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Research paper

A socioeconomic analysis of biocontrol in integrated pest management: A review of the effects of uncertainty, irreversibility and flexibility

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ABSTRACT

European regulations on the sustainable use of pesticides aim to promote integrated pest management (IPM) strategy and the use of biological control agents. However, uncertainty over benefits and costs, irreversibility effects as well as flexibility in adoption of this technology needs to be considered. Economic evaluation of IPM using simple cost-benefit analysis may be inadequate. Therefore, the need to develop evaluation tools that takes the aforementioned constraints into consideration is imperative. To this end, we introduce the maximum incremental social tolerable irreversible costs (MISTICs) as a tool for such evaluation. Only when the incremental reversible benefits of the IPM strategy outweigh possible irreversible costs of such a strategy by a minimum threshold (hurdle rate) should introduction of biocontrol be considered. Our approach allows assessment of an IPM strategy from a private (farmers) point of view to be extended to a social context.

We aim to evaluate the MISTICs value of biocontrol adoption for Western Corn Rootworm in maize cultivation and wireworms in potato cultivation for selected European Union member states (Germany, France, Austria, Spain and Italy) based on the option and net present value using the McDonalds-Siegel Stimulation. We also evaluate the potential irreversible costs associated with biocontrol introduction.

The farm-level MISTICs per hectare for biocontrol of Western Corn Rootworm in maize cultivation in the selected countries were estimated to be less than €150/ha while biocontrol of wireworms in potato cultivation, well above €200/ha. These results suggest that the introduction of biocontrol for wireworms in potato cultivation, given the higher MISTICs values, is more economically viable compared to the biocontrol of Western Corn Rootworm in maize. The model can also be extended to include other factors such as regulatory hurdles.

1. Introduction

The European Union (EU) directive 2009/128/EC on the sustainable use of pesticide in pest management emphasizes the use of alternative (non-synthetic) products in pest control becomes mandatory from the 1st of January 2014. Member States have to set-up a national action plans that implements the principles of integrated pest management (IPM) as prescribed in Annex III for professional users including farmers. According to the FAO [16] "*IPM means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms*". Directive 2009/128/EC as well as the EU legislation 1107/2009, which approves low risk active substances, are policies that will affect European farmers. This implies that sustainable pest control methods, such as the use of biological control agents (*henceforth biocontrol*), must be preferred over chemical application if they provide adequate pest control [10].

The application of biocontrol in IPM may lead to reversible and irreversible effects. Irreversible effects are associated with patterns that are observed long after the project ceases, which impacts human health, pesticide application, greenhouse gases emissions

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and farm machinery investment. Reversible effects stop as soon as the project causing these effects is terminated. Irreversible and reversible effects are associated with negative and positive externalities, thus, benefits and costs may accrue to both farmers (private) and the general public (external). However, these benefits and costs are plagued with some level of uncertainty [33]. Some of these uncertainties are related to efficacy of biocontrol on pest density, level of pesticide reduction, impact on non-target organisms etc. In the case of inadequate pest control, farmers can postpone adoption of biocontrol. As a result, the decision to immediately invest or delay investments in biocontrol corresponds to degrees of flexibility.

Economic evaluations of IPM are based, among others, on the comparative study of environmental risk assessment [12,13,38,39]. Mullen et al. [12] also explore the willingness to pay of society in reducing the estimated risk posed by pesticide application. Although the use of environmental risk assessment for the economic analysis of biocontrol would provide insights for benefits associated with IPM strategy, the social and economic costs of IPM are not adequately addressed. There are limited studies that have endeavored to conduct a comprehensive costs benefit analysis of biocontrol. However, an economic analysis of biocontrol within an IPM program based on a simple cost benefit analysis (CBA) may be biased as it only captures reversible effects which are considered stable [26,28]. In such a case, a net present value (NPV) equal or greater than zero would imply that it is worthwhile to invest in that specific program. Given the uncertainty and irreversibility associated with biocontrol application and the flexibility in deciding to adopt the technology, a simple CBA analysis may over- or underestimate the investment value [33].

The aforementioned uncertainty, irreversibility and flexibility of biocontrol application on European staple crops such as maize and potato require a more comprehensive economic analysis. Maize is an important crop for the EU-27 as it is cultivated on 13.2 million hectares with an annual yield of 48.5 million tons (2007) with France, Romania, Germany, Hungary and Italy together cultivating ca. 5 million hectares [18]. Total European potato production in 2009 was estimated at 124 million tons with the 5 majors producers; France, Germany, Netherlands, Belgium and Great Britain having a combined output of ca. 28 million tons in 2007 [36]. Staple crops in Europe, such as maize and potatoes, are exposed to a number of pests. Amongst these pests are the western corn rootworm larvae, *Diabrotica virgifera virgifera LeConte* (*henceforth WCR*) and the click beetle larvae, *Coleoptera: Elateridae,* (*henceforth wireworms*) in maize as well as wireworms in potatoes [2,18]. WCR has resulted in pest management expenses and yield loss of over USD 1 billion in the U.S maize producing regions [3,15,17]. Its spread to Europe has had a significant negative impact on maize production [15,17]. Meissle et al. [18] identified WCR as one of the most important arthropod pests in European maize production. Wireworms, comprising a number of species, indirectly affect the quality of potato due to tunneling (holes) which is a "quality" problem for farmers in many parts of Europe [14].

Investments in biocontrol of WCR and wireworms by European farmers may have uncertain costs and benefits, irreversible effects to the society while farmers have an option to delay purchase of the technology. Such investments should only be made if the benefits from biocontrol exceed the cost by a certain threshold and not if the NPV is equal or greater than zero. Ideally, a threshold that is tolerable to society for the introduction of biocontrol technology when biocontrol is subjected to flexibility, uncertainty and irreversibility has to be estimated. Demont et al. [8] estimated a quasi-option value ***or maximum incremental social tolerable irreversible costs—MISTICs*** for transgenic crops from a benefit-cost perspective among EU member states. Wesseler et al. [34] also applied a similar option model as a decision tool for the introduction of genetically modified (GM) maize in the Europe Union (EU-15). Another study also used the option approach to economically evaluate the treatment of diseases in agricultural crops under risk and uncertainty [25].

The concept of the real option valuation and resulting MISTICs are closely aligned to what is called the call option in financial economics. The call option is the right, but not the obligation to buy an amount of asset from a seller of an option at a specific time and price. The seller is mandated to sell the asset to the buyer if he/she wishes so. The buyer, however, must pay a premium to obtain the right and would only exercise this right if the spot price of the underlying asset in question is higher on the day of transaction. This premium may be perceived as a proxy for the flexibility of the buyer of the option.

We propose a similar MISTICs calculation from earlier studies (see Demont et al. [37] and Wesseler et al. [34]) as an alternative to a simple CBA for the biocontrol of WCR and wireworms in maize and potato cultivation for a number of selected European countries (Germany, France Austria, Spain and Italy). Our estimate of the MISTICs for biocontrol application using McDonald-Siegel Stimulation therefore gives decision-makers (e.g. farmer) a tool to argue for immediate release or postponement of the biocontrol technology based on their respective reversible benefits and irreversible costs.

To the best of our knowledge this is the first study to apply MISTICs to biocontrol in an IPM context. There are several constraints to this analysis such as the estimation of the irreversible benefits of a biocontrol strategy as well as the assumption that current output of maize and potato are affected by WCR and wireworms. This study also reverts to estimates of pesticide reduction and carbon dioxide (CO_2) emission used by Wesseler et al. [34] in the welfare analysis of the introduction of transgenic maize in the EU-15. For this study, the estimation of the benefits of pesticide reduction is rather conservative considering that pesticide application could have higher negative externality effects. For instance, the valuation of CO_2 emission [see Refs. [6,30]] reduction from sustainable use of pesticides due to biocontrol is not truly taken into consideration.

2. Material and methods

Given the health and environmental implications of conventional European agriculture systems, farmers do not only have to maximize their profit but also ensure the welfare maximization of EU citizens. The decision to adopt biocontrol brings with it uncertainty and some irreversible effects, the producer has to decide whether to adopt now or wait till a later date when more information on costs and benefits become available. Under the neoclassical decision-making framework, biocontrol should be adopted if expected that the net social reversible benefits are greater than the net social irreversible cost or their ratio, known as the hurdle rate, is equal or greater than one [37]. The decision-making on biocontrol by farmers can be derived using the real (call) option approach, where farmers have a right to undertake biocontrol (real option) but are not obliged to do this. There is a premium paid for this right since it protects the farmers against losses should the future flow of information reveal that net social reversible benefits are lesser than anticipated while postponing adoption of biocontrol involves forgone net social reversible benefits [37]. The value of the benefit would have to exceed the value (premium) of the option for it to be exercised. The option value or ***maximum incremental social tolerable irreversible costs*** is dependent on the net social reversible benefits.

The aforementioned reversible and irreversible benefits and costs can be categorized into private and external while a combination of both categories is considered social (see Table 1). The private costs and benefits of biocontrol accrue only to primary