*International Food and Agribusiness Management Review*
***Volume 20 Issue 1, 2017; DOI: 10.22434/IFAMR2016.0081***

Received: 6 April 2016 / Accepted: 12 September 2016

# Business models for maximising the diffusion of technological innovations for climate-smart agriculture

## RESEARCH ARTICLE

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## Abstract

Technological innovations will play a prominent role in the transition to climate-smart agriculture (CSA). However, CSA technological innovation diffusion is subject to socio-economic barriers. The success of innovations is partly dependent on the business models that are used to diffuse them. Within the context of innovations for CSA, the role that innovation providers' business models play in the successful adoption and diffusion has received limited attention. In this paper we identify critical issues for business models for CSA technological innovations (BM*f*CSATI). Our results indicate that current BM*f*CSATIs are not optimised for diffusing CSA technological innovations. Critical business model elements include the value proposition, channels, customer relationships, key resources, key partners, and cost structure. We find a disparity between the views of CSA technological innovation providers and potential users. The paper explores the implications of the results and develops recommendations for CSA technological innovation providers' business models.

**Keywords:** business models for sustainable innovation, business models for sustainability, business model canvas, Europe, new technology based firms, technological innovations
**JEL code:** Q16, O00, O32

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## 1. Introduction

The development, adoption and diffusion of pro-environmental technological innovations is critical for enhancing sustainability (EIT, 2014; European Commission, 2014a; Montalvo, 2008). This is also the case with agriculture. Agriculture will adapt to changes in weather patterns associated with climate change, and plays a role in limiting greenhouse gas (GHG) emissions (Coumou *et al.,* 2014; Kurukulasuriya and Rosenthal, 2003; Trnka *et al.,* 2014) whilst feeding future global population (Bogdanski, 2012; Nelson, *et al.,* 2009). These challenges mean that the development, adoption and diffusion of appropriate technological innovations is an urgent priority. However, the adoption of technological innovations, including within agricultural contexts, can often be impacted by a range of socio-economic barriers. These barriers impact both the production and marketing of technological innovations, as well as their adoption and use (Montalvo, 2008).

Climate-smart Agriculture (CSA) is a programmatic response to these challenges, seeking to encourage sustainable increases in agricultural productivity and incomes, the building of resilience and adaptation to climate impacts as well as reduction of GHG emissions where possible (FAO, 2010, 2014). As such, innovations consistent with these principles need to be adopted by agri-food chains.

The successful adoption and diffusion of technological innovation is dependent upon many factors. The support of appropriate and effective business models is noted as one promising strategy for enhancing the success of technological innovations (Boons and Lüdeke-Freund, 2013; Teece, 2010). Business model innovation has also been identified as a critical component of the transition to a sustainable future (Hansen *et al.,* 2009). By examining the business models that support technological innovation, key organisational factors that promote or inhibit adoption and diffusion can be identified and explored. In turn, this allows interventions, in terms of changes to business strategy or policy, to be designed. This is especially pertinent for technological innovations for agriculture, as previous business model approaches within this context have to date only considered the user or adopter perspective (Sivertsson and Tell, 2015), or only within developing country contexts (Chesbrough *et al.,* 2006).

In this paper, we identify critical issues for the business models of CSA technological innovation providers. We do this by exploring the barriers of both CSA technological innovation providers and potential users and what they think could enhance diffusion. These factors are then applied to a business model framework, the business model canvas (BMC). Through this process, we show that the current business models employed by CSA technological innovation providers are not optimised to current market demands, and as such, can be seen to be inhibiting the adoption and diffusion of CSA technological innovations.

We are guided by the question: what are the critical issues of CSA technological innovation business model development for the adoption and diffusion of CSA technological innovations?

In order to answer this question, we review previous research on business models and their relationship to innovation and sustainable innovation. Generic critical issues are drawn out from the literature on business models for sustainable innovation (BM*f*SI); these are mapped onto the much used BMC (Osterwalder and Pigneur, 2009) to create a theoretical framework.

This research is carried out within the context of the CSA Booster, a Climate-KIC funded European project investigating the adoption and diffusion of CSA technological innovations. European technological innovations providers with innovations consistent with the principles of CSA (i.e. that they enhance agricultural productivity and either contribute to climate adaption or mitigation), formed the focus of the empirical investigation. Climate change is high on the agricultural policy agenda in the European Union, with actions including European Commission strategies to encourage member states to 'climate proof' their agricultural sectors and improve decision-making (European Commission, 2014b).

## 2. Literature review

*Business models*

Business models emerged as a concept in the late 1990s (Shafer *et al.,* 2005). They describe how organisations create value, select customers, assign processes and enter markets, and can be used for analysis, comparison, management and innovation (Benijts, 2014; Doganova and Eyquem-Renault, 2009; Osterwalder *et al.,* 2005). Many business model frameworks have been developed to aid the analysis and description of business models, with examples including the component business model (Pohle *et al.,* 2006), business reference model (Fettke and Loos, 2007) and the much used and publicised BMC (Osterwalder and Pigneur, 2009). The core elements of a business model (Boons and Lüdeke-Freund, 2013; Chesbrough and Rosenbloom, 2002; Osterwalder *et al.,* 2005; Osterwalder and Pigneur, 2009) include the identification or articulation of the:

- value proposition, involving how value is generated;
- customer segment, highlighting who the users or customers will be;
- customer relationships, focusing on how the business engages with its customers;
- channels, which highlights how customers are reached, including awareness raising and the provision of information;
- key activities, articulating activities required to carry out the other business model functions;
- key resources, concerning the critical assets needed;
- key partners, highlighting those actors that are critical to delivery of the value proposition;
- cost structure and the revenue streams, outlining key costs and how an organisation generates revenues.

Business model frameworks can be used to explore and plan how an organisation will operate and compete, or to identify areas that need improvement; this last aspect is especially pertinent to the case in hand.

Research on business models can be categorised into three distinct streams (Wirtz, 2011). First, in conjunction with the 'dotcom' boom around the turn of this century, research focuses on the interaction between technology and business models. For example, how the internet changed revenue models, or the relative success of innovations due to business model choices (Chesbrough and Rosenbloom, 2002). A second stream looks at how businesses organise or structure themselves. The third stream is more strategically focused, considering how organisations compete through the evolution of their value proposition and business model innovation (Chesbrough, 2010).

Business model innovation is a common and often dominant topic across these three strands of research (Boons and Lüdeke-Freund, 2013). On the one hand, technological innovation is explored in terms of how new products and services interact with existing business models. This contrasts with investigations of how the innovation of business models themselves can extract extra value from existing products or services (Baden-Fuller and Morgan, 2010; Wirtz, 2011). This presents three combinations for business models and innovation: either an innovative business model for existing products, an existing business model for an innovation or an innovative business model for innovative products.

Conventional economic and management theory assumes that a good innovation will succeed in the market. This assumption however is increasingly challenged by business model approaches. Many business model scholars assert that innovations often require innovative business models in order to be diffused and be adopted successfully (Bohnsack *et al.,* 2014; Boons *et al.,* 2013; Teece, 2010). This may be the case with regards to CSA technological innovations and serves as a strong rationale for examining critical issues for business models for CSA technological innovations (BM*f*CSATIs). In summary, the specific business models used by technology providers impacts the relative success of these innovations in the market.

Business models can act as a common language within innovation networks, allowing actors to identify and discuss opportunities for the commercialisation of innovation (Boons and Lüdeke-Freund, 2013). Business models can become 'market devices' (Doganova and Eyquem-Renault, 2009), able to boost the diffusion of

emerging innovations by overcoming barriers (Wells, 2008), and connecting production with consumption (Boons and Lüdeke-Freund, 2013; Iles and Martin, 2013; Wells, 2008). This is an important point, as CSA technological innovations experience socio-economic barriers to their diffusion. A business model perspective may identify deficiencies in the current approaches of CSA technological innovation providers and highlight ways to boost CSA technological innovation diffusion.

Indeed, business model innovation is seen to be able to counter several barriers associated with the development and diffusion of innovations generally (Chesbrough, 2010). These barriers can include issues such as low initial margins, making competition with established technologies more difficult. In addition, the innovation may target new and different customers and distribution channels, meaning greater uncertainty when compared with established technologies, requiring actors to challenge dominant logics and norms. In order to become successful, technology providers will have to develop compelling value propositions, advantageous cost structures, the ability to capture value and consider how the innovation will interact or be used by customers (Teece, 2010). Many of these factors have been identified as barriers in relation to CSA technological innovations.

*Innovation and sustainability*

Eco-innovations add economic value whilst simultaneously reducing environmental impacts (Horbach *et al.,* 2012). CSA technological innovations are consistent with this definition due to the improved productivity and/or reduced GHG emissions embodied within CSA principles. Similarly, sustainable innovations are those that take into account environmental, social and economic considerations in their development and use (Larson, 2011). From this, we can conceive of sustainable innovations, eco-innovations and CSA technological innovations as having many similarities, meaning literature that examines eco-innovation, or sustainable innovations and business models, may shed light on the critical issues for BM*f*CSATIs as well. As shown, the success of an innovation depends, at least in part, on the development of a business model that is able to support its adoption and diffusion. Wider factors that impact the success of eco-innovations and sustainable innovations will have a corresponding impact on how business models are designed so that they are optimised for adoption and diffusion.

For instance, consumer variables impact the success of sustainable innovations. Factors such as attitudes and cognitive processes affect adoption and relate to contextual and demographic factors. For example, Bhate and Lawler (1997) found that psychographic and situational variables, such as feelings towards the environment, rather than demographic factors, such as age or educational level, had the greatest impact on consumer purchasing decisions. More practically, Lin *et al.* (2013) note that sustainable innovations must meet user needs to be adopted and successful.

Price and quality are also found to be critical factors for sustainable innovations. The price competitiveness of a sustainable innovation, compared to standard products, can be critical to its success (Brouhle and Khanna, 2012). Similarly, quality is a premium consumer concern, meaning that if a sustainable innovation does not compare favourable in this regard to other products, it is unlikely to be successful (Brécard *et al.,* 2009). The influences of knowledge and information flows have also been found to affect the rate of diffusion of sustainable innovations (Lee *et al.,* 2006). Specifically, the media can increase the demand for sustainable innovations by highlighting environmentally detrimental practices and effects. Stakeholder inclusion in the development of sustainable innovations also impacts success, as this can increase demand and market acceptance of new sustainable products (Byrne and Polonsky, 2001; Carrillo-Hermosilla *et al.,* 2010). A further critical factor is a well-developed and effective delivery chain (Jabbour, 2008; Jabbour *et al.,* 2013).

These factors illustrate consumer or demand side factors, which in turn must be taken into account when designing business models that support the adoption and diffusion of sustainable innovations.

*Business models for sustainable innovation*

A well-defined body of research exists which focuses on the role of business models for sustainable innovation. Having considered the more general business model to innovation relationship, and explored CSA technological innovations in relation to sustainable innovation, we will now consider business models for sustainable innovation. After this the potential critical factors for CSA technological innovation providers will be synthesised on the BMC.

As shown above, many factors can impact the success of sustainable innovations, but a business model perspective allows the form and operation of firms to be examined and connected to the performance of sustainable innovations. A key contribution in terms of BM*f*SI is provided by Boons and Lüdeke-Freund (2013), who synthesise research on sustainable innovation and sustainable business models. It is highlighted that BM*f*SI can be conceived at three levels.

First, at the organisational level, business models illustrate how an innovation connects to other firm functions, such as marketing. This perspective is noted as somewhat neglected, with much research seeing firms as 'black boxes'. An innovation must be marketable and so the innovation process should include firm functions such as in sales and marketing. This perspective encourages us to ask whether CSA technological innovation providers have CSA technological innovations that are marketable and attractive to potential users. Or if the products are not marketable or attractive, if this is restricting adoption and diffusion. These points draw attention to the role of an effective value proposition in boosting the diffusion of innovations.

Second, the inter-organisational level of analysis draws attention to interactions within the supply chain and other external factors. This highlights business model aspects such as channels (used to link to customers), customer relations and key partners. For sustainable innovations, this highlights principles consistent with sustainable supply chain management (Seuring and Müller, 2008), such as encouraging suppliers and downstream actors, including customers, to act sustainably. The inter-organisational level also highlights how an innovation interacts with users more generally, in terms of how easy it is to adopt (Kemp and Volpi, 2008). This raises questions as to whether CSA technological innovation providers are suitably connected with potential customers and wider networks in the supply chain.

The third level – the societal level – links to systems-levels thinking for sustainable transitions (Geels, 2005). The question here is the extent to which the sustainable innovation offers value to society as a whole. This level of analysis is likely to have limited value, as we focus on CSA technological innovation providers – at the actor or organisational level – in this paper.

Several broad and generic normative requirements have been developed for business models aiming to provide sustainable innovations (Boons and Lüdeke-Freund, 2013). It is highlighted that the value proposition should include environmental and/or social aspects in addition to economic elements; that the supply chain includes suppliers who take on responsibility towards both their own and the focal organisation's stakeholders, in line with sustainable supply chain management; and that the customer interface should encourage and motivate consumers to take on responsibility for their own and wider stakeholder actions. For both the supply chain and customer interface, the focal company should not just shift their responsibilities onto other actors, but rather ensure that additional and relevant responsibilities are induced. Finally, the financial model should include social and environmental externalities and ensure a fair distribution between relevant stakeholders. These normative requirements are purposefully generic and do not specify a particular business model; rather, they must be adapted to specific contexts or objectives, in this case CSA.

For less generic, practical examples, several case studies on success factors for BM*f*SI are noteworthy. Through an examination of an eco-efficient product-service system innovation, Ceschin (2013) stresses that some financial or institutional protection can allow experimentation to take place, which could for example involve investors who are willing to take a longer-term view and forego short-term returns. Such support

may also be needed by a wider set of stakeholders. The innovation should also be developed with a clear vision, as this allows the expectations of key stakeholders to convergence, providing strategic direction.

An examination of the preferences of renewable energy investors showed that the value proposition should include either 'best service', 'lowest price' or 'best technology' – here the value proposition is seen as the key element (Loock, 2012). Whilst a study into algae biofuel for aviation noted critical factors to include the support of a broad range of actors, a sympathetic regulatory environment, innovative and customised business models and a thorough market adoption strategy (Nair and Paulose, 2014).

*Critical factors for business models for climate-smart agriculture technological innovations*

We aim to identify critical issues for the business models of CSA technological innovations providers in this article. By reviewing and synthesising the key factors for BM*f*SI and wider factors impacting the success of innovations, we produce a provisional set of critical issues, mapped onto the BMC. Previous investigations into BM*f*SI have predominantly been normative and generic, or have focused on different contexts to agriculture. Mapping these factors onto the BMC allows us to create an initial framework (Figure 1), where we can test the applicability of wider factors empirically within the context of agriculture, and specifically CSA. In this sense, we use this business model framework as a lens through which to explore critical issues for the diffusion of technological innovations. This allows us to see which aspects of the business model relate to specific critical issues.

The BMC is used extensively by practitioners, from entrepreneurs launching start-ups through to high-level decision-makers in FT Global 500 companies (Hanshaw and Osterwalder, 2015). The BMC acts firstly as a business model framework, providing a complexity-reducing backdrop for our analysis (Ching and Fauvel, 2013). We also use this framework due to its wide acceptance within the practitioner community, which we hope will make our results more widely applicable and understood.

<table>
<tr>
<td rowspan="2">Key partners<br>Access to partners necessary to provide value proposition; i.e. suppliers, investors etc.</td>
<td>Key activities</td>
<td rowspan="2">Value proposition<br>Compelling and relevant to CSA.</td>
<td>Customer relationships<br>Ensure successful diffusion of CSATIs. Encourage wider CSA consistent behaviour.</td>
<td rowspan="2">Customer segments</td>
</tr>
<tr>
<td>Key resources<br>Access to sufficient resources to provide value proposition.</td>
<td>Channels<br>Access to customers who demand CSATIs.</td>
</tr>
<tr>
<td colspan="2">Cost structure<br>Allow competitive pricing, and economic viability to the CSATI producer.</td>
<td colspan="3">Revenue streams<br>Encourage move to 'jobs done' rather than 'per unit' pricing.</td>
</tr>
</table>

**Figure 1.** BM*f*CSATIs critical issues according to the literature. BM*f*CSATI = business models for climate-smart agriculture technological innovation, CSA = climate-smart agriculture, CSATI = climate-smart agriculture technological innovation.

The 'value proposition' articulates how value is created (Osterwalder and Pigneur, 2009). It should address the problems faced by end-users. Without a well-developed, articulated and demonstrable value proposition that meets end-user needs (Lin *et al.,* 2013), CSA technological innovations will face difficulties in terms of marketing and sales. A poor value proposition would fail several of the 'success factors' identified in relation to sustainable innovations more generally, such as the role of price and quality (Brécard *et al.* 2009; Brouhle and Khanna, 2012), and overcoming potentially negative user attitudes (Bhate and Lawler, 1997).

'Customer relationships' describe the relationship that a business has with customers, such as whether a CSA technological innovation provider will pursue a 'one-off' sale of a product, or whether further 'after-sale' services are offered. This building block also articulates the extent to which customers and end-users provide input to development or co-creation efforts with CSA technological innovation providers. How a firm links to end-users and creates a relationship with them is important for BM*f*SI (Boons and Lüdeke-Freund, 2013), as this is how user behaviour is influenced. For a BM*f*SI the customer relationship should encourage wider sustainability actions and could also act to minimise rebound effects. More widely, stakeholder engagement during the development process can increase the market acceptance of sustainable innovations, signalling that the customer interface should be broader than just the sales of the product (Byrne and Polonsky, 2001; Carrillo-Hermosilla *et al.,* 2010). For BM*f*CSATI, the customer interface should encourage optimum usage of the innovation and seek to encourage wider action for CSA by end-users.

'Channels' link a business to its customers. Having a well-developed channel is a requirement for the successful diffusion of CSA technological innovations. This is highlighted as a critical aspect of BM*f*SI (Boons and Lüdeke-Freund, 2013), as the channel includes the marketing and awareness raising activities and strategies. Information provision is a key factor in the success of sustainable innovations (Lee *et al.,* 2006), meaning the channel operation should ensure that CSA technological innovations have high awareness rates, and that CSA technological innovation providers ensure enough information is provided to the market.

'Key resources' are required to provide any product or service; this factor alone highlights this as a critical issue. However, the resources available to provide sustainable innovations will also effect price and quality (Brouhle and Khanna, 2012).

'Key partners' are needed as firms do not operate in isolation. Other actors often hold the resources required for delivery of the value proposition. The 'delivery chain', highlighted by Jabbour (2008) and Jabbour *et al.* (2013), confirms the importance of this block for sustainable innovation. Further, connections to wider networks could enhance the probability of a supportive regulatory environment (Ceschin, 2013).

'Revenue streams'*:* BM*f*SI should seek to develop more innovative revenue models, including shifting towards pricing on 'jobs done' rather than per product (Boons and Lüdeke-Freund, 2013). This enhances the opportunity for de-materialising production and consumption.

The 'cost structure' should be minimised, maximising the chance for profit. For BM*f*CSATIs the revenue model should at least allow the firm to be economically viable, ensuring that their products are priced competitively, as price is still a key consideration for end-users as with conventional innovations (Brécard *et al.,* 2009; Brouhle and Khanna, 2012).

A review of BM*f*SI literature and wider research on the key success factors for sustainable innovations indicates that the above noted business model elements are critical for the success of technological innovations, and in this case technological innovations for CSA. In Figure 1, these critical issues are mapped onto the BMC (Osterwalder and Pigneur, 2009).

## 3. Methods

*Research approach/methods*

Data for this research was collected through the 'CSA Booster', a European project funded by Climate-KIC. As part of the CSA Booster, data was collected that explored perceived barriers to the diffusion of CSA technological innovations as well as what would be required within the market for increased adoption and diffusion of CSA technological innovations. Data was collected from both CSA technological innovations providers as well as potential end-users. Data collection was undertaken with partners in the Netherlands, France, Italy and Switzerland.

As CSA and related CSA technological innovations are a relatively new phenomenon, with little previous research conducted within developed world contexts such as Europe, the research took an exploratory approach. As such, the theoretical framework (Figure 1) utilised wider knowledge of a more generic and normative nature. This theoretical framework was then tested with empirical data collected within the context of CSA technological innovation diffusion to test the applicability of previous knowledge and to identify those business model elements most critical to the successful adoption and diffusion of technological innovations.

Due to this exploratory approach, a qualitative stance was adopted. Semi-structured interviews with key informants were chosen as the data collection method, as this enabled rich and in-depth data to be gathered on factors acting as barriers to the diffusion of CSA technological innovations as well as what needed to improve to increase the diffusion of these innovations through the market.

Both innovation providers as well as potential users of CSA technological innovation providers were included within the empirical sample. This allowed data to be collected from both those firms whose business models are the target of this research, as well as potential users within their target market. The potential users included actors such as farmers' associations, consumer goods companies and retailers, allowing the inclusion of perspectives from across agro-food chains. This adds value, as an awareness of how innovations will be used and integrated by users is noted as an important factor for innovation and the business models used to diffuse them (Stubbs and Cocklin, 2008). The user perspective also provided an external view on the current activities and operations of CSA technological innovation providers, enhancing the validity of the data and results. Financial actors were also included in the empirical sample due to their role in financing to both CSA technological innovation providers and users.

Table 1 and 2 provide an overview of the data sources. Interviews used a semi-structured format. The questions were designed to identify key barriers faced, and what would be required within the market for an increase in the adoption and diffusion of CSA technological innovations. All project partners performed interviews, enhancing the geographical range and diversity of the data, using a standardised questionnaire protocol and recorded into a standardised template.

Analysis of the data involved thematic coding, where typical and frequent answers were coded, as well as any data that was critical to the answering of the research question. Coding went through several iterations to enhance internal consistency within the themes developed. Once complete, a range of codes and categories were produced identifying key themes or critical issues. These were then applied to the BM*f*CSATI framework developed in Figure 1, which highlights which aspects of the business model are impacted. An overview of the conceptual and analytical process followed by the research is shown in Figure 2.

**Table 1.** Climate-smart agriculture technological innovation provider data sources/participants.[1]

| | CSA technological innovation providers | Interview country |
|---|---|---|
| A1 | Provides software and new tools, managed through the internet, in order to optimise yields and quality of grapes in vineyards. | France |
| A2 | The technology combines two competencies: remote sensing and agronomic models to develop precision farming and integration of satellite data in agronomic models. | France |
| A3 | New technology is represented by the new certification service and related tool for communication. This approach can assist and improve products and processes sustainability. | Italy |
| A4 | Biogas plants trading within Swiss emissions scheme and improve the quality of fertilizer. | Switzerland |
| A5 | Feed additive that can reduce GHG emissions from ruminants. | Switzerland |
| A6 | LED farming/urban farming. | the Netherlands |
| A7 | Use water treatment plant by-products to produce fertiliser and pig feed additives. | the Netherlands |
| A8 | Water salinity regulator. | the Netherlands |
| A9 | Remote sensing technologies for water. | the Netherlands |
| A10 | Precision irrigation systems that integrates meteorological data. | the Netherlands |

[1] CSA = climate-smart agriculture, GHG = greenhouse gas.

**Table 2.** Climate-smart agriculture technological innovation user data sources/participants.

| | Users | Interview country |
|---|---|---|
| B1 | Financial services, with interests in agro-food chains. | the Netherlands |
| B2 | Dairy products company. | the Netherlands |
| B3 | European-level farmers' association and trade body for agro-cooperatives. | the Netherlands |
| B4 | Farmers association. | the Netherlands |
| B5 | Sugar processor. | the Netherlands |
| B6 | Consumer goods provider. | the Netherlands |
| B7 | Agro-chain investor. | France |
| B8 | Vendor for livestock feed products. | France |
| B9 | Financial and industrial actor of French oleaginous and protein seeds industry. | France |
| B10 | Potato farmers' association. | Italy |
| B11 | Farmers association. | Italy |
| B12 | Support organisation for clean/pro-environmental farming techniques. | Switzerland |
| B13 | National retailer. | Switzerland |
| B14 | Global 'snacks' provider. | Switzerland |
| B15 | Supermarket. | Switzerland |
| B16 | Chocolate provider. | Switzerland |

## 4. Results

Empirical data collected through the interviews will now be examined through the BM*f*CSATI critical issues framework, and compared to the critical issues that emerged during the literature review (Figure 1). Each aspect of the framework will be examined in turn and illustrated with examples from the data. During the data analysis it became clear that some key factors were relevant to more than one building block of the BM*f*CSATIs framework. As data was collected from both the supply and demand perspectives, the coding was carried out separately. This has the advantage of allowing the different perspectives to be compared and contrasted, before identifying a combined set of critical issues.

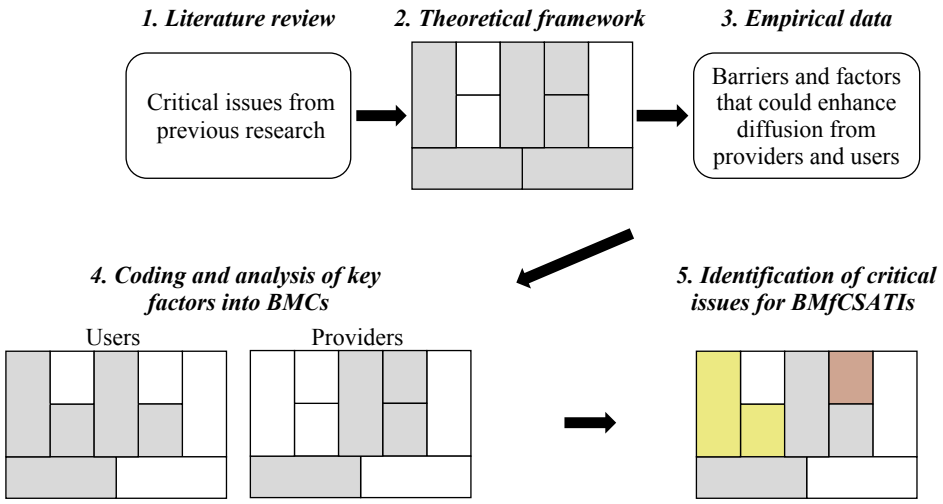


**Figure 2.** Overview of conceptual and analytical process of the research. BMC = business model canvas, BM*f*CSATI = business models for climate-smart agriculture technological innovation.

*Climate-smart agriculture technological innovation provider perspective*

Value proposition – the value proposition was identified as a critical issue for BM*f*CSATIs, as it highlights the value of a technological innovation to the potential user. This has a large impact on marketing and sales, and in turn on adoption and diffusion.

CSA technological innovation providers noted difficulties in terms of proving the value and demonstrating the impact of their CSATIs. As these related to the role of the value proposition, these factors were located in the value proposition of the framework.

> [The] main problem was convincing potential customers that it works, since it's a new technology. (A7)
> Convincing customers is a hard one. We do have small-scale pilot and demonstration projects at farmers' places but [it is] still hard to convince the actual customers of buying the product. The risk for the farmer is high if it doesn't work. It depends on the local circumstances, but mostly the out-roll phase is the complicated one, it goes slowly. (A6)

An enhanced ability to conduct impact analysis and verification, as well as the creation of 'CSA' certification was noted as a change that could enhance adoption and diffusion, i.e. that these actions would boost the adoption and diffusion of CSA technological innovations. These factors increase value, by highlighting the potential impacts of the innovations, and so were located within the value proposition block.

> Scientific verification, which is cheap and a support service for research activities, would be very useful. (A5)
> Moreover, linking to potential customers ... could be a real asset. (A10)

Channels – CSA technological innovation providers noted difficulties in accessing customers. This was relevant to the 'channel' building block, as this describes how firms connect with their customers and end-users; in the case of CSA technological innovation providers:

> Clearly reaching the customer is the biggest issue at the moment. (A10)

Correspondingly, CSA technological innovation providers noted that improved access to customers would enhance their ability to diffuse their innovations. This clearly linked to the role of the channel block in a business model.

> We are looking for a European network to increase adoption of this technology in different regions in Europe. We would love to have better access to knowledge institutions, retailers and customers. (A6)

Key resources – it was found that CSA technological innovation providers found it difficult to access capital and investment. This barrier was coded into the key resources block, as capital and finance can be conceptualised as a key resource required to provide the value proposition. For instance, without this, CSA technological innovation providers lack the resources for suitable marketing campaigns or investment into customer relations development.

> We don't ask for investors. The growth has been funded by clients, but we faced barriers; we are an innovative firm, not mature, so we can't give guarantees for investors. But at this step we want to control the development of our own technology. (A1)
> Also the investment and access to investors is something they could really use. (A9)

Improved access to investment and finance was also articulated as something that would enhance the diffusion and adoption of CSA technological innovations.

Key partners – regulatory and policy difficulties were noted as a barrier and were included within this building block, as they relate to poor access to wider networks, including those related to policy and lobbying. Without access to actors with influence or understanding of policy, CSA technological innovation providers noted that their technological innovation were at a disadvantage.

> On the policy side it is also very interesting. It is hard to get water boards and the ministry along … the policy environment is not made for these kinds of technologies. (A8)

CSA technological innovation providers noted improved access to wider networks would enhance their ability to diffuse the technological innovations.

> We are looking for a European network to increase adoption of this technology in different regions in Europe. We would love to have better access to knowledge institutions, retailers and customers. (A6)

Cost structure – the data indicated that CSA technological innovations providers felt that their CSA technological innovations were too expensive and had uncompetitive return of investment (ROI) periods. Whilst this would impact their value proposition, high costs can be traced most directly to cost structures, a specific block in the framework.

> Currently we are charging 20,000 euros for a device but we want to bring this down to 6,000 euros since it clearly was too expensive. (A9)

Figure 3 presents an overview of the results for the CSA technological innovation providers, highlighting the specific barriers and changes that could boost adoption and diffusion. These factors are plotted into relevant blocks within the business model framework.

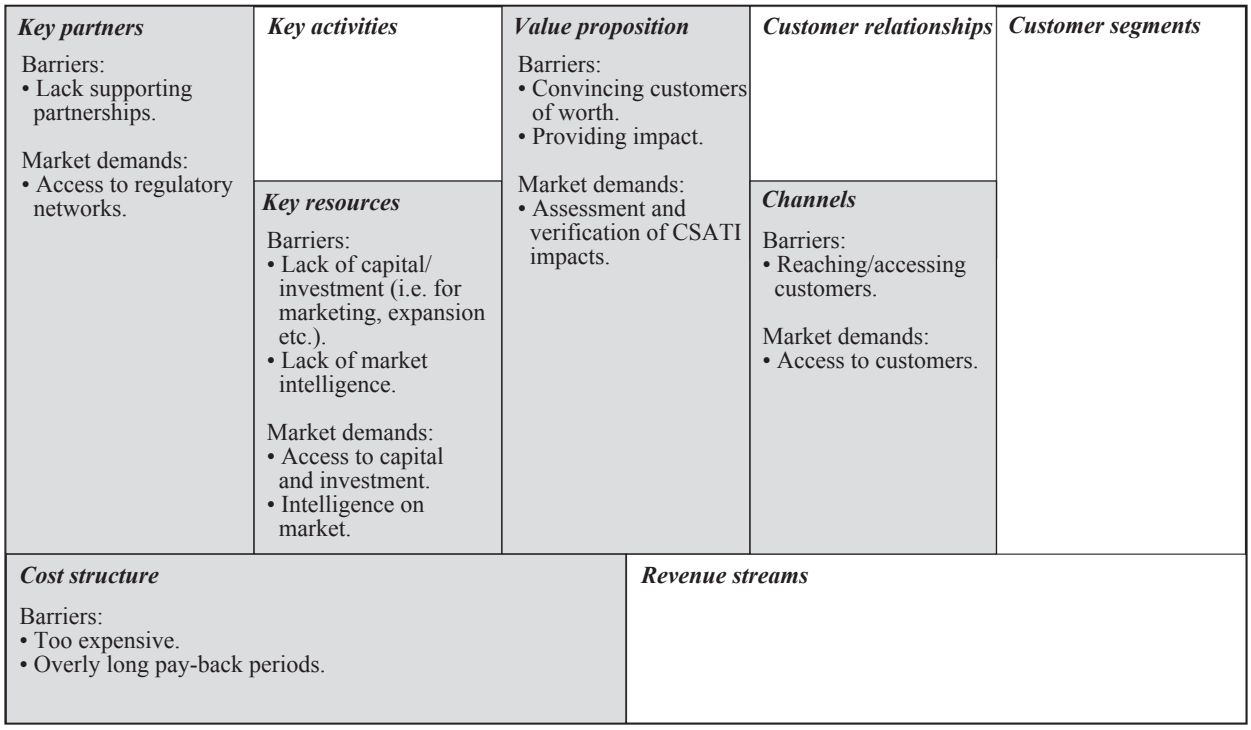


**Figure 3.** Critical issues for business models for climate-smart agriculture technological innovations provider perspective results summary. CSATI = climate-smart agriculture technological innovation.

*Climate-smart agriculture technological innovation user perspective*

Value proposition – the customers and user perspective indicated a lack of verified impact or proof that CSA technological innovations would deliver as advertised. Through the coding, this was felt to highlight a deficiency with regard to the value proposition, as end-users were unsure or unconvinced of the technological innovations actual value.

> Technologies should have a proven impact, so farmers are convinced to use it. (B2)

Information on the economic impacts of the technology should be emphasized to increase the adoption and diffusion of CSA technological innovations. For instance, one potential user noted:

> Don't just focus on climate impacts but actually economic impacts, cost benefit analysis. (B4)

These factors together were felt to correspond well to the value proposition aspect of the business model framework, and in the empirical case, can be considered a critical issue for BM*f*CSATIs.

Channels – CSA technological innovation users highlighted they had too little information of available CSA technological innovations, with no knowledge of, or access to, providers.

> Not enough knowledge about such technologies. (B14)

Changes that would increase adoption and diffusion mirrored the barriers, and included a desire for clear and 'user friendly' information.

> It's more a language and communication issue. Talk to farmers about how the growing season is this year, don't talk about climate change. It's all in the language. (B4)

Make it connect with the daily business on the farm. Start with climate adaptation; as soon as you start with climate mitigation it becomes a 'far away story'. Adaptation is more realistic to farmers, more closely linked to their daily lives, and easier to explain. (B4)

Customer relationships – data indicated that users thought it was difficult to transfer knowledge to farmers.

> Also the knowledge of how to use the technologies, if there are any, is difficult to transfer to the farmers. (B16)

Greater user involvement in the research, development and design process, through closer links with CSA technological innovation providers was noted as likely to improve CSA technological innovations for users, enhancing adoption and diffusion.

> Ask the farmers what they need, then do the research. Demand driven research and development. (B4)
> Also do you research together with farmers; only then will you be able to have an impact. (B4)

These factors were coded into the customer relation block as this articulates how a business engages with its customers (and where information exchange is likely to take place). This could be in terms of the amount of information, or at what stage customer engagement begins.

Cost structure – users identified similar difficulties to the providers in that they saw CSA technological innovations as generally too expensive (compared to existing products), with overly long return on investment periods. As with the similar response by providers, this was coded into the cost structure block.

> Many technologies have long payoff times and do not fulfil internal payoff criteria. (B13)
> Often costs. For instance, with the drip [irrigation] system: if you have a lot of acres, you will need a lot of rubber. Cost can be an issue then. [It is] only beneficial if you have the right conditions. In the end it is a cost-benefit analysis. (B4)

Figure 4 provides an overview of the barriers and factors that could enhance future adoption and diffusion noted by the respondents. These factors are positioned into the relevant areas of the business model framework.

## 5. Discussion

This research provides two contributions. Firstly, by mapping normative and generic critical issues for BM*f*SI on to the BMC, we developed a theoretical framework for critical issues for BM*f*CSATIs. Second, with empirical data we have been able to explore this theoretical framework and highlight critical business model issues for the diffusion of CSA technological innovations. Whilst previous research has identified factors that hinder the adoption and diffusion of CSA technological innovations factors, the novelty of this research is the application of these factors to the business models of CSA technological innovation providers. In this way, we identify critical issues for technological innovation diffusion in specific areas of the business model. By applying the barriers and factors that could boost the adoption and diffusion of CSA technological innovations to a business model framework, we are able to identify critical business model issues and propose business model innovations that could boost adoption and diffusion.

As data was collected from both the providers and potential users of CSA technological innovations, we are also able to compare supply and demand perspectives of the current BM*f*CSATIs, and highlight potential deficiencies of CSA technological innovation providers' business models, from two perspectives. This is an interesting result and further contribution, as it shows that perceived deficiencies of the current business models of CSA technological innovation providers are not mutually recognised by the two groups.

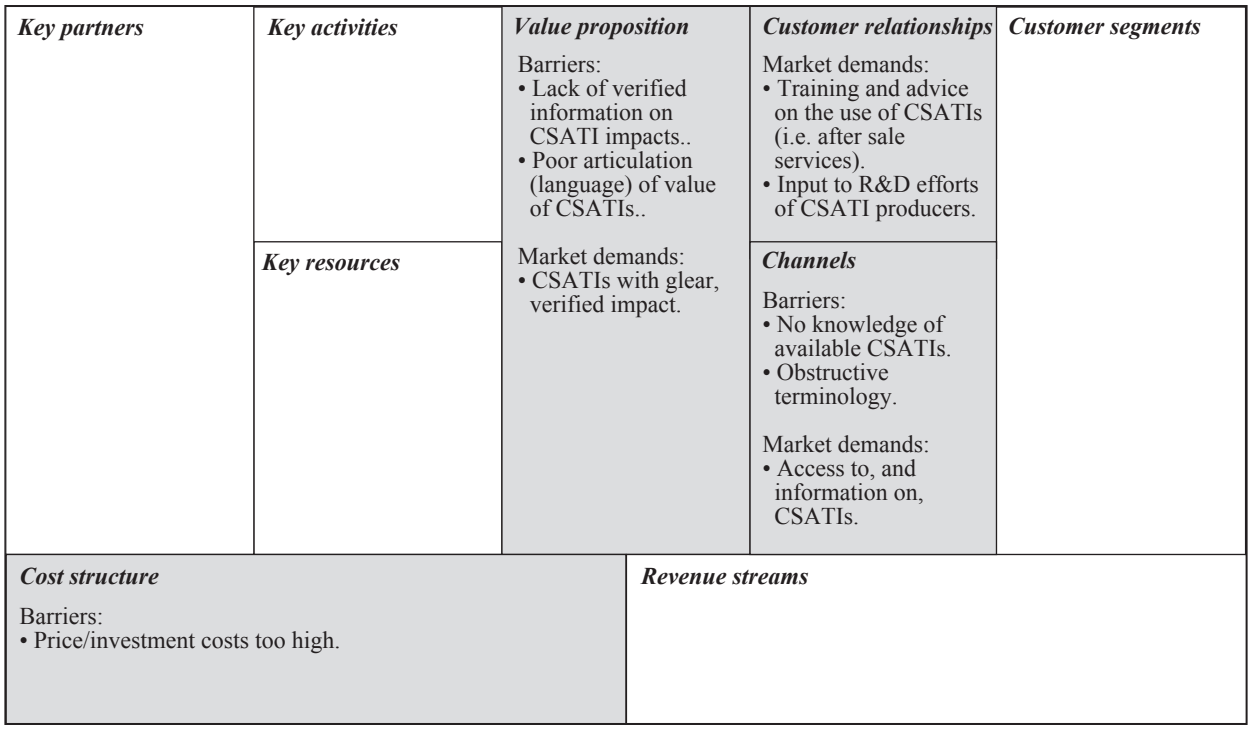


**Figure 4.** Critical issues for business models for climate-smart agriculture technological innovations user perspective results summary.

Both groups identified problems and potential changes concerning the value proposition, channels and cost structures. But CSA technological innovation providers identified critical issues for key partners and key resources, which were not identified by potential users. This may not be surprising, as these are internal aspects of a business model, and not easily recognisable to customers or users. However, this is not the case with the deficiencies noted by potential users with regards to customer relationships, which were not recognised by the innovation providers. Figures 2 and 3 highlight graphically the critical issues for BM*f*CSATIs for both the user and provider groups, whilst Figure 5 provides a synthesised BMC, providing an overview of critical issues for BM*f*CSATI diffusion.

*Assessment of critical issues for business models for climate-smart agriculture technological innovations and previous knowledge*

A crucial question is what changes or innovations to these business models would increase diffusion rates of CSA technological innovations? This question allows this research to connect to the wider literature on business models and innovation, which often seeks to understand how business models innovations can enhance the diffusion of innovations (Baden-Fuller and Morgan, 2010). Our finding is that the current business models of CSA technological innovation providers, within our sample at least, do not currently appear to be designed or operating in an optimal way to diffusion CSA technological innovations. This lends support to assertions within the literature that appropriate business models are required for the success of innovations (Bohnsack *et al.,* 2014; Boons *et al.,* 2013; Teece, 2010).

The BM*f*SI literature highlights several critical issues, which are reflected well in the results. One critical issue includes the need for low initial margins, to allow competition with establish firms (Chesbrough, 2010). Current CSA technological innovations were identified as overpriced and as having overly long ROI periods by both the innovation providers and potential users; this indicates that either margins are too high, or that the wider cost model of innovation providers is not optimised. This impacts on the value proposition through the need to provide proof or verification, which is likely to be exacerbated by the perceived high

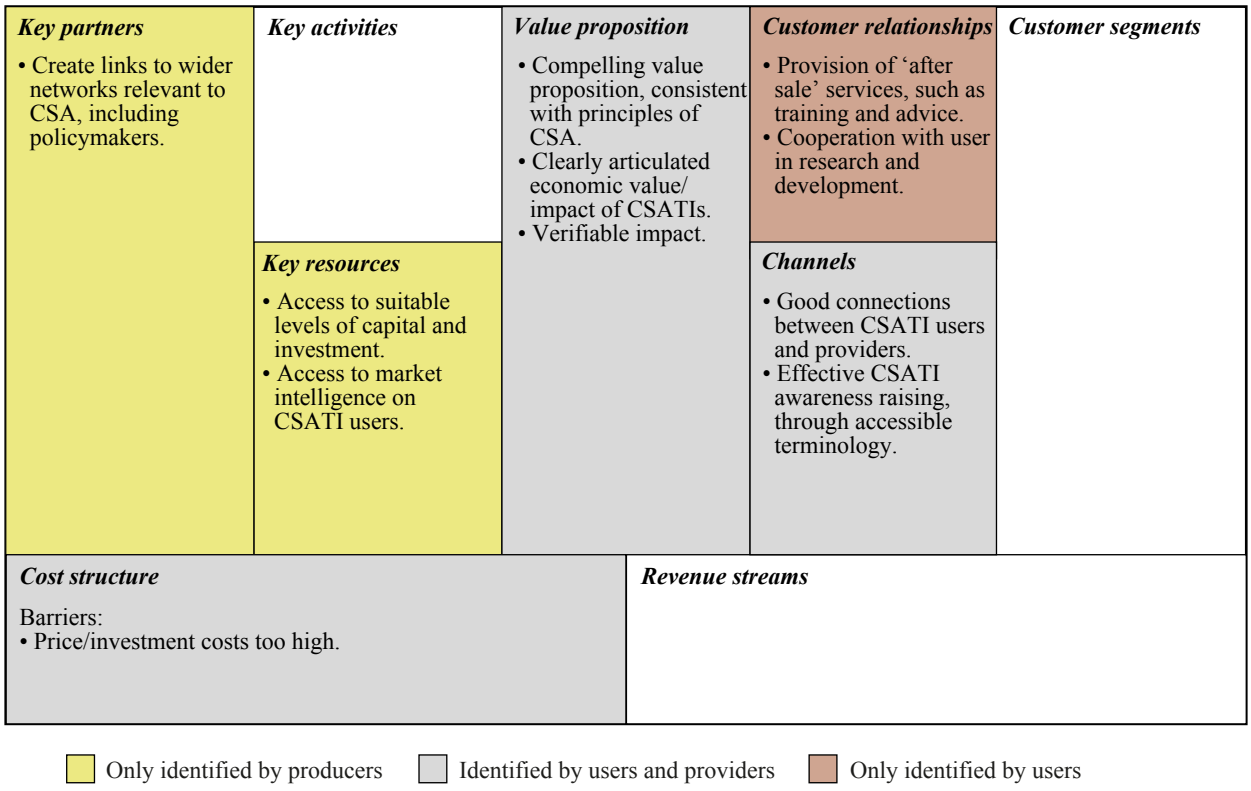


**Figure 5.** Aggregated critical issues for business models for climate-smart agriculture technological innovations.

price. Such factors correspond to the importance of price and quality identified within literature as important for the success of sustainable innovations more widely (Brécard *et al.,* 2009; Brouhle and Khanna, 2012).

A second critical issue concerns how customers will use the innovation (Teece, 2010) and the importance of integrating stakeholder perspectives, including those of customers, in the research and development process (Byrne and Polonsky, 2001; Carrillo-Hermosilla *et al.,* 2010). Previous research also emphasises the importance of ease of adoption (Kemp and Volpi, 2008). Neither of these factors was recognised by the innovation providers, but were highlighted as factors that could increase diffusion by the potential users. This was coded into the customer relationship block. This discrepancy is important, as the lack of recognition of this factor by the innovation providers means that this critical issue is unlikely to be acted upon and integrated into future iterations of their business model.

A third critical issue was located within the channel block and relate well to the previously identified importance of links to customers (Boons and Lüdeke-Freund, 2013), and to the significance of information for the success of sustainable innovations (Lee *et al.,* 2006). Access to customers, or awareness of CSA technological innovation, was recognised by both sets of respondents. However, the importance of accessible information provision to the market was only noted by the potential users, highlighting a further area where innovation providers are unaware of a deficiency and critical issue.

The need for a supportive regulatory environment for sustainable innovations highlighted by Nair and Paulose (2014), was found to be a critical issue in this case. A perception existed that CSA technological innovations were disadvantaged by the current policy environment. This was coded into the key partners block, as it reflects a lack of access or influence in the wider networks that can influence the market.

A move away from per product pricing to 'jobs done' pricing is advocated in the BM*f*SI literature (Boons and Lüdeke-Freund, 2013). This factor was not recognised within our results by either providers or users.

This could be due to the more normative nature of the issue within the literature, compared to the more practical issues faced within the empirical sample. Equally, some CSA technological innovation providers may be charging via per 'jobs done', but neither providers nor users see this as a barrier or a market demand, meaning it was not uncovered by our questioning.

*Implications and innovations for business models for climate-smart agricultural technological innovations*

Building on the normative recommendations of the literature, it is possible to take each building block of the BM*f*CSATIs and the associated critical issues, and identify innovations that could encourage greater adoption and diffusion of CSA technological innovations.

The value proposition building block for BM*f*CSATIs involves several critical issues. These include problems demonstrating impact and proving value, and ensuring that the economic value of CSA technological innovations was clearly articulated. Linked to the value proposition is the cost structure, with both users and providers noting that CSA technological innovations were too expensive with overly long return on investment periods. In order for BM*f*CSATIs to be enhanced, the value proposition must be made more compelling. This will involve reducing the price of CSA technological innovations, which may mean alterations to the cost structure, hence also reducing their ROI period, as well as ensuring that impacts of CSATIs are assessed to give users confidence. Loock (2012) notes that the value proposition should contain either the lowest price, best service or best technology.

The customer relationship building block also contained several critical issues, including a demand for more 'after sale' services, as well as interaction with users during the development phase of the innovations. Business model innovation here should focus on the development of complementary services, such as training or education programs. To satisfy demands for user involvement in design, consideration and integration of principles such as user-centred design and/or open innovation models may improve BM*f*CSATIs (Abras *et al.,* 2004).

The lack of access to finance and capital, within the key resources block, could be addressed through moderation of the 'key actors' area of the business model. A lack of access to capital or investors may reflect poor links to wider networks including policymakers or venture capitalist. These difficulties will require different innovations within business models, but are all critical issues. Access to capital or investors as well as links to policymakers indicate business models that are too closed; BM*f*CSATIs need to open up (Huizingh, 2011) and create stronger links with wider stakeholders.

*Assessment of the business model perspective*

The BM*f*CSATIs framework, based on a synthesis of BM*f*SI and BMC, performed well in highlighting critical issues for the adoption and diffusion of CSA technological innovations and how they interact with the business models of innovation providers. This approach followed the third stream of business model research as it investigated how innovations and their associated business models compete in the market, impacting innovation adoption and diffusions (Chesbrough, 2010; Wirtz, 2011). We have identified key organisational level business model factors, peering into the 'black box' of firms, noted as somewhat neglected in the literature to date (Boons and Lüdeke-Freund, 2013). The sample enabled us to include several inter-organisational elements and how these relate to the business model.

The framework we developed through a review of literature on business models, sustainable innovations and their interaction, successfully identified all but one of the critical issues highlighted in the data; this can be observed by comparing Figure 1 and 4. The critical issue which did not emerge from the coding, revenue streams concerning 'jobs done' pricing, may not have been a critical issue purely because it may operate already within this market, and not be perceived to be a barrier.

Although business model innovations offer avenues for improvement in the adoption and diffusion of CSA technological innovations (as outlined in the previous section), external assistance will be required where external influences are present, which are beyond the control of the innovator. These may include low consumer demand for CSA products as well as more general policy and regulatory issues that would be unlikely to be overcome via business model innovations alone. Indeed, it is highlighted by (Ceschin, 2013) that sustainable innovations may require financial and regulatory protection during their infancy, which is an issue that must be addressed by external stakeholders,

## 6. Conclusions

This article has highlighted and explored critical issues for BM*f*CSATIs. By identifying both barriers and factors that could improve the adoption and diffusion of CSA technological innovations, and by locating where in the business models of innovation providers these barriers and factors operate, we have examined how business models impact the adoption and diffusion of technological innovations. Business model deficiencies were identified, as well as remedial business model innovations.

As current BM*f*CSATIs are non-optimal, they can be seen to be one barrier to the uptake of CSA technological innovation in Europe. That said, CSA technological innovations represent a relatively new market area, meaning many innovation providers are small and young firms likely to be subjected to many of the barriers inherent within start-up firms. The central practical implications include the need to develop innovation provider business models through both internal business model innovation and external supporting actions, such as the provision of advice or access to finance.

By conducting this research, we have contributed to a wider literature on business models and their relationship to innovations and sustainable innovations. There was broad consistency between the generic and normative factors identified in the construction of the theoretical framework, and the empirical findings. Whilst we feel that the framework performed satisfactorily, the data used to populate it represented a relatively small sample. This opens up opportunities in the future to supplement the study's exploratory approach. The BM*f*CSATIs would benefit from further development, possibly through the use of in-depth case studies or a broader sample in order to validate the results.

## Acknowledgements

The authors are grateful for the financial support provided by Climate-KIC that enabled the research upon which this paper is based.

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