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Relative Importance of Barriers and Levers to Intercropping Systems Adoption: A Comparison of Farms and Co-Operatives

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Abstract: This paper focuses on the barriers and levers to the adoption of Wheat–Pea intercropping systems. More precisely, we define a hierarchy of the main barriers and levers to adoption using the Relative Importance Index (*RII*) method. This method allows comparison of incentives, negative (brakes) and positive (levers), for adoption at two levels of the value chain, i.e., the farmer and the co-operative level. For this comparison, we conducted two surveys: one on 71 Belgian farmers and the other on 19 French co-operatives. Our results show that the barriers of high importance for the farmers are both internal and external, while the co-operatives consider only internal barriers. That is, the farmers mainly focus on external (market access and public subsidies) and internal (lack of technical advice and extension, as well as collection and storage problems) obstacles to evaluate the intercropping system. For the co-operatives, the most important barriers are related to the sorting and storage of the mixture (internal barriers). Regarding levers, farmers and co-operatives converge on the importance of almost the same external levers, e.g., building new value chains through contracts and labeling, specific extension services for farmers and logistical support for co-operatives.

Keywords: adoption; intercropping; barriers and levers; relative importance index

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1. Introduction

Conventional agriculture based on short crop rotations (wheat/beet/potato, wheat/corn, wheat/sunflower or wheat/barley/rapeseed) is heavily dependent on chemical inputs [1]. Tillage and the massive removal of soil nutrients lead to an increasing need for fertilization, resulting in fragile crops that are often vulnerable to disease. Farmers then use phytosanitary products that have a negative impact on the soil microflora and microfauna, and negative externalities on human health [2–4]. These so-called main crops (cereals, oilseeds, beets, potatoes) therefore have negative impacts on the biotope (pollution, soil erosion degradation) as well as on the biomass (loss of biodiversity, loss of disease resistance).

The cereal–legume intercropping system is an archetypal example of diversification. It provides a quantitative dry matter yield equivalent to that produced by these two pure crops, while increasing protein yield and reducing nitrogen fertilization requirements [5–7]. The objective of the intercropping is to link two nutritionally and morphologically complementary crops. The legume can provide the cereal with a portion of the nitrogen supply through its ability to fix nitrogen from the air [8]. In return, the cereal becomes a creeping system for the legume, which is prone to lodging.

From an agronomic point of view, the introduction of crop species diversity can lengthen the rotation and disrupt the cycle of pests and weeds, often punctuated by the same succession of crops that foster their propagation. The new system can contribute to enriching the soil through the organic matter it produces and thus participate in modifying the soil's fertilization balance (mineral removal, organic matter contribution, atmospheric nitrogen fixation) [9,10]. Finally, crop diversification can change the time and space distribution of the landscape to break the monotony of field crops. This may provide new forms of habitat for wildlife (pollinating insect, soil fauna, pest hunters), and the crop diversity is a natural barrier against the spread of pests, diseases and weeds that spread at a steady pace in a homogenized space [11,12].

In an economic perspective, the benefits of this diversification are often misperceived by farmers due in part to the yield losses that this new system may generate for the main crop. In contrast, crop diversification can reduce the costs associated with the use of chemical inputs through the input services provided by the biological diversity of the intercropping [13–15]. In addition, diversification can be an insurance mechanism against field crop price volatility. Finally, the association can be valued in profitable niche markets [16].

Since intercropping systems reduce the mineral nitrogen inputs, they are interesting for farmers because their production cost is lower and for society because they are less polluting. Yet, like other diversification systems, they face barriers to adoption [17]. The objective of this paper is to analyze the barriers and levers to the adoption and diffusion of the intercropping system. Therefore, this study aims to identify the type of organizational mechanisms and policy that is relevant to support the development of intercropping systems. Indeed, in contrast to previous literature we define a ranking between the most important barriers and levers using the Relative Importance Index (*RII*) approach. This method allows a comparison of the negative (barriers) and positive (levers) incentives for adoption, at two levels of the value chain [18], i.e., the farmer and the co-operative level. For this comparison, we conducted two surveys: one on 71 farmers and the other on 19 co-operatives.

The remaining sections of the paper are organized as follows. In Section 2, we present a brief review of the literature on the ecological and economic advantages of the wheat–pea intercropping system, as well as on the barriers and levers to adopting the intercropping system. In Section 3, we present the material and the method for our data collection. Then, we define a hierarchy of the relevant barriers and levers for adoption using the relative importance index (*RII* method). Section 4 discusses the results before concluding on the relevant stakeholder adoption strategies and public policies fostering the adoption process.

2. Literature Review

2.1. Ecological and Economic Advantages of the Pea & Wheat Intercropping System

Introducing cereal and legume intercropping can improve the three pillars of a sustainable farming system: (i) the agronomic pillar, by providing free organic inputs for fertilisation; (ii) the ecological and environmental pillar, by increasing biodiversity on the field and the ecosystem services it provides; (iii) the social and economic pillar, by increasing the protein quality of wheat and peas and hence their market value.

An organic nitrogen contribution. The symbiotic relationship between the legume and the bacteria housed in the root system nodules allows the plant to fix atmospheric nitrogen and thus meet its needs in nitrogen nutrients. It is thanks to the high competitiveness of cereals in terms of nitrogen uptake and the sharing of the same soil with the legume that wheat can benefit from the natural nitrogen supply released by the legume roots [19,20]. For the farmer, the interest is twofold: (i) a reduction of mineral nitrogen inputs and thus of production costs, and (ii) a less polluting production since the mineral nitrogen usually used in conventional agriculture is highly leachable. The competitiveness of the cereal on nitrogen uptake ends up capturing the residual mineral nitrogen of the previous crop, while the symbiotic fixation of atmospheric nitrogen by the legume provides a resource for its own need and completes the missing needs of the complementary plant [21–24].

An increasing biodiversity of the cropping ecosystems. Diversification by intercropping systems allows the restoration of biodiversity by introducing new species and lengthening the crop rotation cycle [25–27]. A self-regulation of ecosystem pests (pea pests) due to the diversity of host plants that limits the population dynamics of these pests is also observed [26]. In addition, there is a positive effect on the number of pollinators and auxiliaries that are very useful for the ecosystem balance and biological pest control [27]. Some authors also find a positive effect of cereal–legume intercropping on ecosystem biodiversity indicators and their ecological and economic utility in agroecosystems [28–31].

The economic benefits of diversification. The intercropping system allows for compensating losses in case of abiotic (water stress, frost, heat stroke) or biotic (diseases, pests) hazards affecting one of the crops. Besides its complementarity on the input use (mainly, nitrogen), the intercropping system is interesting in organic agriculture where the production of protein crops still needs to be strengthened given the fragility that characterizes the creeping pea, which is less competitive against weeds [8]. By associating crops that are not sensitive to the same diseases, it strengthens the crops and reduces the damage related to diseases and weeds, while it improves its sanitary and economic performance [32–35]. Thus, the intercropping system not only achieves the objective of phytosanitary products reduction, and thus, the production cost, but also the objective of securing yields in the case of interannual variability. The intercropping also increases the gross margin by raising the protein content of the wheat grain [36,37], mainly in organic farming, where the production of soft wheat has a higher market value. However, nitrogen supply is essentially the main limiting factor to the increase of the protein content [35]. That is why the problem of mineral fertilization in organic agriculture is circumvented by intercropping soft wheat with a legume such as pea.

2.2. Barriers and Levers to Adoption and Internal/External Incentives

The private interests of stakeholders in agricultural value chains may not be aligned with this social interest, even if the intercropping system appears to be more sustainable and hence, more efficient for society. This is because diversified systems are innovative systems and therefore face a number of barriers to adoption. Up to now, the literature on the adoption of these systems has mainly tried to identify the barriers and levers (see [17] for a review), without attempting to measure their importance for the stakeholders or to classify them. Our contribution therefore aims to fill this gap in the literature by providing the first ranking of the different barriers and levers to the adoption of an innovative agricultural system using the Relative Importance Index (*RII*) approach. Moreover, our analysis does not stop at the level generally considered in the literature, that of the farmer (for a counterexample, see [1]). We indeed compare the nature and the ranking of these barriers and levers at two levels: the farmers level and the co-operatives level.

The second research gap leading to our research is the rather poor organizational characterization of the barriers and levers. An implicit difference between internal and external barriers and levers to adoption inside the organization (the farm or the co-operative) can be found in the literature. An example of an internal barrier inside the farm is the problem that it may encounter in selecting two different crop varieties that must be compatible with the same crop system (e.g., cultural agenda, morphological compatibility). Moreover, despite the usefulness of the wheat–pea intercrop on the reduction of pests, weeds and diseases, the system does not completely solve the issue of the relevant phytosanitary practices to cope with the pressure of weeds, pests such as pigeons, aphids and sitones. Indeed, the design and the fine-tuning of an innovative crop system remains difficult to set-up given the variability and complexity of agro-climatic parameters specific to each agroecosystem [21,29,38–42]. The farmer's lack of knowledge in the innovative crop system fine-tuning generates unpredictable and random yields, which are a source of uncertainty about the economic viability of the intercropping strategy [25]. Despite the savings in the use of chemical inputs for fertilization and phytosanitary treatment, the cost of production of this wheat–pea combination remains high if one does not reason over a pluriannual period by taking into account the effects of the intercrop over the entire cycle of the long rotation [25,43,44].

There is also a set of external barriers to adoption. Upstream, the market lacks suppliers of specific inputs adapted to the wheat–pea intercrop (seeds, fertilizers, phytosanitary products), which remains a niche market [45,46]. In addition, neither the technical advisors in agricultural organizations nor in co-operatives are likely able to provide technical advice specific to wheat–pea intercropping systems. Downstream, collection can be complicated for co-operatives or collectors due to the dispersion of production in small volumes. Sorting and storage of the wheat–pea mixture after harvest still remains difficult to manage [5,8]. The wheat–pea mixture also faces strong competition from much cheaper feed commodities (mainly, soybean meal and corn) [1,47,48]. Finally, wheat–pea intercropping is not eligible for subsidies, neither from the CAP system nor from the prime system for ecosystem services [49,50].

There are, however, some levers that can be implemented to foster the adoption of the intercropping system and its products in the value chain. These levers, both technical and organizational, concern, first of all, the increase of the intercropping products market value. This implies the development of new food and feed chains that value the plant protein [51–53]. The organic feed market is an interesting outlet for wheat–pea production. Even if the proof of the pea nutritional quality and its virtue in animal feed is less easy than for flax and its "Bleu Blanc Coeur" value chain, a "success story" of innovative chain building [54].

To understand how the internal and external organizational barriers and levers can impact the adoption process of the intercropping system, we have recourse to the Nelson and Winter evolutionary approach [55]. The latter emphasizes how the organization manages its innovation process in a context of change and evolution fraught with uncertainty [56–58]. It also highlights the dependence of the innovation process on the evolutionary trajectory of the technology, where evolution is defined as a process of change driven by internal and/or external organizational drivers [59]. Several internal drivers determine the organization's ability to absorb innovation and manage the innovation process: its size, its debt, its human and business resources, and its organizational routines, as well as its diversification [60]. External drivers also impact its evolution, such as the public and private incentives, the technological opportunities as well as their appropriation possibilities, and market opportunities making the value of the innovative product.

The relative importance of internal and external drivers also makes it possible to account for two kinds of innovation regimes. First, a tacit innovation regime in which technological innovation evolves regardless of the organization activities, and a more endogenous, cumulative innovation regime that depends on the firm's own technological progress. Cumulative change means that the organization develops/adopts innovations because it has the favorable internal drivers [61].

3. Material and Methods

3.1. Survey

In this study we surveyed Belgian farmers in the Walloon region and French co-operatives in the Auvergne–Rhone–Alps region. We choose the Walloon region mainly because this region offers eco-system services subsidies for farmers developing farming systems that are considered sustainable. For this reason, the intercropping system is blooming, whereas it is practically non-existent in the Flemish region. Farmers have also discovered that this crop has some advantages other than ecological ones. In particular, the land ratio in intercropping is higher than in the conventional system where the wheat and the legume are cropped separately. In addition, the Walagri co-operative, which manages the marketing of the intercropping, has succeeded in building a value chain through a tripartite contract between farmers, co-operatives and an industrial in order to increase the market value of the wheat and peas protein quality.

In France, no regional public incentives such as eco-systemic subsidies exist for the services that intercropping systems may provide. Meanwhile, intercropping is quite common in organic farming, and peas and wheat may have a great value on the market. In contrast to Belgium, the market for organic farming is large enough for co-operatives to specialize in some of their sorting, collection and storage facilities for these products. Conversely, this process of specialization leads to more "conventional" cooperatives refusing to collect, sort and store products from this type of system. This is why we decided to study both types of co-operatives in France.

This study is based on two complementary surveys. The first is an online survey sent to 320 cereal (wheat, barley, spelt) farmers in Belgium in the Walloon region. The second is a postal survey sent to 34 French co-operatives mainly engaged in the collection and marketing of cereals. A total of 71 Belgian farmers and 19 French co-operatives responded. This represents a response rate of 22.18% for the farmer questionnaire and 55.88% for the co-operative questionnaire. In the co-operative sample, we targeted 9 co-operatives that received mixed cereals and legumes or were equipped with optical sorters, and 10 co-operatives that collected cereals or legumes separately. The objective was to avoid the sampling bias that would have resulted from interviewing only co-operatives that had adopted intercropping or those that had not. Postal questionnaires and telephone interviews lasting an average of 40 min were used to collect responses to the questionnaires.

Both surveys are based on a literature review on the intercropping systems adoption [36]. They are structured in three similar parts. The first part deals with the characteristics of the farmer and his/her farm (e.g., agricultural area, level of education, experience, membership, etc. or the co-operative (e.g., legal status, staff, members, turnover). The second part deals with the farmer barriers (e.g., adapted variety, specific inputs, management of the innovative cropping system) or co-operative barriers (e.g., volume, location of farmers and buyers, availability of silos) to adoption. The third part deals with the farmer levers (e.g., labeling, contracting, extension and training services) or the co-operative levers (e.g., labels and certification, upstream and downstream contracting, logistical support, changes in CAP design) to adoption. In the surveys, the order of the barriers and levers is randomized in order not to influence the answers of the farmers and co-operatives regarding the importance of each of the barriers and levers.

Understanding the adoption process at the two upstream levels of the value chain (farm and cooperative levels) is essential to ensure a wide diffusion of intercropping systems. Indeed, there is a double interdependence between these two levels: (i) a contracting interdependence, as these two levels are contractually linked in terms of the raw material provision and its quality; (ii) a technological interdependence, as the sorting and storage function performed by the cooperative is highly dependent on the management of the intercropping by the farmers.

Given this double interdependence between these two upstream levels, it seems important to compare the obstacles and levers that farmers and cooperatives consider important as well as their ranking.

3.2. Data Analysis

We used STATA 15 (https://www.stata.com/stata15/ (accessed on 1 February 2023)) software to code and analyze the data. We used the Relative Importance Index method to identify and classify the main drivers of the farmer and co-operative decision to adopt the intercrop.

Relative Importance Index (*RII*)

Since we use the Likert scale (1—not important up to 5—extremely important) in the survey to measure the importance of each of the adoption barriers and levers, parametric methods are not practicable and applicable for assessing the preferences of the respondents, so the mean and standard deviation of the variables were not considered suitable to determine the overall ranking [62]. Relative Importance Index (*RII*) is a non-parametric technique widely used by construction and facilities management researchers for analyzing structured questionnaire responses for data involving ordinal measurement of attitudes. For this type of analysis, a calculated weighted average for each factor, divided by the upper scale of measurement, was adopted to provide an importance index [18,63,64]. The *RII* is calculated using Equation (1)

$$RII = \frac{\sum_{i=1}^{5} w_i n_i}{AN} = \frac{5n_1 + 4n_2 + 3n_3 + 2n_2 + 1n_1}{5N} \quad (1)$$

where w_i is the constant that shows the weighting of each response (1—not important up to 5—extremely important); n_i is the frequency of the responses (i = 1 to 5 based on the Likert scale); A is the maximum value in the Likert scale (5); N is the total number of the responses.

The *RII* value ranges from 0 to 1, with 0 not inclusive. The higher the value of *RII*, the more important the criteria. The comparison of *RII* with the corresponding importance level is measured from the transformation matrix as proposed by [65]. We defined three importance levels: High: $0.7 < RII \leq 1.0$; Medium: $0.4 < RII \leq 0.7$; Low (L): $0 < RII \leq 0.4$.

We also made additional analysis with Spearman Rank Correlation Coefficient Test to better identify if there is agreement or disagreement among the diverse groups on ranking factors. This test is generally used to understand agreement on the relative importance of the identified factors [66]. We find no significant disagreement between the two groups of stakeholders.

To compare the *RII* of each barrier and lever, we follow the Nelson and Winter evolutionary model [55] that considers two categories of incentives: (i) internal incentives, related to the resources and skills available to the organization to integrate the innovation as a routine; and (ii) external incentives, related to the market structure and institutional framework outside the organization that may impact the innovation adoption decision. We use this typology of incentives to analyze the similarities and differences between the different barriers and levers to adoption at the farm level, as well as at the co-operative level.

4. Results and Discussion

Using data from two surveys at the two upstream levels of the value chain (farmers and co-operatives), we calculated the relative importance of internal and external barriers and levers for adopting the intercropping systems. Our results mainly show that barriers of high importance for farmers are internal and external to the farm, while those of importance for the co-operatives are only internal to the organization (storing and storage of the mix) (Section 4.1). Regarding levers, farmers and co-operatives converge on the importance of the same external levers (Section 4.2). This finding provides a sound basis for further studies to test the robustness of the farms and farmers typology. A limitation of this study is the availability of precise sociodemographics variables of the farmers and co-operatives that that would have allowed multivariate analyses.

4.1. The Farm and Co-Operative Barriers to Adoption

The results of the *RII* analysis on the barriers to the adoption of wheat–pea intercropping (see Table 1) show that half of the barriers (6 out of 12) are considered as highly important by farmers. On the other hand, the co-operatives consider only 3 out of 16 barriers to be of high importance for the adoption and diffusion of the intercropping system.

For the farmers, 2/3 of these obstacles of high importance come from the farm environment (external incentives), especially those related to the lack of market incentives (lack of industrial buyers, lack of recognition of the ecosystem services provided by the intercropping) and the lack of advice and support from partners. The internal incentives, related to the lack of skills to properly manage the agroecosystem of intercropping, represent only 1/3 of the obstacles.

Table 1. Barriers to wheat–pea intercropping system adoption.

	Identified Barriers	*RII*	Importance	Rank	Category
Farmers	Lack of large industrial	0.76	High	2	External
	Difficulty to manage the existing varieties	0.75	High	2	Internal
	Lack of technical guidelines for production	0.75	High	2	Internal
	No compensation for ecosystem services	0.74	High	4	External
	Lack of specific advice	0.73	High	5	External
	Problems with collection, sorting and storage	0.71	High	6	External
	Non-competitive selling price	0.70	Medium	7	External
	Insufficient control of phytosanitary problems	0.69	Medium	8	Internal
	Unstable or inadequate performance	0.67	Medium	9	Internal
	Lack of appropriate input suppliers	0.66	Medium	10	External
	High production cost	0.58	Medium	11	Internal
	Complexity in the storage management of the mixture	0.91	High	1	Internal
Co-operatives	Costly sorting of the mix	0.81	High	2	Internal
	Irregular supply by farmers	0.72	High	3	External
	No technical solution for sorting the mixture	0.65	Medium	4	Internal
	Risk in Investment	0.57	Medium	5	Internal
	Adaptation cost of the product to market requirements	0.55	Medium	6	External
	Insufficient production volume	0.45	Medium	7	External
	Poor marketing of the intercrop	0.38	Low	8	External
	Inadequacy of the intercrop with the industrial requirements	0.37	Low	9	Internal
	Legal issues related to the marketing of products	0.34	Low	10	External
	Poor knowledge of new distribution channels	0.29	Low	11	Internal
	Lack of dedicated technical advisors	0.25	Low	12	Internal
	To be a co-operative	0.25	Low	13	Internal
	Lack of managerial skills	0.24	Low	14	Internal
	Sale price instability	0.24	Low	15	External
	Costly market access	0.22	Low	16	internal

On the contrary, for the co-operatives, 2/3 of the obstacles are related to internal factors and mainly concern two key operations of storage and sorting of the wheat–pea mixture (complexity and cost of sorting management). The high importance of this barrier to storage and sorting is unanimously recognized by both farmers (*RII* = 0.71) and co-operatives (*RII* = 0.91).

We also compare the relative importance of internal and external barriers by calculating their median *RII* for both farmers and co-operatives. The results show a significant difference between the two stakeholders and confirm the previous findings. For farmers, external barriers dominate, as the median *RII* is 0.72, compared to 0.69 for internal barriers. For co-operatives, internal barriers dominate with a median *RII* of 0.57 compared to 0.45 for external barriers. That is, the external barriers have no significant importance for co-operatives. Therefore, the barriers considered to be of high importance by farmers are both internal and external, while co-operatives consider only internal barriers as highly important.

First, the farmers mainly focus on external obstacles to intercropping system valuation, e.g., market access and public subsidies. Access to the wheat–pea market is difficult to market mainly because the volumes produced are small and highly variable. This explains why there is no constant demand from large industrial buyers. Without the increasing returns that result from the great demand, the diffusion of the product coming from this diversified cropping system will not occur [57]. For farms as well as for co-operatives, the entry decision into an emerging value-chain such that market wheat–pea intercropping products requires the ability of economic agents to adapt their strategies to consumer demand [1]. However, organizations base their strategic choices on their technical, organizational and financial capabilities. To break out of the routines of the pure crops conventional system, organizations must explicitly or implicitly acquire the new knowledge disseminated in their professional network. They can also invest in the acquisition of new skills needed to manage commodity chain activities if these provide a competitive advantage [37]. However, the price signal in the value chain does not yet provide a clear understanding of the competitive advantage and there is a lack of external incentives and support to carry out these news skills [60].

The second category of external barriers comes from public policies, including the lack of payment for ecosystem services. Payment for ecosystem services is justified by the costs associated with the adoption of these cleaner and, therefore, socially beneficial production systems, including the risks taken by farmers and co-operatives [67]. A reconsideration of the role of public authorities in this area would be profitable, since this agroecological transition requires long-term investments and economies of scale to allow for "technological unlocking" and to get out of a purely market production logic with its suboptimal results in terms of negative externalities for the environment and human health [68–70].

In contrast, internal barriers are mainly due to technical management difficulties from the intercropping system. The fine tuning of the intercropping system is indeed hard to set up because of the number of parameters that need to be taken into account. Farmers wonder about the ideal position of the intercrop in their classical rotation and its impact on the latter in terms of annual and interannual yield variation. In crop and livestock systems, the introduction of the wheat–pea intercrop leads to a lengthening of the rotation at the expense of forage autonomy, which is considered as the main argument for its adoption. In cereal systems, the introduction of the wheat–pea intercrop, as a substitute for another minor crop or between two major crops, seems to be easier. However, its impact on the following crops and the impact of the previous crops on the intercrop yield, or the cumulative effects of the intercrop in the rotation, even if they are mentioned, remain to be studied. The persistence of these elements of uncertainty leads to systematic errors in predicting the costs, future demand and profitability associated with adopting this innovative and agroecological production system [71–74]. All these elements of internal uncertainty for the farms (lack of shared and recognized knowledge in the producer community, lack of decision tools to change their current technological model, uncertainty about future problem-solving procedures) contribute to the reinforcement of their routine and anchorage in the conventional production model [75].

In addition, buying new seeds for diversification is a specific investment that, due to its cost, can be a major obstacle to the adoption of a diversified system [1]. The investment in new varieties of wheat and peas for the intercropping system is essential but highly risky as long as quality standards are unstable. This creates a situation of uncertainty for the seed companies, which prevents them from making the necessary investments to select new varieties adapted to the wheat–pea intercropping. For example, the difficulties encountered in the genetic selection of protein peas, essentially due to the cost of investments in stabilizing critical criteria of resistance to telluric diseases, partly explains the halting of the French public policy (protein plan) in the 1970s.

The lack of specialized advice is also a major obstacle slowing down the adoption and diffusion of the wheat–pea intercropping system. It is directly linked to the lack of technical management references for farmers and does not seem to be a determining factor for co-operatives. In fact, it is a common obstacle to crop diversification and innovative cropping systems [1,76–79].

Regarding the co-operatives, the most important barriers are related to the sorting and storage of the mixture. To sort efficiently, the agenda of the harvest of wheat and legumes has to be carefully designed, and the variety of peas has to be chosen according to the costly sorting equipment. For the co-operatives, the main problem lies in the management of cells in silos of storage. Due to the low and variable volume of wheat and pea mixture, it is costly for the co-operatives dealing only with classic crops to manage efficiently the cells dedicated to the mixture. That is why the co-operatives are generally reluctant to adopt the intercrop in their collection and storage system. These constraints are further amplified insofar as there is an irregularity in the time and space of farmer supply [80–82]. Only the co-operative marketing mainly crops and legumes coming for organic production systems are more skilled in the management of low volume productions and more specific products like mixtures [83].

4.2. The Farmer and Co-Operative Levers to Adoption

Table 2 shows the results of the *RII* analysis applied to the different adoption levers. First, farmers and co-operatives converge on the importance of external levers, e.g., building new value chains through contracts and labeling, specific extension services for farmers and logistical support for co-operatives. Indeed, 11/12 of the farmer levers and 11/14 of the co-operative levers are external.

Table 2. Levers to wheat–pea intercropping system adoption.

	Identified Levers	*RII*	Importance	Rank	Category
Farmers	Increasing Mix quality market value	0.87	High	1	External
	Specific training for farmers	0.81	High	2	External
	Set-up of local procurement contracts	0.79	High	3	External
	Involvement of R&D results in advice	0.78	High	4	External
	Advice and extension for development	0.76	High	5	External
	Eco-labeling the wheat–pea value chain	0.72	High	6	External
	Role of public stakeholders in the value-chain building	0.72	High	6	External
	Official public quality label	0.71	High	8	External
	Profitability of the intercropping system	0.70	Medium	9	Internal
	Role of supermarket	0.64	Medium	10	External
Co-operatives	Potential for certification	0.67	Medium	1	External
	Existence of marketing contracts	0.64	Medium	2	External
	Change of the CAP	0.60	Medium	3	External
	Logistical support from industrial partners	0.58	Medium	4	External
	Geographical proximity to industrial buyers	0.56	Medium	5	External
	Existence of production contracts with farmers	0.55	Medium	6	External
	Third party contracting (farmer/co-operative/processor)	0.50	Medium	7	External
	Bonus for quality of products	0.49	Medium	8	External
	Sharing the marketing value	0.49	Medium	9	External
	Benefit from tax reduction	0.47	Medium	10	External
	Technical assistance for the intercropping system	0.46	Medium	11	Internal
	Relationships network with public and private institutions	0.42	Medium	12	External
	Access to new information sources	0.39	Low	13	Internal
	Geographical proximity to the producers	0.37	Low	14	Internal

Second, our results show that 8/10 of the levers are considered of high importance by the farmers, in contrast to the co-operatives who do not consider any of the listed levers of high importance. Almost all (12/14) of the listed levers are considered of medium importance by the co-operatives, while only 2 out of 10 levers are considered of medium importance by the farmers. This difference is explained by the fact that none of the levers identified by the co-operatives mitigate the impact of their main obstacle to adoption, i.e., the difficulties related to the storage and sorting of the mixture. Moreover, since the co-operatives cannot directly intervene in the production of the wheat–pea mixture, they have no impact on the second major constraint, i.e., the irregularity of production.

For farmers, market incentives are the main external incentives to adoption since they may increase the value of the wheat–pea mix quality. Contracting on a territorial scale, as well as the labeling of the mixture, are also levers considered of high importance by the farmers. A public policy incentive, through premiums for ecosystem services, as well as advice and training on the fine-tuning of the intercropping system, are also considered to be of high importance in strengthening the adoption dynamics.

Regarding the role of the market incentives, Table 2 shows that the main lever for farmers is to improve the market value of the mix quality. Similarly, the co-operatives consider the certification of the quality as an important lever to increase value. Pea proteins, like wheat proteins, are among the leading products of the new healthy diet [84] and can therefore benefit from the current development of market niches related to vegetable proteins [85–88]. The strategy of eco-labeling [89–93] seems to be also a promising venue for increasing market value according to the farmers. Conversely, co-operatives are relatively more supportive of a change in the CAP to value the ecosystem services provided by crop diversification [94].

Due to the risk aversion associated with adopting a new cropping system [95], the strategy of contracting in the local value chain is considered of high importance by the farmers and the co-operatives. This allows them not only to reduce uncertainty about supply/demand and prices, but also to create a customized local demand that can cope with price volatility. Moreover, contracting allows a better sharing of risks and value generated in the market [1].

After the increase of the market value through contracting, training and advice is the second most important lever for farmers. The fact that 22% of the farmers interviewed have no agricultural training partly explains the importance of this lever among farmers. Although it does not appear to be a priority for co-operatives, the latter rank it in the first category of levers, that of medium importance. Advice to farmers by professional agricultural organizations and business partners has long been considered as a very important policy lever for the promotion and diffusion of innovative farming systems [96–104]. These stakeholders, including co-operatives, in advice and extension can therefore play a role as catalysts for the acquisition of the skills needed to adopt these diversified cropping systems. This is especially the case since 58% of the farmers in the survey are members of a professional agricultural organization and 47% of them are members of co-operatives.

5. Conclusions

To analyze the adoption of wheat–pea association systems within value chains, we have recourse to recent developments of the evolutionary model dealing with the internal and external incentives of organizations. We apply this approach to the barriers and levers classification method using score tests (Relative Importance Index, *RII*). The computation of these indices allows a comparison of the adoption incentives, negative (barriers) and positive (levers), at two levels of the value chain: the farm level and the co-operative level. For this comparison, we conducted two surveys: one on 71 Belgian farmers and the other on 19 French co-operatives.

Our results show that the barriers considered to be of high importance by farmers are both internal and external, while the co-operatives rate highly only internal barriers. That is, the farmers mainly focus on external obstacles to intercropping system valuation (market access and public subsidies) and internal obstacles (lack of technical advice and extension, as well as collection and storage problems). For the co-operatives, the most important barriers are related to the sorting and storage of the mixture.

Regarding levers, farmers and co-operatives converge on the importance of external levers. For example, the building of niche markets through contracting and labelling to increase the value of the mix high protein quality, or technical advice provided thanks to the support of co-operatives. However, there is a big difference between farmers and co-operatives in the importance of these levers. While farmers rate these levers highly, co-operatives consider them to be of medium importance. That is, it seems that co-operatives are not convinced that there are external levers able to solve their main problem, the collection and storage of the mix.

These results also raise the question of the type of policy that is relevant to support the development of these intercropping systems. If both stakeholders seem to agree on the priority to be given to the building of a niche market that may increase the value of the mix protein quality, the opinions diverge with regard to the type of public support. Belgian farmers seem to be calling for a continuous support from the Walloon region through its premium scheme for ecosystem service provision. French co-operatives, on the other hand, are calling for a change in the CAP scheme to better compensate the intercropping systems.

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