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RESEARCH ARTICLE

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Abstract

A large proportion of the literature on the international trade of agricultural products has focused on evaluating the impact of sanitary and phytosanitary (SPS) restrictions on trade, in particular when these restrictions are issued by states. At the same time, very few studies have analysed the impact of SPS measures promoted by specialist international organisations. One explanation for this different handling would be that, as the result of the scientific work of independent expert committees, international measures are seen as rational, neutral and thus not particularly distortionary. We refer to this as science-based international discipline. In this work, we assume that, while founded on scientific bases, the SPS standards recommended by the international organisations may be relevantly inefficient in regulating trade due to the existence of path dependence phenomena. Drawing on North's neo-institutional approach, we study a scientific evaluation standard relating to the efficacy of phytosanitary treatments, known as 'Probit 9', which is systematically used by the international bodies responsible for regulating trade. The aim is to demonstrate that, while facilitating the emergence of highly robust SPS risk management systems, such a standard has prevented the emergence of other equally effective and potentially less costly risk management methods, leaving us to ponder this situation of 'lock-in' so typical of path dependence. We illustrate this issue with the case of 'certified wooden pallets' and the associated international certification standard, ISPM 15.

Keywords International trade · SPS measures · Probit 9 · Path dependency

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Introduction

The list of food or environmental crises that can be ascribed to trade is so long that it is impossible to deny that the international trade of agricultural and agri-food products is a vector of major sanitary and phytosanitary risks (Castonguay, 2005; Jenkins, 1996; Zepeda et al., 2001; Whattam et al., 2013). Faced with such risks, importing countries have always protected themselves by means of trade restriction measures that we now refer to as non-tariff measures, and more particularly as sanitary and phytosanitary (SPS) measures. Often imposed unilaterally by importing countries or bilaterally with the agreement of partner countries, SPS measures have enjoyed an impressive boom since the beginning of the 1990s.[1]

The development of national SPS regulations, as well as that of international trade disputes, quickly drew the attention of researchers in economics and social sciences. The former (the economists) have often focused on evaluating the distorting power of national SPS measures, by measuring their 'barrier' effect on international trade and social welfare (Calvin and Krissof, 1998; Beghin & Bureau, 2002; Disdier et al, 2008; Marette & Beghin, 2010). They generally arrive to the conclusion that, while national SPS standards can facilitate trade, they can also act as trade impediments, or, even worse, be voluntary used for protectionist purposes, showing so their deep political nature rather than their scientific legitimacy. The second (mainly researchers in law, political sciences or sociology) have questioned the capacity of actual multilateral trade regime to build a neutral and efficient international trade space, and in particular its capacity of resolving members' trade disputes based on scientific knowledge (what is known as 'science-based trade discipline': Atik & Wirth, 2003; Bonneuil & Levidow, 2012; Wirth, 1994). They often conclude to the inefficacy of WTO's trade regime, showing that international regulatory devices, as trade disputes resolution bodies or the very concept of risk, which should be neutral, technical and scientifically measurable objects, are in fact objects deeply political and partisan in nature. In this work, we try to contribute to the analysis of the impact of SPS measures on international trade in a third different way. Different in the sense that, on the one hand, we are interested in SPS measures promoted by international authorities (and not by national ones), and, on the other hand, we assume that these international standards may be inadequate not because they would be the result of a partisan selection process, but because, although based on scientific knowledge, they would be the result of a path-dependent selection mechanism (North, 1990) specific to international institutions of scientific expertise.

With the application of the Agreement on Sanitary and Phytosanitary Measures in January 1995 (SPS Agreement, 1995), the WTO recognised that each member state has the right to impose trade restriction measures to ensure the safety of imported agricultural and agri-food products (art. 2.1). Nevertheless, while recognising this

[1] 198 SPS notifications submitted during 1995 compared to 1,632 during the course of 2018. Source: WTO-SPSIMS dataset. As with SPS measures, the number of technical barriers to trade (TBT) has also increased since the 1990s. In this paper, however, we chose to focus exclusively on SPS aspects linked to the trade of fresh produce.

right, the main aim of the Agreement is to regulate the sovereign production of such restrictive measures in order to avoid duplication and protectionist excesses. To this end, the SPS Agreement entrusts science, and in particular scientific proof, with the role of assessing the validity of the restrictions imposed (art. 2.2) by proposing three conditions. The first is that the states base their requests for restrictive measures on internationally recognised scientific studies illustrating the extent of the risk involved and the validity of the requested restrictive measure (art. 2.2 and 3.3). The second condition is that, when faced with the choice of several equivalent restrictive measures (in terms of the level of quarantine security they provide), states prioritise those which minimise the economic impact on trade (art. 5.4 and 5.5). The third and final condition is that where international standards exist, states make every effort to comply with them (art. 3.1 and 3.2).

International standards are determined by specialist international science-based bodies recognised by the WTO: the World Health Organisation together with the Food and Agriculture Organisation (WHO/FAO) with regard to all issues relating to food intended for consumption by humans and animals (e.g. Codex Alimentarius, maximum residue limits); the World Organisation for Animal Health (OIE), which prepares standards for managing epizootic risks (thus relating to animals); and the International Plant Protection Organisation (IPPO), which prepares standards for managing phytosanitary risks (thus relating to plants). In the case of interest to us here, plants, it is the IPPO which prepares the international phytosanitary risk management standards, referred to as ISPMs (International Standards for Phytosanitary Measures), based on suggestions submitted by the member states. To this end, the IPPO calls on groups of experts from around the world (EWGs) as well as scientific criteria on which there is a general consensus and which serve to evaluate the efficacy of the measures suggested.

According to the WTO, the scientific nature of the work undertaken by these science-based international organisations (determination, evaluation and harmonisation of SPS standards) would be proof not only of the strictest efficacity of the standards developed but also of their utmost neutrality (Atik & Wirth, 2003; Bonneuil & Levidow, 2012; Wirth, 1994) compared to the SPS measures imposed by the states. In light of their singular and partisan nature, national measures could be suspected of reflecting political opportunism or disguised commercial protectionism.

While there is a certain logic to the WTO's position, we suggest that despite the eminently scientific work carried out by the specialist international organisations, there is no guarantee that the international standards they develop are either neutral (no partisan interests) or efficient (in the economic sense of the word). In this respect, we call on the theory of institutional path dependence developed by North (1990), according to which the existence of increasing returns of adoption combined with high transaction costs allows the persistence of sub-optimal standards over time, despite the existence of alternative solutions which are probably more efficient. More precisely, we suggest that, when international organisations choice a scientific criterion (one among others) to evaluate and select the most effective SPS treatments, and make it an evaluation standard, this criterion will be also subject to the risk of path dependence, because of its new institutional nature (that of standard).

A better understanding of this problem (the path dependence of scientific standards), which we feel is insufficiently developed in the economic literature (compared to the path dependence of technical or institutional measures), would enable the international organisations tasked with developing phytosanitary standards to promote innovation and change, or at least to pay more attention to the weak signals of change coming from the communities of scientific experts.

To support this point of view, we propose here to study the case of a 'statistic' largely known as 'Probit 9'. This statistic is used systematically as a standard in the international processes of scientifically evaluating the efficacy of phytosanitary treatments. Our aim is to show that, while facilitating the emergence of highly robust (in statistical terms) SPS risk management systems, this standard (Probit 9) has prevented the emergence of other equally effective and potentially less costly risk management methods, leaving us to ponder this situation of 'lock-in' so typical of path dependence. In order to illustrate the relevance of this standpoint, we will use the case of 'certified wooden pallets' and the associated international certification standard, ISPM 15. This purely instrumental choice is based on the fact that certified wooden pallets are the most commonly used material element in global trade and that the standard used to certify them (ISPM 15) has, for a number of years, been the subject of criticism by the scientific community targeting the 'Probit 9' standard.

Finally, the document is organised as follows: in the first section, we quickly recall the theoretical and methodological framework used in this case study. We then examine 'Probit 9' and the factual elements underpinning the success of this statistic and making it a 'de facto' international standard of evaluation. In the third section, we call on the existing scientific literature (and in particular that published by the community of entomologists) to show why this standard poses a problem with regard to certifying wooden pallets intended for use in international trade and, more broadly speaking, in research and innovation activities in the field of phytosanitary risk management. In the fourth section, we address the question of the institutional economics standpoint and return to the concept of path dependence before concluding.

Theoretical framework and methodology

While the theory of path dependence, in particular in technical terms, is generally associated with the publication of an article by David in 1985 concerning the history of the QWERTY keyboard (David, 1985), the main elements of this theory were formalised a little earlier by another economist, Arthur (1984, 1989, 1990). Arthur made his work on 'increasing returns', the watershed between 'conventional economics' and so-called "positive feedback economics". Within the framework of conventional economics, the hypothesis of diminishing marginal returns of production or adoption means that the economic system always tends (ex-ante or ex-post) towards Pareto efficiency, i.e. the best possible allocation of a factor of production, long-term stable equilibrium prices or the adoption of the most efficient production technology on the market.[2] On the contrary, in the case of economic systems characterised by increasing returns (of production or adoption), such a process of optimum selection (ex-ante) or adjustment (ex-post) can in no way be guaranteed. More precisely, the existence of increasing returns means that the choice of path taken depends more on potentially insignificant variables (the little accidents of history, past choices) than on the capacity of the path chosen to maximise the efficiency of the system. Furthermore, increasing returns make it very costly to backtrack (towards a fork in the path which, with hindsight, appears more effective). In this case, we talk of lock-in situations.

As recalled in a recent paper (Lubello & Codron, 2020), the ideas of Arthur and David spread quickly within the spheres of political science (Pierson, 2000), social science (Granovetter, 1985) and economics (Krugman, 1994; Pomeranz & Topik, 1999), in particular among the neo-institutionalists (North, 1990; Williamson, 1991).[3] It was in the 1990s that North (1990) developed a theory of 'institutional path dependence' by introducing the notion of transaction costs, developed by Coase (1937, 1960) in addition to increasing returns of adoption. Both of these factors disturbed the operation of competitive markets by making the path towards Pareto optimum non-automatic, or at least unpredictable.

Just as Arthur's work on increasing returns made it possible to differentiate conventional economics from positive feedback economics, the work of North produced the same differentiation with regard to considerations concerning institutions, in particular in the field of property rights. It should be recalled that a 'Darwinian' interpretation of the history of western institutions long prevailed in this domain (Alchian, 1950; Alchian & Demsetz, 1973; North & Thomas, 1973), according to which private ownership systems—and more generally speaking institutional experiences of capitalist market economy systems—proved that they were economically and socially more efficient simply because they survived while alternative (and in particular socialist) systems failed. This interpretation was implicitly or explicitly underpinned by the idea that, as the economic and institutional worlds were subject to the law of diminishing marginal returns, only the most efficient systems could survive over time. North (1990) ultimately opposed this vision, observing that economic under-development persists over time and that this persistence can be interpreted as the consequence of a situation of institutional lock-in. He put forward that this situation was generated by the presence of increasing returns of adoption and high transaction costs which prevented institutional change, even in the presence of more efficient alternatives (namely the experiences of developed countries).

Echoing North's work (1990), we suggest that, within the framework of international trade, the presence of increasing returns of adoption and high transaction costs (i.e. bilateral or multilateral negotiation costs and contract enforcement costs), can only encourage the emergence of path dependence and institutional lock-in. In this respect, the case of international agri-food markets is an excellent example. Known

[2] This is what Arthur (1989) defines as an ergodic system.

[3] For a broader overview of Arthur's theses in the fields of economics, management, politics and social sciences, see Donnelly's article (Donnelly, 2009).

for their high level of environmental and contractual uncertainty (unstable supply, high price volatility, difficulty in evaluating the intrinsic quality of the products traded, SPS risks associated with their trade), the international agri-food markets are characterised by high transaction costs (Ménard, 2000; Ménard & Valceschini, 2005; Pavez et al., 2019). In line with the theory of institutional path dependence, there is no guarantee that in the presence of such costs, the institutions which emerge to make international trade safer and more predictable (i.e. the international trade institutions and standards) will maximise trade flows and social well-being.

To finish, and still in line with the path dependence literature, the analysis method used can only be comparative (North, 1990). Indeed, in order to speak of a situation of path dependency, it is necessary to be able to compare the current solution (technical, organisational or institutional) with an alternative solution that would be really existing, more efficient and materially achievable (not ideal). In this respect, Williamson says 'real costs in relation to real choices is what comparative institutional economics is all about' (1994, p 96).

Sensitive to the criticisms raised by Liebowitz and Margolis (1990, 1995) about the possible misuse of the notion of path dependence, Williamson (1994) proposes the concept of 'remediability'[4] (1994, 2014) to evaluate this kind of phenomena. This concept has two functions: to replace the 'efficiency' principle of the Nirvana's economics (Demsetz, 1969), and then in order to isolate among all the presumed cases of 'path dependence' those that would represent real cases of market failure.

For Williamson (1994, 2014), a case of path dependence (in the sense of market failure) exists when (1) the initial choice (arrangement) leads to an inefficient outcome and (2) alternative feasible solutions (arrangements) exist and can be implemented with expected net gains, (3) but the shift to this better account is not obtained. While the first two conditions define what is a 'remediable' situation (remediable inefficiencies), the third reveals the inefficient nature of the coordination system (market). The three conditions together define what Williamson calls 'path dependency'. In light of this concept, only by continuing down a given path, despite the existence of alternative feasible (remediable) solutions, are we authorised to talk of path dependence and lock-in.

Finally, Williamson (1994) reminds us that, while it is sometimes abusive to conclude that 'path dependence' situations exist when the persistence of bad choices are the expression of poorly informed (limited knowledge) individuals (private ordering), it is less abusive if the public sector (public ordering) is involved. This is provided that '(1) the public sector is better informed about network externalities; (2) the requisite collective action is easier to orchestrate through the public sector (possibly by fiat); and/or (3) the social net benefit calculus differs from the private in sufficient degree to warrant a different result' (Williamson, 1994, p 95).

[4] Williamson (2014) defines a remediable mode of organization or practice, an existing mode of organization or practice, for which "(1) superior feasible alternative can be described and (2) implemented with expected net gains, and which is (3) presumed to be effective…If such abuse is ignored, an existing mode should not be described as inefficient unless a feasible superior alternative is described for which net gains will be realised after implementation costs are taken into account".

We will now attempt to demonstrate that, as an international standard for evaluating the efficiency of SPS measures (be they international or national), the case of Probit 9 corresponds to a case of path dependence characterised by 'remediable inefficiencies' due to the existence of more appropriate alternatives.

Probit 9: the historical accidents of a success story

In 1934, the American biologist, Chester Bliss, published an article in the review 'Science' describing the 'Probit' model (Bliss, 1934), a statistical binomial regression model, with the aim of estimating the extent to which an independent variable would influence the probability that a binary dependent variable (i.e. which can only take 2 discrete values, 0 or 1) takes the value 1. Starting with the assumption that such a probability is distributed according to a normal law, the model proposed by Bliss helped a number of experimental works to be developed further and allowed dichotomic variables, such as that a sample of insects is killed or not by a given dose of pesticide, to be processed appropriately. The Probit model is thus nothing more than a statistical tool for evaluating the efficacy of the treatment. In this paper, the author arbitrarily translated the probability percentage into probability units (shortened to produce the name of Probit) such that Probit 0 corresponds to a probability of 0.01% that the dependent variable takes the value of 1, Probit 5 corresponds to a probability of 50% and Probit 10 corresponds to a probability of 99.9999%, always within a confidence interval of 95%.

Some years later, in 1939, Baker, the head entomologist at the United States Bureau of Entomology and Plant Quarantine, published a circular for the United States Department of Agriculture (Baker, 1939) entitled 'The basis for treatment of products where fruit flies are involved as a condition for entry into the United States'. Calling on the works of Bliss (1934) and Fisher (1935), Baker recommended Probit 9 as the level of efficacy to be achieved for a phytosanitary treatment (initially against fruit and melon fly) to be accepted (Haack et al., 2011), i.e. a probability of 99.9968% that a sample of 93,613 individuals presents no survivor after treatment (according to Couey & Chew, 1986).

The decision by Baker and the USDA to choose Probit 9 was thus justified by the high level of quarantine security it achieved with regard to insects (such as the fruit fly) among which the rates of infestation and reproduction were relatively high. It should be recalled that at this time, the USA was faced with large-scale phytosanitary crises (1907, 1929, 1966, 1975) linked to imports of fresh agricultural produce and the introduction of the fruit fly (Ceratitis Capitata) to its national territory. It was thus against this backdrop that the USDA adopted Probit 9 as the reference criterion for approving quarantine treatments for a wide variety of pests (Schortemeyer et al., 2011),[5] despite the mixed opinions of certain researchers within the institution

[5] Even recently, the USDA APHIS amended its Phytosanitary Treatments Manual, and in particular the cold treatment protocol for fruit fly with a view to eliminating options not guaranteeing a level of efficacy equal to Probit 9 (USDA, 2002).

concerning the excessive severity of the evaluation criterion adopted (Follett & McQuate, 2001; Follett & Neven, 2006; Liquido et al., 1997).

Other countries subsequently followed the example of the USA, adopting efficacy evaluation criteria identical, or very similar, to Probit 9 (99.99%, i.e. Probit 8.71), sometimes in bilateral trade negotiations (Follett & Neven, 2006; Lubello & Codron, 2020) and sometimes in disputes taken up with the Dispute Settlement Body (DSB: WTO, 1998).[6] Without ever becoming an official (de jure) international evaluation standard, its implicit adoption by the IPPO and its convention (IPPC) has made it a 'de facto' international standard for evaluating the efficacy of quarantine treatments since the beginning of the new millennium. On this matter, it should be recalled that in a 2008 report by the Technical Panel of Forest Quarantine (TPFQ: IPPC, 2008), one of the commissions of the IPPO, stated that all processes for evaluating the efficacy of phytosanitary measures 'ultimately require the Probit 9 test'. Haack et al. (2011) emphasise that as recently as 2010, in a preparatory document of the annexes to ISPM 15, it was established that 'the level of efficacy required to be able to talk about a successful treatment is 99.9968%, at a confidence level of 95%, for the organisms selected'. Some years later, in 2013, the Phytosanitary Measures Commission (IPPC, 2013) organised a 'scientific session' entitled 'Phytosanitary Security Based on a Probit 9 Treatment Standard'.

Finally, it is enough to examine the details of the phytosanitary treatments recommended by the IPPO to see that almost all the latter are based on scientific research which used Probit 9 as the criterion for evaluating the efficacy of the measure. Table here below (Table 1) lists the 21 'phytosanitary treatments for regulated pests' contained in ISPM 28 as well as the 4 treatments currently recommended within the framework of ISPM 15 governing the 'use of wood packaging material used in international trade'.

To finish, aside from the historical context of its emergence, the international success of Probit 9 may be ascribed to the high level of quarantine security it affords importing countries, the possibility for the latter to cover a wide range of uncertainties by focusing on the least favourable hypothesis (contamination), its ease of calculation (using a table or a computer) and its broad use in the field of pesticides' efficacity evaluation (Griffin, 2013).

What's wrong with Probit 9 and which alternatives?

Since the beginning of the new millennium, a large volume of research has been conducted—essentially by entomologists—calling the relevance of Probit 9 into question as a general standard for evaluating the efficacy of phytosanitary treatments. While proposing potentially more appropriate methods, this research raises the issue of several problems.

[6] Example of the USA-Japan dispute. Document WT/DS76/R, available here https://www.wto.org/french/tratop_f/dispu_f/76r.pdf

Table 1 ISPM and Probit 9 (source: IPPC, prepared by the author)

NORME	Organism targeted	(Main) supporting research	Efficacity level % Probit9 = 99.9968
ISPM 28–1 (2009–2017)	*Anastrepha ludens*	Hallman & Martinez (2001)	99.9968
ISPM 28–2 (2009–2017)	*Anastrepha obliqua*	Bustos et al. (2004)	99.9968
ISPM 28–3 (2009–2017)	*Anastrepha serpentina*	Bustos et al. (2004)	99.9972
ISPM 28–4 (2009–2017)	*Bactrocera jarvisi*	Heather et al. (1991)	99.9981
ISPM 28–5 (2009–2017)	*Bactrocera tryoni*	Heather et al. (1991)	99.9978
ISPM 28–6 (2009–2017)	*Cydia pomonella*	Masour (2003)	99.9978
ISPM 28–7 (2009–2017)	*Tephritidae*	Bustos et al. (2004)	99.9968
ISPM 28–8 (2009–2017)	*Rhagoletis pomonella*	Hallman & Thomas (1999)	99.9968
ISPM 28–9 (2010–2017)	*Conotrachelus nenuphar*	Hallman (2004)	99.9880
ISPM 28–10 (2010–2017)	*Grapholita molesta*	Hallman (2004)	99.9949
ISPM 28–11 (2010–2017)	*Grapholita molesta*	Hallman (2004)	99.9932
ISPM 28–12 (2011–2017)	*Cylas formicarius*	Follett (2006), Hallman (2001)	99.9952
ISPM 28–13 (2011–2017)	*Euscepes postfasciatus*	Follett (2006)	99.9950
ISPM 28–14 (2011–2017)	*Ceratitis capitata*	Follett & Armstrong (2004)	99.9970
ISPM 28–15 (2011–2017)	*Bactrocera cucurbitae*	Hallman & Mangan (1997)	99.9889
ISPM 28–16 (2015–2017)	*Bactrocera tryoni*	Hallman & Mangan (1997)	99.9981
ISPM 28–17 (2015–2017)	*Bactrocera tryoni*	Hallman & Mangan (1997)	99.9886
ISPM 28–18 (2015–2017)	*Bactrocera tryoni*	Dohan et al. (2012)	99.99
ISPM 28–19 (2015–2017)	*Dysmicoccus neobrevipes,* etc	Dohan et al. (2012)	99.9902
ISPM 28–20 (2016–2017)	*Ostrinia nubilalis*	Hellman & Hellmich (2009)	99.9914
ISPM 28–21 (2016–2017)	*Bactrocera melanotus,* etc	Waddel et al. (1993)	99.9914
ISPM 15 HT (2002)	*Several pests*	Smith (1991, 1992)	99.9949
ISPM 15 MB (2002)	*Several pests*	Liese & Reutze (1985)	99.9968
ISPM 15 SF (2013)	*Pine wood nematode*	Sousa et al. (2010)	99.9968
ISPM 15 DH (2013)	*Pine wood nematode, ALB*	Houver et al. (2010)	99.9968

1) First, the impracticality of Probit 9. As recalled above, Probit 9 was chosen as an evaluation criterion of the efficacy of phytosanitary treatments based on successful experiments on fruit and melon fly (Baker, 1939) and, more generally speaking, on insects in the *Tephritidae* family (Schortemeyer et al., 2011). These insects are often invisible to the naked eye, reproduce with considerable ease and present high levels of infestation. These few elements not only justified the demand that a treatment offer a high level of quarantine security but also provided sufficiently large samples (greater than 93,613 individuals) quickly and at a low

cost so that the efficacy of the treatment can be tested at such a high level of probity (Probit 9). What, however, should be done when confronted with quarantine pests which reproduce slowly or display a natural infestation level so low that populations of at least 93,613 individuals can neither be found (in nature) nor bred (in the laboratory)? Follett and McQuate (2001), for example, recall that in the case of *Cryptophlebia*, a quarantine pest in the *Tortricidae* family, it would take between 15 and 20 years to be able to breed and test between 90 and 100 thousand individuals. Other studies illustrate the difficulty, if not the impossibility, of testing Probit 9 efficacy levels for certain quarantine pests (Haack et al., 2011; Schortemeyer et al., 2011).

2) Second, the weak reliability of Probit 9. In contrast with the case of quarantine pests with low infestation rates, fungi—recently added to the ISPM 15 list of pathogenic organisms (2010)—would appear to pose the opposite problem. In light of the very high level of natural infestation of these pathogens, testing the efficacy of a treatment for a value equal to Probit 9 (and thus a population of 'only' 93,613 individuals) could prove insufficient (Griffin, 2013; Haack et al., 2011; Schortemeyer et al., 2011).
3) Third, the choice of mortality criterion, of which the Probit model is simply a measurement (and thus evaluation) tool. Since the works of Bliss (1934) and Baker (1939), measuring the efficacy of a treatment has been almost exclusively associated with the observation of mortality levels in the organism treated. For a long time, this choice has limited the possibility of other criteria being adopted and thus of other risk management systems being developed (Landolt et al., 1984). More recently, work relating to irradiation (Ferrier, 2010; Follett & Neven, 2006) as a phytosanitary treatment served to recall that, alongside the mortality criterion, there is also the criterion of the fertility of the surviving individuals, no longer making the number of survivors the sine qua non condition of successful treatment. At the same time, other studies have created correspondence table between the size of samples to be tested and the Probit levels to be achieved (lower than 9), with mortality no longer the criterion to be evaluated but the probability of survival, within a given cargo, of a couple of fertile insects sufficiently close to be able to produce offspring: in this case, we refer to an 'alternative treatment efficacy approach' (in particular Follett & McQuate, 2001). As an example, for an insect with a naturally low infestation rate (compared to that of the fruit fly) and a slow reproduction rate which could potentially be present in a fruit cargo of 20 tonnes, it would be somewhat excessive to use a phytosanitary treatment previously tested on a sample of 93,613 individuals (Probit 9). A phytosanitary treatment tested on a sample ten times smaller (Probit 8.5) would be largely sufficient to achieve the same level of quarantine security (Follett & McQuate, 2001).

Without wishing to be too exhaustive, it should be recalled that the alternatives to Probit 9 proposed by different authors include the 'Maximum Pest Limit Approach', the 'System Approach', the '3 Steps Approach', the 'Nonhost Status Approach' and the 'Pest Eradication Approach' (Follett & Neven, 2006; Griffin, 2013; Haack et al., 2011; Landolt, et al., 1984; Liquido et al., 1997; Schortemeyer et al., 2011; Uzunovic, 2013). The alternative approaches seem share some common points. First, they reverse the evaluation rationale: it is no longer the chosen Probit level (independent variable) which determine the size of the sample to be tested (dependent variable), rather the knowledge of the behaviour of the quarantine pests and their proliferation environment (independent variable) which serve to determine the size of the sample to be tested and thus the Probit level to be respected (dependent variable). This reversal of the rationale therefore makes it possible to adjust the cost of producing scientific proof according to the quarantine pest in question. Second, using these alternative methods would consequently facilitate the emergence of alternative phytosanitary treatments better suited to the extent of the real quarantine risk and probably less costly to adopt.

All these elements serve to reiterate the limits of the Probit 9 model as a necessary and sufficient statistic to assess the efficacy of a phytosanitary treatment. These studies also demonstrate the arbitrary nature of the rational criteria selected, at a given point of time in history, to justify such a choice and which, in light of the progress made in scientific knowledge, have lost their initial legitimacy. While, unfortunately, no empirical studies have—to the best of our knowledge—calculated the presumed economic advantage of these new approaches, we nevertheless feel that they offer us a glimpse of the logic underpinning it.

When the 'Probit 9 standard' becomes an economic problem for international trade of wood pallets

In this last section, we will examine the two main variables that can generate path dependency phenomena: on the one hand, increasing returns of adoption and, on the other, transaction costs. In line with the chosen theoretical framework, the former reinforces path dependence, while the latter reflects the difficulty of getting out of it.

Increasing returns of adoption in ISPM 15

In this first subsection, we suggest that the existence of increasing returns of adoption has contributed to the strengthening of the Probit 9 standard at two points in time: before and after its adoption by IPPO.

As pointed out by Griffin (2013), even before its 'de facto' adoption by IPPO, the use of Probit 9 as a standard for assessing the efficacy of phytosanitary treatments was already widespread in the agrochemical industry of many Western countries (especially in US). More precisely, it was a widely accepted standard in the field of efficacy evaluation of phytosanitary products intended for agriculture (pesticides). The adoption of this same evaluation criterion by IPPO and its application to all phytosanitary treatments (physical, thermic, irradiation treatments), could be then analysed as a consequence of the existence of increasing returns of adoption, or, to put it in an another way, the existence of network externalities (Liebowitz & Margolis, 1994; North, 1990): the probability that IPPO endorses this evaluation criterion, increasing with the increase of the number of member-countries already using this criterion.

Once Probit 9 adopted by IPPO, increasing returns still work in its favour by pushing IPPO's Technical Commissions to select phytosanitary measures based on scientific researches using Probit 9 and to discard all those that don't meet with it. Put another way, the greater the number of compatible Probit 9 phytosanitary measures already accepted, the more likely it is that new measures will be accepted only if they will meet the same criterion.

In the field of ISPMs (28 or 15), history seems to go in this direction. Not only because almost all the measures adopted by the IPPO are based on scientific researches that have used the Probit 9 as critical threshold for evaluating their effectiveness (Table 1), but also because the phytosanitary measures that have been rejected (or which are waiting for approval) are most often those based on scientific researches that have not used the Probit 9 criterion or have not been able to reach an equivalent threshold of reliability.

More explicitly, in the version adopted in 2002, ISPM 15 provided for two treatments: heat treatment (in an oven at 56 °C for 30 min at the heart of the wood) and treatment by fumigation (methyl bromide). As recalled above, the scientific research called on to validate these first treatments all used Probit 9 as the efficacy evaluation threshold (Haack et al., 2011). Amended several times (2013 and again in 2018), ISPM 15 now recommends two additional treatments: fumigation by means of sulfuryl fluoride (SF) and micro-wave treatment (DH). These two additional treatments were added to the list of approved treatments, in 2013, in light of impact evaluation studies compatible with the Probit 9 standard, namely the work of Sousa et al. (2010) for SF and that of Hoover et al. (2010) for DH (IPPC, 2010).

Always in the 2002 version of ISPM 15, annex 3 provided a list of 12 alternative measures 'taken into consideration for approval', which included the two treatments finally approved in 2013. The 10 remaining alternatives measures, which are avenues still to be explored, have in common the fact that they are all based on scientific studies providing proof of effective treatment which is not always compatible with the Probit 9 standard.

One example we feel is particularly striking to illustrate the selecting/discarding process at work in IPPO technical commissions, is the work of Fleming et al. (2003) on micro-wave treatment of the Asian long-horned beetle (ALB). As the authors of this article recall, the ALB is not only an insect in the Cerambycidae family, which appears on the list of priority pests presented in the annex of ISPM 15 since 2002, but is also an insect characterised by a relatively long life cycle (one year) and by a relatively low reproduction rate, causing Haack et al. (2011) to claim that it is impossible to obtain samples compatible with the requirements of the Probit 9 standard, i.e. samples of at least 93,613 individuals. Conducted on a sample of 300 individuals and therefore unable to satisfy the standard imposed (Probit 9), the work of Fleming et al. was deemed insufficient by the experts committee, despite the fact that it demonstrated that this insect was particularly sensitive to heat and that, in the best possible conditions (blocks of dry poplar), a mere 5 s of micro-wave exposure at a temperature of 60ºC were sufficient to kill the entire sample.

It was not until 2010, and the study conducted by Hoover et al. (2010) on the pine wood nematode (PWN), that the Technical Panel on Phytosanitary Treatments (TPPT) returned to Fleming's work. As recalled above, the work published

Table 2 Price comparison: wooden vs plastic pallets (Source: Raja, RotomShop)

Item	Unit price, batch > 60 (Raja)	Unit price, batch > 60 (RotomShop)
ISPM 15 wooden pallet, 800*1200 (heavy load, 4 T)	€23.95	€15
ISPM 15 wooden pallet, 800*1200 (semi-heavy load 1.6 T)	€20.85	€9.3
Plastic pallet, 800*1200 (heavy load, 4 T)	€55.95	€43.91
Plastic pallet, 800*1200 (semi-heavy load (1.6 T)	€24.45	€28.34

by Hoover et al. was the document which led to micro-wave treatment (DH) being approved for PWN. As the pine wood nematode is a pest for which it is easy to breed hundreds of thousands of individuals, the work of Hoover et al. provided evidence (compatible with Probit 9) that micro-wave exposure to a temperature of 60 °C for 1 min was sufficient to eradicate this pest. Once this had been demonstrated, the TPPT (IPPC, 2010) established (by deduction) that this measure could be applied to the ALB which, thanks to the work of Fleming et al., (2003, 2005) was known to be more sensitive to heat than the PWN: *ubi major minus cessat.*

This is, in our view, a striking example of how increasing returns of adoption work in IPPO technical commissions, reinforcing the current standard by selecting new measures only when finally compatible with the standard, and by discarding the other ones.

The cost of complying with ISPM 15 vs the cost of changing Probit 9 standard

In this second subsection, we will examine two costs linked to ISPM 15: the cost of adopting the common phytosanitary measure (complying cost) and the cost of changing the measure (negotiation cost). In our case study, this last cost includes the cost of changing the scientific standard (Probit 9) used to select technical measures. Each of these two costs plays a role in the path dependency process, particularly when, from a short-term perspective, the (non-updated) negotiation costs would appear higher than the (non-updated) current complying cost.

Since the 1940s, wooden pallets have been the key element of national and international logistics. In 1975, there were 350 million units in the world (Duprez, 1976), while in 2016, the USA alone counted some 849 million pallets, including newly produced and reconditioned units (Gerber et al., 2020) and in China, one of the youngest producer, 655 million pallets are produced per year (Tang Ying, 2012). Building on a positive environmental balance compared to other materials (FCBA, 2012) and boasting a relatively long service life (extended by easy repairs), wooden pallets benefit from a lower selling price than their direct rival, plastic pallets (Table 2).

As recalled above, wooden pallets—despite these advantages—constitute a powerful vector of quarantine risks which can affect the environment in importing countries, in particular their forests (Henin et al., 2019). Unlike plastic or aluminium pallets, wooden pallets therefore need to be treated. Regardless of whether they are imposed unilaterally or agreed bilaterally (bilateral trade protocols) or multilaterally (ISPM 15), these treatments necessarily involve an additional cost which reduces the final price competitiveness of the wooden pallets compared to rival solutions. This cost, which is generally referred to as a 'certification cost' or 'compliance cost', may vary according to the number of alternative treatments to which the exporting country is subjected and to their level of complexity.

In the case of European countries, for example, only three of the four treatment methods recommended by ISPM 15 can be used, as methyl bromide fumigation has been prohibited since 2010 following the ratification of the Montreal Protocol (in 1987). Of these treatment methods, the only one which can rely on a historic industrial sector is heat treatment in an oven (HT). Although it is the dominant solution, heat treatment in an oven (HT) displays certain disadvantages, as shown by Lallemand (2004): extensive use of energy, a long treatment duration which is not always effective (homogeneity issue[7]), the possible deterioration of the wood and a relatively high average cost, estimated at $2 per unit. By deeming this estimation to be credible, the certification cost can be estimated, at best, at approximately 10% of the price of the end product, which is non-negligible. Being able to rely on equally effective and less costly alternative treatments to the HT is thus not only a means of improving access costs to foreign markets for exporting countries, but also serves to enhance the competitive margins for the wooden pallet industry vis-à-vis industries producing rival solutions.

To provide an idea of the extent of the compliance cost linked to ISPM 15, let us take the example of Brexit. Following its withdrawal from the European Union and thus the European Phytosanitary Area (2000/29/CE) from 1 January 2021, the UK and the EU become third-party countries with regard to one another. Pending a possible bilateral agreement, trade between the two parties will be governed by international law. With regard to pallets, the UK will no longer be able to benefit from existing exemptions with the EU and vice-versa. The two economic blocs will be obliged to procure (or produce) pallets certified ISPM 15 or EUR-EPAL (pallets essentially produced on the European continent and certified ISPM 15 since 2010). In light of the UK's current technical incapacity to treat a number of pallets in line with its commercial requirements (Henin et al., 2019), it would be easy to imagine that this certification cost might increase the average cost of trade between these two operators.[8]

If the example of Brexit is useful to understand the existence and the extent of the compliance costs, it is all the more useful to analyse the negotiation costs in a multilateral context. In the event of a no deal Brexit, the UK and the EU essentially have three options: (i) to conclude a new bilateral trade agreement reviving the former

[7] There is a certain amount of criticism levelled at the results of the treatment. As wood is not a homogenous material (differences in density, humidity, presence/absence of fungi, etc.) and is a poor conductor, the heat cannot spread evenly. As the temperature is controlled at only a few points in the heart of the wood, it is impossible to know the temperature at all points of the planks during treatment.

[8] The newspaper articles on this issue speak for themselves: The Times (22/07/2020): 'Wooden pallet is Brexit stumbling block'; Bloomberg (21/07/2020): 'The Wrong Kind of Pallets Threatens Border Trouble After Brexit'; Les Echos (30/01/2020): 'Brexit: l'étonnant casse-tête de la circulation des palettes'.

reciprocal exemptions (the solution which seems most likely); (ii) to accept the international certification cost as provided for by the current ISPM 15 (in this case, we return to the considerations addressed in the previous paragraph, i.e. higher compliance costs than before); or (iii) to refer the matter to the international instances to complement ISPM 15 with other treatment processes which would be simpler and less costly to implement than those currently available. Among these three options, the first one seems to involve negotiation costs (because of the necessity of a new bilateral agreement) but not complying costs, the second one complying costs but not negotiation costs (because of countries would accept the international current standard), only the third seems to involve at the same time complying costs (temporary accept ISPM 15 standard) and high negotiation costs (in view to modify the standard in a multilateral context).

As highlighted in a previous work (Lubello & Codron, 2020), if negotiating a bilateral trade agreement could be costly, modifying an international standard (such as the ISPMs) in multilateral organisations could be costlier and lengthier (approximately ten years). Costlier, because of this process calls on different resources and implies several costs: human resource costs (entrepreneurs, diplomats, consuls, technicians, scientists), material costs linked to the negotiations (audits, visits, travel for delegations to or from the partner country) and costs linked to the production of new 'scientific' proofs (funding for laboratory tests, investment in research). All these costs are difficult to quantify but of course they could be qualified as transactions costs.

Concerning the slowness of scientific expertise process in multilateral organisations such as IPPO, several factors can be mentioned. Firstly, a simple glance at the voting procedure used by the main international trade organisation (unanimous or qualified majority vote: Low, 2011; Verenyov, 2003) is sufficient to explain the long decision-making times: longer than signing a simple bilateral trade protocol. Secondly, the fact that scientific experts called upon to compose IPPO technical commissions are nominated by the government of its member-states (CCI, 2005) could explain the cautious and conservative attitude of such committees. Thirdly, as the number of scientific issues to be dealt with by IPPO technical commissions is considerable, it is normal that this results in a very long timetable, as shown by the latest stable revision of ISPM 15 realised in 2018, i.e. 16 years after the first version (2002).

Paraphrasing to North (1990), when transact is costly and lengthy, then, not only institutions matters, but their stability over the time too. Institutions' stability (in our case Probit 9 standard), at the same time as it makes the world more predictable and coordination simpler, it generates path dependency, lock-in situations and what Williamson (1994) more simply calls maladaptation costs, i.e. the cost that trade partners must pay while awaiting a better solution.

In order to illustrate this particular consequence of path dependent process at work within the IPPO's technical commissions (maladaptation costs), we come back on the example of Flaming et al. (2003). As mentioned above, the work of Fleming on ALB had shown that, taking advantage of its high sensitivity to heat, it was possible to effectively eradicate this pest by exposing infested blocks of wood for 5 s to a temperature of 60 °C, in a micro-wave oven. This treatment, initially not validated because it did not comply with the Probit 9 standard, was nevertheless approved several years later only because another research (Hoover and alii, 2010), this time compatible with the Probit 9 standard and carried out on another pest (PWN), less sensitive to heat than ALB, had proven the effectiveness of an identical treatment (micro-wave oven, 60 °C) but 12 times longer (60 s). As a result, today, ISPM 15 recommends for ALB the same treatment than for PWN: a treatment 12 times longer and more energy consuming than necessary, but which does not question the legitimacy of the evaluation criterion: Probit 9.

If researchers in the field of entomology qualify this type of solution as 'overkill', (the tendency to transpose treatments designed for highly invasive and resilient pests to less invasive pests with little resistance for want of changing the evaluation model), from the standpoint of the economic analysis, this additional cost (in terms of both energy and time) is a maladaptation cost between the problem to be addressed (eradication of the ALB) and the approved treatment (for the pine wood nematode) selected via the scientific criterion (Probit 9).

Given the impossibility, for us, of quantifying both compliance and transaction costs involved, we suggest that maladaptation costs may be a useful, even if anecdotal, way of showing the existence of a path dependence situation with respect to probit 9 as well as to all the NIMPs based on this standard. A situation that we can also describe as 'remediable' (in reference to Williamson, 1994) given the existence of several alternative models (Follett & Neven, 2006; Griffin, 2013; Haack et al., 2011; Liquido et al., 1997; Schortemeyer et al., 2011; Uzunovic, 2013)[9] that IPPO seems still to ignore.

Conclusion

A large proportion of the economical literature on international trade of agricultural products has focused on two mains issues: evaluating the impact of sanitary and phytosanitary (SPS) restrictions on trade, in particular when these restrictions are issued by states, and questioning the capacity of actual multilateral trade regime to build a neutral and efficient international trade space, and in particular its capacity of resolving members' trade disputes based on scientific knowledge. In this work, we have tried to contribute to the analysis of the impact of SPS measures on international trade in a third different way, by interesting in SPS measures promoted by international authorities (and not by national ones), and, by assuming that these international standards may be inadequate not because they would be the result of a partisan selection process, but because, although based on scientific knowledge, they would be the result of a path-dependent selection mechanism (North, 1990) specific to international institutions of scientific expertise.

[9] It should be recalled that alternative models to Probit 9 suggested by these authors include the 'Maximum Pest Limit Approach', the 'System Approach', the '3 Steps Approach', the 'Nonhost Status Approach', the 'Pest Eradication Approach' by means of the 'Sterile-Insect Technique' (SIT), 'Male Annihilation' or 'Autocidal Biological Control'.

To this end, we looked at a statistic, called Probit 9, and its adoption by the IPPO as a standard for evaluating the effectiveness of the phytosanitary measures it recommends. We have tried to show that the adoption of such a standard, while providing the IPPO's technical commissions with a robust and reliable tool for evaluating the effectiveness of phytosanitary treatments, was accompanied by the emergence of several lock-in points, recently highlighted by the scientific community (Sect. 3) and characteristic of the so-called path dependency phenomena.

In accordance with the theoretical framework of Positive Feedback economics (Arthur, 1990) and Neo-institutional economics (North, 1990), we have attempted to show the accidental nature of the success of Standard Probit 9 (Sect. 2), as well as the existence of increasing returns of adoption and high transaction (negotiation) costs (Sect. 4) in the context of ISPM 15.

We have used the Brexit example to suggest that there are significant compliance costs associated with adopting the current ISPM 15 (and implicitly the Probit 9 standard), as well as high negotiation (transaction) costs associated with the possibility for stakeholders (UK and EU) committing to change the current standard. The presence of potential high transaction costs as well as increasing returns of adoption leads us to say it would not be surprising if UK and EU ended up complying with the current ISPM 15 without seeking to change it.

Unfortunately, given the limited economic data available on the topic, we are unable to quantify the compliance costs or transaction costs that would be involved in ISPM 15 and its possible amendment. Therefore, based on essentially anecdotal and qualitative evidences (the existence maladaptation costs for example), we limit ourselves to suggesting, without demonstrating, the existence of a pathway-dependent selection process for phytosanitary measures under IPPO and ISPM 15.

We feel that the history and implications of ISPM 15 that we have explained here are an excellent example of this nesting phenomenon and argue in favour of increased knowledge on the part of the international organisations responsible for producing SPS standards of the path dependence mechanisms which can characterise any adoption of a standard or a technical quarantine protection measure. This increased knowledge will, in our opinion, facilitate the emergence of a more competitive, and thus more efficient, standards market.

Finally, we hope that this work, together with the previous work on international cold-treatment standards (Lubello & Codron, 2020), shows the interest in analysing the impact of SPS measures on trade from a less common theoretical angle in international economics, that of path dependency.

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