Extended Abstract
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Paper Title	**Undesired effects of joined pollution regulation sourced by a multi-use production factor**

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Abstract	***200 words max***
We focus on possible counter-intuitive effects when environmental policy makers implement economic regulation instruments aiming at reducing pollution. We consider a multi-technology and joined pollution framework to assess to what extend introducing a tax affecting a polluting input might lead to increased pollution. We show how this kind of unexpected effects may theoretically occur, and we show symmetrically that such occurrences are found when a first rank policy directly targeting pollution may lead to input demand increase. We consider a quantitative model of the European agricultural supply to explore when this problem may happen, considering a wide range of producers and a wide range of tax levels related to first and second rank policies. The occurrence of these undesired effects does not prevent policy makers implementing environmental regulation facing very few counter-intuitive cases in terms of tax level and farming system.	

Keywords	multi-use production factor; joined pollution; nitrogen fertilizers; mathematical programming model
JEL Code	Q18; Q54 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***

The expansion of agricultural land had a significant role in this increase, but it was mainly the intensive use of production factors that prompted the current levels of agricultural output (Matson et al., 1997). However, externalities related to the intensive use of nitrogen (N)-enriched fertilizers constitute one of the notably negative externalities of conventional agricultural systems. In this study, we specifically focus on soil and groundwater pollution by nitrates (NO3), air pollution by ammonia (NH3) and greenhouse gas emissions since fertilizers constitute one of the main anthropogenic sources of nitrous oxide (N2O) (Erbas and Solakoglu, 2017).

The three considered pollutants are a specific case of nonpoint source (NPS) pollution. There is a significant uncertainty regarding the entering point of these pollutants, as well as the contribution of each emitting source to the overall pollution. Consequently, rigorous observation and measurement of effluent flows is relatively difficult. Scientific literature is particularly abundant regarding the performance of first-best instruments (Russell and Powell 1999). However, given the diffuse origin of NPS pollutants, these approaches of regulation are unattainable, because of the necessary massive expenditures on monitoring (Larson et al., 1996). NPS pollution control can be addressed through second-best instruments which usually involve

controlling input use via taxes, limiting output levels, management practices and land-use policies (Helfand and House, 1995 and Shortle and Horan, 2001).

Methodology	***100 – 250 words***

Our theoretical model is based on a profit maximisation problem involving multiple inputs and multiple outputs. The inputs in our case study are the multiple nitrogen intakes by different crops, while the outputs are the nitrogen related pollutants. We first submit our model to a constraint of an input tax and then to a constraint of an emissions tax. We then apply this to a realistic context via the European agricultural supply model AROPAj. AROPAj is a cluster of mathematical programming models designed to represent the economic behaviour of European farming system sets (Barberis et al, 2020). Each individual model refers to a farm group which maximizes its gross margin subject to technical and economic constraints. AROPAj is calibrated with the Farm Accountancy Data Network (FADN), along with other databases corresponding to climate scenarios and land use.

The STICS crop model provides us with the nitrous oxide (N2O), nitrate (NO3) and ammonia (NH3) lost quantities of 9 crops for various fertilizer input and irrigation water quantities. These values are run through a multiple linear regression model that allows the estimation of emission coefficients per nitrogen and water for the air and soil pollutant and the GHG considered. The AROPAj model is then fed with these loss coefficients as part of the constraints matrix. Variations in nitrogen fertilizer demands and nitrogen losses in the form of nitrous oxide, nitrate and ammonia in response to the implementation of taxes applied either to fertilizer consumption or to N-losses are calculated for 1993 farms.

Results	***100 – 250 words***

Our contribution shows how a formal problem allows us to demonstrate the existence of possible undesired effects when taxing the production factor used for several outputs or used under different technologies. Through this work, we extend the case of undesirable effects shown by Jayet and Petsakos (2013) in a similar context.

Beyond this generalisation, we show that there is a symmetry considering, on one hand, the case of second best instruments leading to increasing pollutant emissions, and on the other, the case of first best instruments leading to increasing demand for polluting factor. The demonstration of this symmetry is provided within a formal framework.

For the 1993 farms studied, we find that when taxing the N-intake, 8% of the farm groups may be affected in some punctual cases (1%) with an increase in total N-losses, whereas a tax on emissions would generate an increase in fertilizer demand for 8% of the farm groups (for 1% of the occurrences). There are a series of factors

that may produce undesired effects when taxes increase, beyond what may arise following the theoretical approach.

One of the most important factors comes from the fact that fertilizer composition may differ among the crops (and possibly among the farm groups). This means that taxing N-intake may lead to fertilizer quantity increase. This effect may be amplified or mitigated by the wide range of values of N-losses per unit of nitrogen intake over crops and farm groups. These aspects are especially relevant when implementing a tax on fertilizer consumption.

Discussion and Conclusion	***100 – 250 words***

Pollution ensues when a production process does not take into account the social damage it causes. Nitrogen fertilizers are a necessary input in agricultural production, but their intensive and ineffective use is the source of three main types of pollutants, nitrous oxide, nitrates and ammonia. In this study, we address the regulation of these nitrogen related losses through incentive based pollution control instruments, specifically a tax on input use and a tax on emissions. Through a theoretical approach, we demonstrate the existence of theoretically unexpected effects of an input tax, resulting in the increase of emitted pollutants. Symmetrically, we show how an emission based tax could lead to an input demand increase. For the application, we use the AROPAj quantitative supply side economic model which represent the economic behavior of European farming, enriched with the estimation of pollutant specific N-loss functions from the STICS crop model. Further analysis of our results is currently in progress.