect could be the result of random fluctuations that are unrelated to the intervention. This can be the case when the intervention period is very long and includes much of the time when the effect has already worn off—as appears to be the case around 2010. To the contrary, estimating a semi-local trend model that exhibits less variation, we find a significant impact: the actual observation of 0.3 is significantly higher than the predicted counterfactual of 0.014 [SD 0.07, 95% CI (−0.007, 0.28)] with a Bayesian one-sided tail-area probability of $p = 0.013$. This means that, if we allow for great variation in our predictions the significance ceases, potentially due to a wearing off effect, but the results are robust to allowing for a considerable amount of variation through an AR(1) process around a long-term trend.

8 Methodological Remarks

Regarding our quantitative approach, the application of a method originally designed for assessing causal impacts of marketing interventions to the introduction of an economic instrument for nature conservation such as EFT, produced interpretable and sensible results. This mainly is a consequence of a neat implementation of the *Causal Impact* package within the **R** environment and the merits of the Bayesian framework. While the spike-and-slab prior allowed obtaining relatively sparse but predictive models, the MCMC simulations allowed a model averaging regarding the inclusion of the most predictive covariates. Building upon these algorithms, predicting a counterfactual time series is the key feature of the Bayesian structural time series approach. Thereby it provides a solution to a fundamental and long standing issue in econometric analysis of causal effects, the problem of not having a controlled experimental setting in analyzing real world phenomena or policies (cf. Box and Tiao 1975; Ashenfelter and Card 1985; Meyer 1995; Heckman 2008; Athey and Imbens 2015).

Another statistical issue is the required length of the time series. While, for example, Box et al. (2016, p. 15) state that long time series of about 50–100 observations are required for proper analysis, i.e. for data with seasonal variability, Simonton (1977) argues that for cross-sectional analyses time series with 4–12 observations per case can suffice. Hyndman and Kostenko (2007) state that it is at least required to have more observations than parameters but also differentiate between requirements for standard time series analysis methods such as regressions with seasonal dummies, Holt-Winters Methods and ARIMA models. They suggest a Bayesian framework for cases in which data is limited—which applies to our case. Furthermore, requirements may reduce if regularizing methods are applied (Hyndman 2014)—like the spike-and slab prior in our model. This is to say requirements very much depend on the data structure, the nature of the observed variables and the modeling approach. In our data set we have yearly data of the dependent and 8 independent variables for the 13 years of the pre-intervention period, and 7 years for which the dependent variable is both observed and predicted as a counterfactual based on the pre-intervention correlations and post-intervention variability of covariates using regularizing priors (Brodersen et al. 2015). There is no seasonal variability in the dependent variable and a rather stable (close to linear) trend with a small jump around 1998–2000, and apparently rather static coefficients in the pre-intervention period without much random variation in the development of our dependent variable over time. Thus, we assume that a Bayesian prediction of a simulated counterfactual time series that takes into account the known post-intervention variation of covariates suffices for a reliable post-intervention estimation, especially since the technique has particularly been developed for short time series forecasting (Scott and Varian 2014).

One potential shortcoming of the model is that covariates such as GDP per capita, population density and value added are potentially endogenous such that designating municipal PA may attract investments or inhabitants through local amenities. In general, such endogeneity may affect our results. However, there are two reasons why we assume those to be negligible, one circumstantial and the other methodological: (i) considering the circumstances of the banking and fiscal crisis starting 2007, the relative importance of municipal PA for GDP and value added appears to be minimal and population movement might be more affected by employment than by local amenities; (ii) while designating a municipal PA takes immediate effect, the change in habitat structure and quality and thus local amenities through conservation action require longer time, such that the prediction based on past and contemporaneous covariates would not be affected by lagged effects of the dependent variable on covariates.

Furthermore, it is important to note that something else could have happened after 2007 that also affected the PA designations, but that it remains an unaccounted for phenomenon which is not captured in the set of controls. We account for economic variables over the 2008 crises, proxies for environmental values in the population such as environmental NGO members, and simultaneous institutional shifts. We are thus confident that we account for the most important variables. Yet, we cannot exclude the possibility of unobserved effects with certainty. There may have been some sudden shift in local decision makers' behaviour and PA designation acts that remains unexplained by our model.

9 Discussion: Motivations, Municipal Competencies, and Welfare Gains

Quantitative results show that the introduction of EFT is followed by an increase in the ratio of municipal and national PA numbers. While national authorities keep designating PA, municipalities designate more of their own PA categories than previous to the introduction of the scheme such that the ratio rises. We can observe a synchronicity of events in the time series, where the rise in the ratio of municipal and national PA coincides with the introduction of EFT in Portugal. Through a comparison of the post-intervention ratio with a simulated counterfactual time series predicted from pre-intervention correlations, we can infer the quantitative effect of an introduction of EFT. Given the Bayesian structural time series approach, these results suggest decentralization in nature conservation decisions through EFT.

For the discussion of these results we focus on three specific aspects: (i) a note on motivational aspects of conservation decisions and causal inference, (ii) municipal nature conservation competencies and their importance for the functioning of EFT, and (iii) welfare implications of decentralization through EFT.

9.1 Motivations of Local Decision Makers to Designate Protected Areas

As a first remark, it is important to note that we observe outcome variables which are the result of the decisions on the local level but not the decision making process itself. As briefly introduced in the theoretical model section (see Sect. 3), there can be a wide variety of actual reasons for designating municipal PA, among which the financial incentive inherent in EFT schemes may be found. Nevertheless, we can observe a synchronicity in the events of introducing EFT and a rise in the ratio of municipal and national PA. Given our theoretical proposition that fiscal remuneration incentivizes the designation of municipal PA and this synchronicity, we would argue that the outcome of decisions for municipal PA is thus a consequence of introduction of EFT. The inference of such a causal effect is however limited to a quantitative perspective. A qualitative analysis of motivations of those municipalities that have actually designated more PA after the introduction of the EFT scheme could identify and scrutinize the underlying decision-making processes and remains a task for future research.

9.2 Conservation Competencies and their Importance for the Functioning of Ecological Fiscal Transfers

Our results regarding a decentralizing effect of introducing EFT are robust to the exclusion of the *number of PA* designations that only have been possible with the 2008 reform of municipal nature conservation competencies. The effect is also significant if we measure outcome in terms of *PA area covered*. However, if we simultaneously measure area covered and exclude those municipal PA that were only possible with the 2008 institutional change the effect ceases to be significant (see Sect. 7 for an explanation). This is to say, the incentive appears to work on both the number of designated municipal PA and the extent of those, but the latter would not have been possible without the simultaneous enlargement of municipal designation competencies. Hence, the effects that EFT can have on the designation of municipal PA in Brazil (Droste et al. 2017) or in Portugal can very likely not be replicated in other countries unless there are comparable nature conservation competencies in place for the designation of municipal PA. The robustness checks thus indicate the importance of municipal competencies for the functioning of the instrument. They are a crucial element for the decentralization effect through EFT incentives and particularly important if only the extent of municipal PA was to be considered relevant for conservation effectiveness.

9.3 Welfare Implications of Decentralization Through Ecological Fiscal Transfers

The fiscal remuneration of ecological public functions likely have welfare related effects (see Sect. 2 for the theoretical underpinning) such as: (a) a compensation of costs incurred to the local level through (supra-)national PA designations; (b) the decentralizing effect which allows to take local conservation preferences better into account; and (c) the increase in the provision of an undersupplied public good. Although we can observe an increase in local PA which we associate with the introduction of EFT, the welfare implications are based on the theory of fiscal federalism. The following remarks thus remain at a conceptual level.

As stated initially, decisions on the EU Natura 2000 network, or nationally important conservation sites, are reasonably better informed at the (supra-)national level where there are well-trained conservation experts with knowledge on the distribution of e.g. endangered species or important corridors for overarching habitat networks. For these (supra-)national PA designations, EFT can (partly) compensate for the costs imposed to the local level and thus reduce negative external effects of higher government level conservation planning. That municipalities have competencies to designate their own PA, however, opens a leeway for an incentive effect beyond mere compensation. Apparently, the relatively low unit value of EFT sufficed to incentivize the designation of additional municipal PA. Given that local decision makers indeed designate PA in (better) accordance with interests at the local level, the EFT induced designations would lead to more precise and locally differentiable preference satisfaction in the decision where to protect nature.

Furthermore, the additional municipal PA increase the provision of undersupplied local public goods such as biodiversity conservation with their potentially long spatial and temporal range spillover benefits. At the same time, however, there may be economies of scale in conservation (Armsworth et al. 2011). It is thus important to recognize that the introduction of EFT does not contradict or substitute but supplement conservation competencies of (supra-)national bodies such as central planning agencies or the European authorities. Thus, based on assumptions of the theory of fiscal federalism, EFT may yield welfare gains through i) compensating municipalities for costs incurred by (supra-)national conservation planning, ii) incentivizing decentral PA designations which are potentially in line with local preferences and iii) increasing the provision of undersupplied public goods and services through small to medium scale PA without counteracting (supra-)national large scale designations. These assertions, however, require more thorough welfare analyses—which remains a future task.

10 Conclusion

Analyzing the effect of the 2007 introduction of EFT in Portugal, we provide quantitative evidence of an increase in the ratio of municipal and national PA numbers in the post-intervention period. Comparing a simulated counterfactual time series, obtained by predicting pre-intervention correlations of socio-economic control variables with the observed outcome variable for the post-intervention period, we find a significant difference between counterfactual predictions and actual observations. We can thus observe a synchronicity of introducing EFT and the rise in the ratio of municipal and national PA, that is unlikely a consequence of random processes. Against the theoretical background, where we model how fiscal incentives may increase the designation of decentral PA through lowering relative prices, this observed decentralization effect has very likely been caused by the Portuguese EFT introduction.

Deducing implications from the theory of fiscal federalism, such decentralization may lead to welfare gains since local preferences could better be taken into account and spatial conservation spill-over effects from municipal PAs are (partially) internalized. At the same time, such an additional decentralization effect does not exclude a centrally planned designation of protected areas of (supra-)national importance, as the municipal competencies do not substitute but supplement conservation competencies of (supra-)national bodies. For such central PA designations the EFT compensates for costs imposed to the local level. Recognizing ecological public functions within fiscal transfers schemes thus has the potential to increase overall performance of the public sector.

An important implication of our analysis is how crucial municipal competencies for the designation of PA are for the decentralizing incentive effect—especially when considering ecological effectivenes in terms of PA coverage. Without those competencies municipal bodies would have no means to directly react to the incentive effect and increase the municipal supply of protected areas. As a response to the (inter-)national demands for biodiversity protection, introducing fiscal incentives through EFT has the potential to increase the likelihood of decentral conservation action, even without the need for additional expenditure, but only if decentral governments have corresponding conservation competencies.

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Appendix: Descriptive Statistics

Summary Statistics

See Table 2.

Table 2 Summary statistics. *Source*: authors' calculations based on ICNF (2015), World Bank (2015), and INE (2015); monetary values are in constant €2005 prices

Statistic	N	Mean	SD	Min	Max
Ratio municipal PA / national PA (*PAratio*)	20	0.173	0.117	0.036	0.375
Value added by agriculture (*VAagr*)	20	3,711,254,633	136,704,563	3,566,115,527	4,110,711,457
Value added by industry (*VAind*)	20	32,371,423,673	2,524,840,175	27,799,037,951	35,769,016,793
Value added by service (*VAser*)	20	96,957,621,027	9,520,538,122	77,956,243,299	108,038,023,839
GDP per capita (*GDPcap*)	20	14,603.360	896.900	12,383.830	15,636.750
Population density (*POPdens*)	20	113.517	1.958	109.576	115.439
Municipal environmental spending (*ENVexp*)	20	573,327.100	53,616.450	468,352	663,297.500
Municipal environmental income (*ENVinc*)	20	210,387.300	47,144.360	134,958	304,035.400
Members environm. NGO per 1000 inhab. (*ENGOmem*)	20	4.600	2.280	1	8

Time Series of Dependent Variable Components for Robustness Checks

See Table 3.

Table 3 Time series of PA designation variables at different government levels. *Source*: authors' calculations based on ICNF (2015)

Year	National PA area (ha)	Municipal PA area (ha)	Number of national PA	Number of municipal PA	No. municipal PA via 2008 reform
1995	623.360	3.282	22	1	
1996	623.414	3.282	23	1	
1997	623.434	3.282	27	1	
1998	710.435	3.282	28	1	
1999	710.435	10.360	28	3	
2000	742.191	10.706	30	4	
2001	742.191	10.706	30	4	
2002	742.191	10.706	30	4	
2003	742.191	10.706	30	4	
2004	742.191	10.706	30	4	
2005	742.191	10.706	30	4	
2006	742.191	10.706	30	4	
2007	742.309	10.706	31	4	
2008	742.309	10.706	31	4	
2009	743.274	11.206	32	7	2
2010	743.274	13.418	32	11	2
2011	743.274	13.418	32	11	2
2012	743.274	13.418	32	11	2
2013	743.274	38.185	32	12	3
2014	743.274	38.185	32	12	3

Monte Carlo Standard Errors

See Table 4.

Table 4 Monte Carlo standard errors of estimated coefficients. *Source*: authors' calculations

	Base model (BM)			BM excluding 2008 reform PA			BM on area of PA		
Variables	MCSE	SD	MCSE /SD in %	MCSE	SD	MCSE /SD in %	MCSE	SD	MCSE /SD in %
VAagr	3.9e−4	4.0*e*−2	9.9e − 1	3.8e − 4	3.9e−2	9.9e−1	5.9e−4	6.1e−2	9.8e−1
VAind	1.2e−3	1.1e−1	1.1	1.3e−3	1.2e−1	1.1	1.8e−3	1.6e−1	1.1
VAser	1.6e−2	4.7e−1	3.3	1.5e−2	4.7e−1	3.1	1.0e−2	4.8e−1	2.1
GDPcap	1.7e−2	4.9e−1	3.4	1.7e−2	5.1e−1	3.4	1.2e−2	5.4e−1	2.3
POPdens	1.4e−2	4.1e−1	3.4	1.4e−2	4.0e−1	3.5	6.4e−3	2.9e−1	2.2
ENVexp	6.7e−4	5.7e−2	1.2	6.4e−4	5.2e−2	1.2	1.1e−3	6.3e−2	1.8
ENVinc	9.6e−4	7.7e−2	1.2	1.1e−3	7.6e−2	1.4	1.6e−3	7.8e−2	2.0
ENGOmem	6.7e−4	5.4e−2	1.2	8.4e−4	5.6e−2	1.5	9.2e−4	5.2e−2	1.8

	BM on area and excluding 2008 reform PA			BM + local trend			BM + semi-local trend		
Variables	MCSE	SD	MCSE /SD in %	MCSE	SD	MCSE /SD in %	MCSE	SD	MCSE /SD in %
VAagr	5.5e−4	5.6e−2	9.8e−1	1.3e−13	4.0e−12	3.1	1.1e−13	3.4e−12	3.1
VAind	1.8e−3	1.6e−1	1.1	1.4e−14	4.9e−13	3.0	1.7e−14	4.6e−13	3.6
VAser	9.6e−3	4.7e−1	2.0	1.6e−14	3.0e−13	5.2	8.0e−15	2.0e−13	3.9
GDPcap	1.2e−2	5.4e−1	2.3	2.7e−8	1.2e−6	2.3	3.0e−8	1.2e−6	2.4
POPdens	6.5e−3	2.9e−1	2.2	2.9e−6	1.8e−4	1.6	2.8e−6	1.2e−4	2.3
ENVexp	1.1e−3	6.1e−2	1.8	4.2e−5	7.2e−4	5.9	3.6e−5	7.5e−4	4.8
ENVinc	1.6e−3	7.9e−2	2.0	5.8e−10	1.8e−8	3.3	6.2e−10	1.8e−8	3.5
ENGOmem	9.5e−4	5.4e−2	1.8	1.3e−9	2.2e−8	5.6	1.3e−9	1.9e−8	6.9

MCSE Monte Carlo Standard Error, *SD* Standard Deviation

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