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KAI P. PURNHAGEN

JUSTUS WESSELER
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Abstract

New Plant Breeding Technologies (NPBTs), including CRISPR gene editing, are being widely used and drive the development of new crops. However, these new technologies are not undisputed, creating uncertainty in how applications of these technologies for agricultural and food uses will be regulated. While in North America regulatory systems are already adapting to NPBTs, in the European Union discussions are still underway regarding how to regulate NPBTs. Information about next steps can be expected with the decision of the European Court of Justice in the summer of 2018 on a case put forward by the French Government on one form of NPBTs and whether this technology should fall under existing GMO regulations. The ruling is unlikely to solve the general problem how NPBTs should be assessed, but it will provide some insights about future directions. This paper discusses different options that are available for the EU considering the legal framework and the international environment in which the EU is embedded. Using an ex-ante regulation versus ex-post liability framework allows us to address the economic implications of different options. The results show that under current conditions, some options are more expensive than others. The least costly option, regulating new crops derived from NPBTs similar to those used in “conventional” breeding, is

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the outcome which is least likely. The most costly option, banning the use of NPBTs altogether, is possible from a legal point of view, but due to the decision making procedure in the EU also not very likely. The most likely solutions at EU level, due to the nature of these new technologies, will require international collaboration, in order to avoid the possibility that they result in an indirect ban of agriculture and food imports

**Key words:** Gene Editing, Real Options, Investment, Regulation, Minimum Harmonization, Maximum Harmonization, European Union

**JEL:** Q15,
Scientific progress has resulted in new methods in plant breeding. Concerns have been expressed by scientists and others that those methods can be abused or create unwanted outcomes and, hence, applications should be closely monitored. These concerns in a combination with the political economy related to the rents being generated and lost by the new methods result in regulatory policies governing the introduction and use of products developed. The appropriate regulatory policies are widely discussed in the United States (US), the European Union (EU) and other countries. While a set of regulatory policies has been developed to govern the approval and use of so called "genetically modified organisms" (GMOs) developed by using transgenic methods progress did not stop. More precise and cost-efficient methods have been developed raising questions about their regulation (e.g. CAST 2018, Purnhagen et al. 2018). In the literature they have been summarised under the term "new plant breeding technologies" (NPBTs) (Lusser et al., 2011). Examples include CRISPR-Cas 9, TALEN, zinc finger printing, oligo-directed mutagenesis (ODM), and more. Examples of food products that have entered the US market include non-browning apples and mushrooms (CAST 2018).

Many of the NPBTs introduce mutations to change the genetic information of an organism. Mutation inducing processes, mutageneses, have a long history in plant breeding. Under EU law, most products produced by using mutagenesis are considered GMOs by definition, but are explicitly exempted from the GMO regulation. A debate started if the mutagenesis exemption, which is dated from 2001, does only apply to those processes available until 2001 or if the exemption also includes future processes. A legal case has been put forward to the Court of Justice of the European Union (CJEU) to clarify the issue. The CJEU has several options to rule on the case. Each option will have implications for the benefits and
costs and hence the incentives for private but also public sector investments in further developing and applying NPBTs. The regulatory outcome can have important economic implications. The additional costs to comply with regulatory safety standards for GMOs have been assessed to be about between 6 and 14 million USD (Kalaitzandonakes, Alston, and Bradford 2007) but as Smyth, Kerr, and Phillips (2017, chapter 3) show they widely range between different jurisdictions.

The economic literature on the economic implications of regulatory policies with respect to new technologies is quite diverse (Shleifer 2010). First, it is foremost a legal question, whether or not a new technology requires additional regulation beyond the current level: which of the current regulatory policies apply and do they address sufficiently well potential risks? These legal questions are not independent of economic considerations. Regulatory policies can be described by ex-ante regulatory standards and ex-post liability rules. In the case of NPBTs, for example, an investor has to comply with the regulatory standards prior to placing a product on the market and ex-post liability in case of non-compliance and/or damage. Many authors have shown that a combination of ex-ante regulatory standards and ex-post liability rules is often superior to either using only one or the other (e.g. Kolstad, Ulen, and Johnson 1990, Shavell 1984). Nevertheless, one has to acknowledge that avoiding ex-post liability is almost impossible. Even if not being hold liable by law an investor may observe negative effects on reputation and related economic consequences.

In this contribution we develop a real option model based on the ex-ante regulatory standards and ex-post liability literature to assess NPBT regulatory policies on private sector incentives for investment in NPBTs. We divide the investment in three phases: the research phase, the approval phase and the market phase. Each
phase will be more or less strongly affected by ex-ante regulatory policies. All three phases are characterised by uncertainty about the time length of each phase. Additional uncertainty is added by the probability of ex-post liability after the product has reached the market.

This set-up allows us to compare different regulatory policies and their implications on the incentives for investment. While in the literature ex-ante regulatory standards have been modelled as one phase, the differentiation into three phases allows us for a more detailed regulatory policy analysis. We are in particular able to show the strong effect of the costs of regulatory standards and ex-post liability rules under uncertainty and irreversibility on the decision to invest. While this is to be expected, as the strong effect of sunk costs on investments is well known from the literature, our model is richer in the details allowing a more detailed policy analysis.

Further, our approach enables us to illustrate the trade-offs of different policy options and factors driving those. Finally, while the model is developed for and motivated by the case of investments in NPBTs, it is generic enough to also provide additional insights into trade-offs between ex-ante regulations and ex-post liability. We are able to show the different outcomes of minimum versus maximum harmonization regarding the regulation of NPBTs, where simply said minimum harmonization refers to decision being made at EU member state level and the EU only provides some general guidelines and maximum harmonization refers to the decision being made at EU level and member states have to comply.

We proceed by first developing the generic model for our analysis before we assess in more detail the legal environment governing the approval of NPBTs in the EU. The assessment allows us to identify four policy options at EU level that are assessed after the real option model has been introduced. The four options
discussed are derived from the assessment at EU level, but they not only apply to
the EU. The policy options are generic and apply to other cases as well that we
discuss before we conclude.

Generic Economic Model

NPBTs can be regulated at several levels of the European Union. One needs first
to acknowledge that the regulation does not start from scratch. The Treaties of the
European Union set out a general framework, and secondary legislation may cover
specific cases. As pointed out in more detail below a regulatory framework at
secondary level can follow different harmonization methods, in particular choosing
between minimum and maximum harmonization or a combination of both of which.
In the case of NPBT’s this results in the four basic options. The options have
different economic implications. The economic implications follow from differences
in costs and benefits companies face under different regulatory policies. In general,
the lower the fixed costs will be the larger the possibility for companies entering
the sector and the more competition about new ideas will emerge. The underlying
assumption made is that the more firms get involved the better this will be ceteris
paribus for the economy under consideration.

In general, the objective of a firm considering to invest in developing new crops
using NPBTs can be modelled as maximizing the real option value of the
investment. There will be a trade-off between the ex-ante regulation a firm has to
follow and the ex-post “liability” costs they may face. We start with the general
model and later compare alternative institutional arrangements and the possible
trade-off’s they include.

Let $F$ denote the value of the option of invest. The firm has to invest into research,
$R$, for developing the new technology that for simplicity are considered to be
completely sunk. In addition there are annual research costs $r_t$, with $t$ indicating time. The time needed to complete research is not known but expectations exist. The time length for this research will be denoted by the random variable $\kappa_1 \in (0, \infty)$. $\kappa_2$ follows an exponential failure function with $g(\kappa) = h_t e^{-h_t \kappa}$ and $E(\kappa) = \frac{1}{h_t}$, where $h_t$ denotes the failure rate. At $\kappa_1$ an application for approval will be submitted. The submission for approval includes approval costs, $A$, that are considered to be sunk, and some annual reversible costs $a_t$. The time length for approval is not known but expectations exist and is denoted by random variable $\kappa_2$. At $\kappa_2$ the product will be approved for market entry generating a benefits stream, $B$, expressed in net-present-value terms at time $\kappa_2$. Firms may face ex-post tort liability and/or reputation costs, $\theta$, if damages linked to the product introduced occur, again modelled as being random and denoted by $\kappa_3$.

The expected value of the investment can be written as follows:

\[
E(V_0) = \{ -R + \int_0^\infty \left( \int_0^\infty \left[ - \int_0^{\kappa_1} r_t e^{-\mu t} dt - A e^{-\mu \kappa_1} - \int_0^{\kappa_2} a_t e^{-\mu t} dt + B e^{-\mu (\kappa_1 + \kappa_2)} - \theta e^{-\mu (\kappa_1 + \kappa_2 + \kappa_3)} \right] g(\kappa_1) d\kappa_1 \right) g(\kappa_2) d\kappa_2 \right) g(\kappa_3) d\kappa_3 \}
\]

This provides the following solution assuming $r_t$ and $a_t$ are constant:

\[
E(V_0) = -R - \frac{r + Ah_1}{\mu + h_1} - \frac{Ah_1 \mu}{(\mu + h_1)(\mu + h_2)} + \frac{Bh_1 h_2}{(\mu + h_1)(\mu + h_2)} - \frac{\theta h_1 h_2}{(\mu + h_1)(\mu + h_2)(\mu + h_3)}
\]

Equation 2 is the expected value of immediate investment. This expectation may change over time. As can be seen from equation 2, if the expectations about the length of the approval process reduces and/or the fixed approval costs are reduced and/or the benefits, $B$, increase the expected value of the investment increases, while, if the opposite happens, the expected value decreases. This is not a negligible possibility regarding the debates around NPBTs.

For keeping the model simple, two future possibilities are considered, one, the future looks bright, $B$ is high, $B_h$, and $E(V_0)$ increases with probability $q$ to $E(V_h)$.
and one where the future looks less bright and \(E(V_0)\) decreases with probability \(1-q\) to \(E(V_t)\), \(q \in ]0,1[\). For keeping the model economical relevant the following is assumed:

**Assumption:** \(E(V_t) < 0 < E(V_0) < E(V_h)\).

Solving the model for a one unit of time, \(t=1\), delay such as one year, provides the following solution, with subscript \(p\) for postponement:

\[
E(V_p) = q \left( -R - \frac{r+Ah_1}{\mu+h_1} - \frac{ah_1}{\mu(\mu+h_1)(\mu+h_2)} + \frac{b_h h_2 h_3}{(\mu+h_1)(\mu+h_2)(\mu+h_3)} - \frac{\theta h_1 h_2 h_3}{(\mu+h_1)(\mu+h_2)(\mu+h_3)} \right) e^{-\mu}
\]

The objective of the firm assuming profit maximization and abstracting from potential issues related to competition among firms is as follows:

\[
\text{max} \{E(V_0), E(V_p)\}
\]

Equation (4) allows to identify the threshold for immediate investment versus postponement by taking the difference between equation 2 and equation 3.

Immediate investment is economical, if:

\[
B_0 > (1 - q e^{-u}) \left( -R \frac{\mu+h_1}{h_1 h_2} + \frac{r(\mu+h_2)}{h_1 h_2} + \frac{A(\mu+h_2)}{h_2} + \frac{a}{h_2} + \frac{b h_3}{(\mu+h_3)} \right) + q e^{-u} B_h
\]

**Lemma 1:** If NPBTs are banned, \(B_0 = 0\), it is always economical to postpone investment in research and development of NPBTs.

**Proof:** By definition \(B_h, R, A, r, a, h_1, \mu, q > 0\) and the right-hand-side of equation 5 always positive.

If all the costs are normalized to one the weighing factor or hurdle rate for the costs can be summarized as:

\[
(1 - q e^{-u}) \frac{\mu+h_1(\mu+h_2)+[(\mu+h_2)(\mu+h_3)](1+h_1)_+h_1(\mu+h_3)+h_2 h_3}{h_1 h_2 (\mu+h_3)}
\]

Equation 6 shows this factor is clearly larger than one. Table 1 shows weighing factors for different parameter values. They are substantially larger than one stressing the importance of regulatory policies on investment.
Lemma 2. A unit increase in all costs require substantially more than one unit of additional benefits $B_0$ for justifying immediate investment.

Proof: By definition $h_i, \mu, q > 0$ and equation 6 is larger than one.

The implications of the model will be discussed in the context of the debate about approval of NPBTs in the European Union.

**Legal Environment in the European Union**

The regulation of NPBTs has been a long contested field in the EU. Several Member States (most prominently Sweden) have introduced specific regulations such as approval requirements. Their conformity with European Union law is, however, yet uncertain. At European Union level (which this article focuses on) there are no specific regulations covering the area of NPBTs. Crops produced using these technologies are can either be subject to existing European Union provisions such as the ones on GMOs or Member State regulatory systems, e.g. in those where an approval procedure exists they are submitted to competent authorities for approval comparable to “conventional” plants. The European Commission has put a halt on this procedure and asked all Member States to not further assess and approve crops processed by using NPBTs until the Commission has published guidelines (European Commission 2015). However, since first these guidelines are still to be expected and second, even if published they would form a non-binding document only, stakeholders operate in a field of regulatory uncertainty until Member States or the European Commission has provided more details.

Meanwhile, academic discussions have evolved around the question whether products from NPBTs are or should be subject to special regulation (Sprink et al., 2016). Those who are in favour of non-special regulation base their argumentation on an argument in fact: as most NPBTs could not be separated from conventional
breeding techniques, they should also not be subject to special regulation (New Techniques Working Group, 2011). In essence, those proponents leave the question open if the current framework is applicable but rather argue that even if it were it should not. Based on this argument, some distinguish between those NPBTs that introduce new genetic elements (which are traceable) and those which do not alter the original elements. While the former should be subject to regulation, the latter should not. Those in favour of regulation either refer generally to inconclusiveness of data involved with NPBT and consequently call for regulation based on the precautionary principle following the regulations for GMOs (e.g. Then and Bauer-Panskus 2017).

**Applicability of EU’s GMO regime to NPBT**

The discussion whether and how NPBT are regulated under the European Union’s current legislative regime has recently gained momentum with the publication of Advocate General (AG) Bobek’s Opinion on the applicability of some provisions of the European Union’s GMO regulatory framework on some products derived from NPBT (Opinion of AG Bobek, C-528/16, ECLI:EU:C:2018:20). This Opinion forms only a non-binding recommendation to the Court of Justice of the European Union (CJEU), which at the time of writing has not delivered its judgment. However, research has shown in most cases the CJEU tends to follow the Opinion of the AG (Arebola et al, 2016). For the purposes of this article we refer to AG Bobek’s Opinion for identifying possible regulatory options for the European Union. In view of a non-existence of a special legal regime to cover products derived from NPBT those products may be subject to the existing regulatory regime for GMOs. Various acts exist which cover the regulation of GMOs in the European Union (see for a summary Wesseler and Kalaitzandonakes, 2011), out of which Directive
2001/18/EC on the deliberate release into the environment (hereinafter Directive)\(^1\) and Regulation (EC) 1829/2003 on genetically modified food and feed (hereinafter Regulation)\(^2\) stand out. Both established, among other tools, an authorization requirement for GMOs, which are released into the environment and for those to be used in food and feed.

The applicability of this GM regime on products derived from NPBTs depends on whether they would qualify as a GMO in the sense of the definition set out in Art. 2 (2) of the Directive. The literature and other stakeholder opinions are diverted over this question (Sprink et al. 2016). It has been observed that NPBTs using mutagenesis (which covers most NPBT) are according to Annex I B Directive exempted from GMO regulation, however, if the development of a GM plant involves a genetic modification step, it would hence be subject to scrutiny by EU GM regulations (Hartung and Schiemann 2014). Others have taken this separation further and emphasized the difference between the legal requirements regarding the scope and the exemption in the Directive (Spranger 2015). While, following this approach, there is large agreement that most of NPBT would fall under the definition, it was debated whether the “mutagenesis” exception would apply to NPBT. Lawyers debated whether this exception should be interpreted in the sense given to the word “mutagenesis” at the time of adoption of the Directive in 2001 (Krämer 2015, Spranger 2015) or whether it also covers NPBT developed after

\(^{1}\) Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms, OJ L 106, 17.4.2001, p. 1–39.

\(^{2}\) Regulation (EC) No 1829/2003 of the European Parliament and of the Council of 22 September 2003 on genetically modified food and feed, OJ L 268, 18.10.2003, p. 1–23.
2001. Possibly in reaction to a misleading framing of a statement to the European Commission on the issue from the German Federal Agency for Consumer Protection and Food Safety (Bundesamt für Verbraucherschutz und Lebensmittelsicherheit 2015) some scholars have interpreted this debate in a way that scholars would argue about whether the Directive is process-based or product based (Sprink et al. 2016). Indeed, the requirement for defining an organism as GM stipulated in Art. 2(2) of Directive 2001/18/EC, namely that “the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination” can be understood in both ways (New Techniques Working Group, 2011, p. 5). In practice, this is important, as most NPBT cannot be distinguished from natural breeding methods in the final product (European Parliament Research Service 2016, p. 5). Legally, however, this does not have much of an effect as essentially the wide scope of the formulation in Art. 2(2) of Directive 2001/18/EC covers most of NPBT, as the wide formulation of the exemptions in Annex I B illustrates arg. e contrario. In essence the main legal question is hence not whether NPBT fall within the scope, but rather how to interpret the exemptions from the scope. More precisely, whether the term “mutagenesis” in Annex I B Directive needs to be interpreted in a historical way (What did the lawmaker intend in the time of writing for the time of writing?, Option 1) or in evolutionary way, taking into account also developments since that time (What would the lawmaker have regulated in case it would have implemented the provision today?, Option 2). Grossly speaking, scientifically driven organisations such as the Swedish Gene Technology Advisory Board, the UK DEFRA and others expressed a clear preference for option 2, most of the time not even mentioning or discussion the possibility of option 1 (Gen-ethisches Netzwerk e.V. 2018). Probably, from a scientific perspective, it was just too obvious that most
NPBT would qualify as mutagenesis. Legal analysts, however, tended to prefer option 1 (Krämer 2015, Spranger 2015). The major reasoning is based on the formulation of Recital 17 of the Directive, which stated that "(t)his Directive should not apply to organisms obtained through certain techniques of genetic modification which have conventionally been used in a number of applications and have a long safety record." The argument was that conventional mutagenesis techniques, in contrast to NPBT, had been in use for nearly 100 years, hence “mutagenesis” in the sense of Annex I B Directive would refer to these conventional techniques only, while new techniques would inherit a bigger uncertainty element in terms of their safety (see in particular Spranger 2015). From a scientific perspective this argument is interesting as classical mutagenesis, while considered safe (Ahloowalia et al. 2004), results in many mutations, which are often random. These random, uncontrolled mutations arguably carry a much bigger risk potential than the targeted interventions of NPBT which are considered to be much more effective (van der Wiel et al, 2017) and much better to monitor (Fernandez et al. 2016).

The AG has adopted the two-step definition and exemption-approach, while highlighting that all products derived from mutagenesis, which satisfy the definition of GMO in the Directive, are covered by the definition of NPBT (Opinion of AG Bobek, C-528/16, ECLI:EU:C:2018:20, para 60). The textual argument is intrinsically plausible: if mutagenesis would not be covered by the definition, there would be no reason to exempt them in the Annex (Opinion of AG Bobek, C-528/16, ECLI:EU:C:2018:20, para 62). As most NPBTs use mutagenesis, they are hence covered by the scope of the Directive. Having adopted the scope-exception approach, the AG needs to emphasis on the legal meaning he provides to the interpretation of the mutagenesis exception. The AG plainly rejected the historical
interpretation, making room for the evolutionary interpretation, which covers also all NPBT using mutagenesis (Opinion of AG Bobek, C-528/16, ECLI:EU:C:2018:20, para 110). The reason provided for is, again, simple: It is unlikely that at the time of writing the Directive in 2001 the drafters did not account for potential technological process (Opinion of AG Bobek, C-528/16, ECLI:EU:C:2018:20, para 77). By introducing the caveat concerning the use of recombinant nucleic acid molecules into the exemption it did, however, already provide a solution for a possible implementation of new mutagenesis techniques into the exemption (Opinion of AG Bobek, C-528/16, ECLI:EU:C:2018:20, para 81). NPBT are hence largely exempted from the application of the Directive’s legal regime.

As the AG rightly emphasizes, this, however, does not necessarily mean that NPBT will remain unregulated. Rather, he invites the European Union to provide clearer and more detailed regulation on NPBT if it wishes to do so. Alternatively, Member States may regulate the use of NPBT. The exception is, that is also cleared by the AG, only a minimum harmonization provision (Opinion of AG Bobek, C-528/16, ECLI:EU:C:2018:20, para 129). Otherwise, he would see possible tensions with the precautionary principle (Opinion of AG Bobek, C-528/16, ECLI:EU:C:2018:20, para 122) and the general tendency in European Union GM regulation to give Member States more leeway to decide if and what kind of GM they would like to introduce to their market (Eriksson et al, 2018). Hence, while the majority of NPBT remain unregulated in view of the European Union Directive, Member States can initiate legislation, which would then bring these kind of laws in turn under the scrutiny of European Union primary law, in particular the freedom of goods in Art. 34 TFEU. If foods and feed are stake, in addition the regime of food and feed law would be applicable (Purnhagen et al., 2018).
The regulative options after the AG’s Opinion

In case the AG's Opinion will be adopted by the CJEU, this would open up four regulative options (Purnhagen et al, 2018):

1) No action will be taken and NPBTs will remain unregulated in terms of specific GMO law and regulations for “conventional” seeds at Member State level apply.

2) Member States take action and regulate these NPBTs under their own laws with effect for their territory.

3) European Union institutions take action and regulate NPBT at the European Union level.

4) European Union institutions in secondary legislation frame Member State laws for NPBTs.

The first two options can be realised within a minimum harmonization strategy, while the second two options would typically be realized by a maximum harmonization strategy, see on these strategies in the literature Gerner-Beuerle (2012).

Assessing the different options.

The results of the ex-ante regulatory standards and ex-post liability can be used to compare the different policy options discussed above. The reference option is Option1 where NPTS are treated similar to “conventional” crops that are not under the scrutiny of the Directive similar to the approval policy in the US (CAST 2018). Firms will have to register new varieties under the seed law in the different Member States, similar to the OMG developed oilseed rape and sunflower in France. In this case B will be large, \( \kappa_1 \) and \( \kappa_2 \) will be low and A and \( a_1 \) as well.
Also the research costs $R$ and $r_t$ will be lower as requirements for field trials such as fencing of field trials and other compliance costs as required for field trials of GMOs (see e.g. Beckmann Soregaroli Wesseler 2008) will not apply. Using equation 6 this simplifies for $A = 0$ and $a_t = 0$ to \(1 - q e^{-u} \frac{(\mu + h_1)(\mu + h_2)(\mu + h_3) + (\mu + h_2)(\mu + h_3) + h_2 h_3 h_3}{h_1 h_2 (\mu + h_3)}\). The bottom row of table 1 shows the effect of zero approval costs on the hurdle rate. The hurdle rate substantially decreases.

**Option 2 - Member States take action and regulate these NPBTs under their own laws with effect for their territory**

In this case the NPBTs are considered to be GMOs but exempted under the mutagenesis clause. Member States can implement additional regulations. As the view among Member States differs (Smart, Blum, and Wesseler, 2015) it is reasonable to expect that some Member States will ban or more heavily regulate their cultivation. They will not have the possibility to establish barriers for trade in products derived from the cultivation of NPBTs. In comparison to Option 1, the average length in approval, $\kappa_1$, as well as the approval costs $A$ will increase, while $B$ will be reduced as the technology cannot be used as widely. The voting results of Member States at the Standing Committee and the Appeal Committee on GMOs can be used as a proxy to determine which Member States might be looking more favourable at NPBTs. Using the results of Smart, Blum, and Wesseler (2015) it is reasonable to assume that countries like Austria, Bulgaria, France, Germany, Hungary, Italy, Luxembourg, Malta, Poland, Romania will prevent cultivations, while countries like Czech Republic, Denmark, Portugal, Slovakia, Spain, Sweden, The Netherlands, and the UK are more likely to allow cultivation following their country rules for “conventional” seeds. This solution may result in regulatory
competition and over time harmonization of regulations is expected (Kerber and van den Bergh 2008).

Option 3 - EU institutions take action and regulate NPBTs at the EU level.
Under this option most-likely the GMO Directive will be applied and NPBTs on a case-by-case basis may either fall under the mutagenesis exemption or not. For those technologies that do not fall under the mutagenesis exemption the steps for the approval of GMOs would apply. Decisions on the technologies would need to be reached following the comitology procedure of the EU. This includes voting by the Member States in the relevant committees where decisions need to be reached by qualified majority rule. Again, looking back at the past experiences on the approval of GMOs, reaching a qualified majority for or against a technology to be included under the mutagenesis exemption is highly unlikely. Finally, the European Commission will decide and they can be expected to follow the advice from the European Food Safety Authority (EFSA). The contribution by Sprink et al. (2016) provides some insights about the possible advice by EFSA. Many of the NPBTs can be expected to fall under the mutagenesis exemption (Purnhagen et al. 2018). While in the end a decision will be reached, the process will be highly time consuming. This will increase the waiting time for plant breeders and the factor \(1 - qe^{-u}\) in equation 6 will become larger and the incentives for delaying investments increase. An advantage of Option 3 is that if decisions have been reached those NPBTs that fall under the mutagenesis exemption do not face additional approval costs \(A, a\).

Option 4 - EU institutions in secondary legislation frame Member State laws for NPBTs.
In this case the European Union would develop a general legislative framework to be voted on by the EU Parliament and EU Council. Member States have the freedom to decide how to specifically apply the framework. This would be similar to the regulatory techniques used in the European Union’s General Food Law (European Parliamentary Research Service 2017). An example to what can be expected for the case of NPBTs are the regulations Member States use for coexistence policies of GMOs. Some Member States use very stringent coexistence policies that are coming close to a cultivation ban while others apply coexistence policies that have almost no effect on cultivation decision by farmers (see Beckmann, Soregaroli, and Wesseler 2014, 2011 for a detailed discussion). Looking at equation 6 the implications of Option 4 are that similar to Option 3 the term $(1 - q e^{-u})$ will increase due to the time delay a decision to be made about the appropriate regulatory policy. Depending on the effort the EU institutions involved will use to reach an agreement the time span can be relatively short with about two to three years as for example when the Directive has been developed in the late 1990’s, early 2000’s. Considering that at that point in time a shared view among Member States that GMO regulatory policies are needed existed (Wesseler and Kalaitzandonakes 2011) and that today views are more diverse it is reasonable to expect that the timeframe for developing the regulatory policy will take more than three years.

**A View Beyond the European Union**

The debate about NPBTs is not only limited to the European Union. The United States and other countries discuss the regulations of NPBTs as well. The United States have announced in May this year that the "USDA does not regulate or have any plans to regulate plants that could otherwise have been developed through traditional breeding techniques as long as they are not plant pests or developed
using plant pests”. This at first-hand may look as a very lenient regulatory policy. A more closer look at NPBTs and regulatory policies discloses that yet many products will be regulated similar to GMOs for reasons such as a combination of different events and plant breeding techniques (CAST 2018). The announcement, while providing regulatory certainty, does not seem to change the approval costs.

The fact sheet approach used for the approval of crops in Argentina has been appreciated in the literature (Purnhagen et al., 2018) for its simplicity. The additional approval costs are almost close to zero for NPBTs reducing the cost factor of equation 6. In Canada products developed by NPBTs will fall under the Novel Food Law, which follows a product based approach. The costs can be expected to be low as in particular many food products derived from NPBTs will not be distinguishable from other products.

The differences in regulatory policies observed around the world can be considered in the context of this paper as a minimum harmonization policy. Countries have the freedom to choose their own regulatory policies as long as those policies are in line with international legal obligations such as, for most, as disciplined by WTO law. There is an important difference between the European Union and the world market. In the European Union regulations at Member State level would only affect cultivation but nor extra-European Union trade. At world market level this is currently not the case. The European Union has currently a ban on imports of food products derived from NPBTs. A similar policy applies for imports into the US depending on the specific trait if they have not received approval by the USDA. The difference in regulatory policies at international level can be expected to increase friction in international trade. Even so, one may argue commodities or food products derived from the application of NPBTs cannot be differentiated from
“conventional” commodities and food products, this did not prevent countries from imposing import restrictions. In many cases it is just enough knowing that NPBTs are applied for imposing import restrictions. Looking at equation 5, this reduces $B_0$ and increases $B_h$ providing strong incentives for delaying investment. Further, the regulatory uncertainties at international level increases the ex-post liability costs for the private sector. Reaching international agreements on trade in NPBTs can have a strong effect on the incentives to invest in applying the technologies as an agreement reached will increase $B_0$ and reduce $B_h$.

**Conclusions**

The regulatory options at European Union level have an effect on the incentives of the private sector to invest in the technologies. Options based on minimum harmonization provide stronger incentives than those based on maximum harmonization. Minimum harmonization reduces research and approval costs including approval length. While minimum harmonization may not provide access to the whole European Union market for cultivation of crops, maximum harmonization will do neither. Countries against the cultivation of crops based on NPBTs have other means for de-facto banning cultivation.

The results of the model show that is difficult to derive a solution with a common hurdle rate for all cost items. This requires a careful interpretation of the results. Nevertheless, the basic result that uncertainty and irreversibility has a strong effect on postponing investment in NPBTs holds. Interestingly the marginal effect of a delay by one or two years is not that strong as a change in the time length for research and approval. At the time of deciding about investment into NPBTs the marginal effect of ex-post liability after market entry have only a small effect on the incentives for investment, while ex-pot liability can be used as a substitute.
for approval costs. Moving in this direction will have a strong effect on incentives for investment. This not only applies at EU but also at international level. A liability system at international level that compensates approval costs will even further strengthen incentives to invest in NPBTs.

The model we present only assesses incentives for immediate or postponed investment in the application of NPBTs by the private sector. The model can be enriched by adding details about the benefits generated including competition issues, but also international market access. The model we present provides the framework.

We illustrate the implications of regulatory policies providing numerical examples. The model predicts that there are gains from regulatory harmonization. They should result in an increase in investments in NPBTs. At this point in time it is not possible to test this for the specific case of NPBTs as they are just entering the market and we leave this for future research.
References

Ahloowalia, B.S., M. Maluszynski, and K. Nichterlein  Global impact of mutation-derived varieties. Euphytica 135, 187–204.

Arrebola, C., Maurício, A.J. & Portilla, H.J. An econometric analysis of the influence of the Advocate General on the Court of Justice of the European Union. Cambridge J. Comp. Int. Law 5, 82-112 (2016). doi: 10.7574/cjicl.05.01.82

Beckmann, Volker, Claudio Soregaroli, and Justus Wesseler (2014): Coexistence. In David Castle, Peter Phillips and Stuart Smyth (eds.), Handbook on Agriculture, Biotechnology and Development, Chapter 25, 372-391. Edward Elgar, Cheltenham.

Beckmann, Volker, Claudio Soregaroli, Justus Wesseler (2011): Coexistence of genetically modified (GM) and non-modified (non GM) crops: Are the two main property rights regimes equivalent with respect to the coexistence value? In "Genetically modified food and global welfare" edited by Colin Carter, GianCarlo Moschini and Ian Sheldon, pp 201-224. Volume 10 in Frontiers of Economics and Globalization Series. Bingley, UK: Emerald Group Publishing. (Downloads: 177, June 12, 2018).

Beckmann, Volker, Claudio Soregaroli, and Justus Wesseler (2010). Ex-Ante Regulation and Ex-Post Liability under Uncertainty and Irreversibility: Governing the Coexistence of GM Crops. Economics: The Open-Access, Open-Assessment E-Journal, Vol. 4, 2010-9.

Beckmann, Volker, Claudio Soregaroli, Justus Wesseler (2006): Co-Existence Rules and Regulations in the European Union. American Journal of Agricultural Economics 88(5):1193-1199.

Bundesamt für Verbraucherschutz und Lebensmittelsicherheit. 2015. Interpretation of § 2 (2) of Directive 2001/18/EC in order to clarify legal

Electronic copy available at: https://ssrn.com/abstract=3244309
status of organism created by New Plant Breeding Technologies (NPBT). Available at [https://corporateeurope.org/sites/default/files/attachments/14._09-28_letter_de_redacted_0.pdf](https://corporateeurope.org/sites/default/files/attachments/14._09-28_letter_de_redacted_0.pdf), last accessed June 19, 2018.

Council for Agricultural Science and Technology (CAST). 2018. Regulatory Barriers to the Development of Innovative Agricultural Biotechnology by Small Businesses and Universities. Issue Paper 59. CAST, Ames, Iowa.

Eriksson, D, E. de Andrade, B. Bohanec, S. Chatzopolou, R. Defez, N.L. Eriksson, P. Van Der Meer, B. Van Der Meulen, A Ritala, L. Sági, J. Schiemann, T. Twardowski, and T. Vaněk. 2018. Why the European Union needs a national GMO opt-in mechanism. *Nature Biotechnology* 36, 18–19.

European Commission. 2015. DG SANTE. Letter to competent authorities. [https://corporateeurope.org/sites/default/files/attachments/18._2015.06.15_lettre_autorites_competentes_redacted_1.pdf](https://corporateeurope.org/sites/default/files/attachments/18._2015.06.15_lettre_autorites_competentes_redacted_1.pdf), last accessed on June 20, 2018.

European Parliamentary Research Service. 2016. New plant-breeding techniques. Applicability of GM rules. Available at [http://www.europarl.europa.eu/thinktank/en/document.html?reference=EP RS_BRI(2016)582018](http://www.europarl.europa.eu/thinktank/en/document.html?reference=EP RS_BRI(2016)582018), last accessed June 19, 2018.

European Parliamentary Research Service. 2017. The EU's General Food Law Regulation. Available at: [http://www.europarl.europa.eu/thinktank/en/document.html?reference=EP RS_IDA(2017)595906](http://www.europarl.europa.eu/thinktank/en/document.html?reference=EP RS_IDA(2017)595906), last accessed June 20, 2018.

Fernandez, O., M. Urrutia, S. Bernillon, C. Giauffret, F. Tardieu, Le Gouis, J., N. Langlade, A. Charcosset, A. Moing, and Y. Gibon. 2016. Fortune telling: metabolic markers of plant performance. *Metabolomics* 12:158, 1-14.

Electronic copy available at: [https://ssrn.com/abstract=3244309](https://ssrn.com/abstract=3244309)
Gen-ethisches Netzwerk e.V. 2018. Collected correspondence. Available at https://www.gen-ethisches-netzwerk.de/files/cibus_bvl_uig_1500.pdf, last accessed June 19, 2018.

Gerner-Beuerle, C. 2012. United in diversity: maximum versus minimum harmonization in EU securities regulation. Capital Markets Law Journal 7(3), 317-341.

Hartung, F., and J. Schiemann. 2014. Precise plant breeding using new genome editing techniques: opportunities, safety and regulation in the EU. The Plant Journal 78: 742-752.

Kalaitzandonakes, N., J. M. Alston, and K. J. Bradford. 2007. Compliance costs for regulatory approval of new biotech crops. Nature Biotechnology 25:509–511.

Kerber, W. and R. van den Bergh. 2008. Mutual Recognition Revisited: Misunderstandings, Inconsistencies, and a Suggested Reinterpretation. Kyklos 61(3): 447–465.

Kolstad, C. D., T.S. Ulen, G.V. Johnson 1990. Ex Post Liability for Harm vs. Ex Ante Safety Regulation: Substitutes or Complements? American Economic Review. 80(4): 888-901.

Krämer, L. 2015. Legal questions concerning new methods for changing the genetic conditions in plants. Available at http://www.testbiotech.org/sites/default/files/Kraemer_Legal%20questions_new%20methods_0.pdf, last accessed June 19, 2018.

Lusser M., C. Parisi, D. Plan D, E. Rodriguez-Cerezo. 2011. New plant breeding techniques: state-of-the-art and prospects for commercial development. Joint Research Centre Technical Report EUR 24760. European Commission Joint Research Centre, Brussels.
New Techniques Working Group. 2008. Final Report. Available at http://www.seemneliit.ee/wp-content/uploads/2011/11/esa_12.0029.pdf, last accessed June 19, 2018.

Opinion of AG Bobek delivered on 18 January 2018(1), Case C-528/16, Confédération paysanne et al v. Premier ministre Ministre de l’agriculture, de l’agroalimentaire et de la forêt, ECLI:EU:C:2018:20. Available at http://curia.europa.eu/juris/document/document.jsf?text=&docid=198532&pageIndex=0&doclang=EN&mode=req&dir=&occ=first&part=1&cid=417388, last accessed June 19, 2018.

Purnhagen, K., E. Kok, G. Kleter, H. Schebesta, R. Visser, and J. Wesseler. 2016. The European Union Court’s Advocate General’s Opinion and new plant breeding techniques. Nature Biotechnology 36, 573-575 (2018).

Shavell, S. 1984. A Model of the Optimal Use of Liability and Safety Regulation. The RAND Journal of Economics, 15(2):271-280.

Shleifer, A. 2010. Efficient Regulation. NBER Working Paper No. 15651.

Smart, R., M. Blum and J. Wesseler. 2017. Trends in Genetically Engineered Crops’ Approval Times in the United States and the European Union. Journal of Agricultural Economics 68(1): 182-198.

Smart, R., M. Blum and J. Wesseler. 2015. EU Member States’ Voting for Authorizing Genetically Engineered Crops: a Regulatory Gridlock. German Journal of Agricultural Economics 64 (4): 244-262.

Smyth, S. J., W. Kerr, P. Phillips. 2017. Biotechnology Regulation and Trade. United States: Springer.

Spranger, T. M. 2018. Legal Analysis of the applicability of Directive 2001/18/EC on genome editing technologies. Available at Electronic copy available at: https://ssrn.com/abstract=3244309
Sprink, T., D. Eriksson, J. Schiemann, and F. Hartung. 2016. Regulatory Hurdles for Genome Editing: Process- vs. product-based approaches in different regulatory contexts. *Plant Cell Reports* 35:7, 1493-1506.

Then, C. and A. Bauer-Panskus. 2017. *Playing Russian Roulette with Biodiversity*. Munich: testbiotech.

USDA. 2018. Secretary Perdue Issues USDA Statement on Plant Breeding Innovation. Press Release Release No. 0070.18. USDA Press.

van de Wiel, C.C.M., J.G. Schaart, L.A.P. Lotz, and M.J.M Smulders. 2017. New traits in crops produced by genome editing techniques based on deletions. *Plant Biotechnology Report* 11, 1-8.

Wesseler, J. and N. Kalaitzandonakes. 2011. Present and Future EU GMO policy. In A. Oskam, G. Meesters and H. Silvis (eds.), *EU Policy for Agriculture, Food and Rural Areas*. Second Edition, pp. 23-323 – 23-332. Wageningen: Wageningen Academic Publishers.

World Health Organization. 1990. *Diet, Nutrition, and the Prevention of Chronic Diseases*. Geneva: WHO.
Table 1. Hurdle Rates for Different Parameter Values

| $E(\kappa_1)$ | 10 | 5  | 2.5 | 1  |
|---------------|----|----|-----|----|
| Hurdle Rate   | 14.59 | 10.80 | 8.91 | 7.78 |
| $E(\kappa_2)$ | 10 | 5  | 2.5 | 1  |
| Hurdle Rate   | 14.59 | 10.70 | 8.76 | 7.59 |
| Hurdle Rate Zero Approval Costs | 8.66 | 4.88 | 2.99 | 1.86 |

Note: the hurdle rates are calculated applying equation 6. Other parameter values are fixed at $\mu = 0.04$, $q = 0.5$, $E(\kappa_i) = 10$ if not otherwise.