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Bioeconomic Entrepreneurship and Key Factors of Development: Lessons from Argentina

Marcelo Sili [1] and Jochen Dürr [2,*]

[1] National Scientific and Technical Research Council (CONICET), Universidad Nacional del Sur, Bahía Blanca 8000, Argentina; sili@uns.edu.ar
[2] Center for Development Research (ZEF), University of Bonn, 53113 Bonn, Germany
* Correspondence: jduerr@uni-bonn.de

Abstract: For Argentina, a country with large biomass availability, scientific-technological capacities and a strong agro-industrial sector, bioeconomy comes with an opportunity for sustainable local and national development. As key actors in bioeconomic transition processes, entrepreneurs become an important source of information for the design and implementation of bioeconomic strategies and policies. However, bioeconomic activity cannot guarantee sustainable development outcomes. Here, we examine factors that influenced bioeconomic entrepreneurship and related sustainability outcomes. Our case study involved interviews with 23 enterprises of varying size and technological level, covering the main sectors and regions of the Argentine bioeconomy. We identify five bioeconomic pathways with distinct characteristics. Among the main factors driving development in these pathways of the Argentinian bioeconomy, entrepreneurs emphasized the rich endowment with natural resources and the high level of scientific, technological and entrepreneurial capacities. Public policies, economic stability and regulatory frameworks were considered as the most critical barriers to bioeconomic development. Entrepreneurs saw their contribution to sustainable development primarily in the generation of new knowledge and employment. Ecological or social motives were less frequently reported. Despite agricultural commodity production being the mainstay of the Argentinian bioeconomy, small-scale local initiatives, which also include socio-institutional and agro-ecological innovations, are coming up. Recommendations to improve the competitiveness of the Argentinean bioeconomy include the elaboration of a national bioeconomic development policy with the participation of private actors and their organizations, and the scientific and technological complex. Moreover, regulatory and normative frameworks have to be adapted and bureaucratic obstacles be reduced. Finally, a national strategy for the bioeconomy in Argentina should pay more attention to entrepreneurship as a driver of transformation.

Keywords: bioeconomy; sustainability; entrepreneurship; innovations; local development; biofuels

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1. Introduction

Some core principles of the bioeconomy concept include the replacement of fossil fuels by renewable bio-based resources, the development of innovative products, processes and value chains, and the generation of a circular, sustainable economic system [1]. For this transformation to happen, entrepreneurs have to play a crucial role by introducing new products and processes and by establishing new ventures [2]. Entrepreneurship is considered as fundamental for rural development [3], entrepreneurs being the key agents of economic activity and largely responsible for innovation and development processes [4]. Entrepreneurship, as a key driver of the transition to a sustainable bioeconomy, is considered in most national bioeconomic policies, however, the measures in many cases are only limited, as in the case of Argentina, where only venture capital is mentioned [2]. Moreover, an adequate political and institutional framework is considered decisive for the sustainable development of the bioeconomy [5]. This includes, for example, stable legal and

macroeconomic conditions, infrastructural development, specific incentives, investments in human capital and research and development (R&D), and also regulations concerning natural resource management, etc. Bioeconomic ventures often act under specific business environments. This includes the location of most enterprises in rural areas where infrastructure and R&D capacities might be limited, along with the dependency on biomass availability, the need to cooperate with actors from different areas, and the importance of knowledge-based innovations [6]. Bioeconomic entrepreneurs have to adapt their business models to these environments and find solutions to the constraints faced. The specific environments, under which entrepreneurs in the bioeconomy (here synonymously called "bioeconomic entrepreneurs") act and how they influence their business, have not been investigated much so far [6]. Only by knowing which business environments are specifically supportive for the bioeconomy to develop, might policy makers as well as other stakeholders be able to improve bioeconomic policies, strategies and programs.

An additional problem is that bioeconomic activities, as such, cannot guarantee sustainable development outcomes. Especially in Latin America, there are concerns that bioeconomic policies will strengthen the dominant agri-business model, exacerbating inequalities, leading to conflicts over land use, and harming the environment [7]. Expansion of plantation economies can lead to a restructuring of local value chains leading to unequal distribution of benefits, and might be detrimental to regional development due to losses in local value added and jobs [8]. However, besides the biofuel sector, where most research has been focused on so far, there is little knowledge of the contribution of bioeconomic ventures to sustainable development in Latin America.

For Argentina, with its huge biomass availability, scientific-technological capacities and a strong agro-industrial sector, the bioeconomy concept represents an opportunity to overcome the historic opposition between agricultural and industrial development strategies, and to achieve a more balanced territorial development [9]. The productive systems that are predominate in the different regions have been gaining international competitiveness in recent decades, from the increasing incorporation of technologies at increasing scales, creating in some of them (and especially in the Pampas region) a superproductivist model linked to agribusiness. Yet, the practices of this model generated deep social, environmental and territorial imbalances [10].

The main drivers of the bioeconomy in Argentina have been, besides its great biodiversity and richness in natural resources, the development of scientific-technological capacities, the application of new, knowledge-based biotechnologies, and new organizational and business models [11]. Nevertheless, R&D capacities are not homogeneously distributed in the national territory. Even with a high level of know-how in basic, agronomic and biotechnology sciences, research groups often do not collaborate with the private sector and scientific results are not being translated into innovations and applications in biotechnologies [12].

On the political level, the government launched a strategic paper on the bioeconomy in Argentina in 2017. The strategy involves strengthening of comparative advantages for regional development, of institutional frameworks and of sustainable energy supply from biomass [13]. Furthermore, the Ministry of Agriculture points out the opportunities associated with the bioeconomy for regional development, the integration of traditional activities and new industrial developments, and for a decentralized, clean production of renewable energies. As strategic pillars, the Ministry mentions the support of regional development, and the promotion of bio-based energy supply and value addition, of scientific-technological development, and of institutional frameworks for the sector [14]. Nevertheless, one of the limiting factors that impeded (bio-) industrial development in Argentina have been unstable macroeconomic policies with high inflation rates and a consequent lack of credits and investments [9].

Given the great potential of the development of the bioeconomy in Argentina, various factors must be considered. On the one hand, there are specific constraints that enterprises might face in this country, and on the other hand, there is the ongoing debate as to whether the bioeconomy can lead to sustainable development. As such, the main purpose of this

paper is to explore the factors that bioeconomic entrepreneurs in Argentina themselves consider to be decisive for their business development, and which sustainability outcomes they can generate with their ventures. In general, "efforts to understand the conditions of the business environment in which bioeconomy businesses operate have been very minimal." [6] (p. 2). This is even more valid in the case of Argentina. Besides one recent document [15] on the factors that promote or inhibit the bioeconomic activities of eleven enterprises, to our knowledge, no other empirical studies have been carried out in Argentina to understand those factors. Also, studies on the sustainability outcomes of bioeconomic enterprises in Argentina are scarce and mainly relate to the biofuel sector.

Our intention is to fill this research gap by using a case study of 23 enterprises of varying size and technological levels, covering the main sectors and regions of the Argentine bioeconomy. By doing this, we want to answer three research questions: Firstly, how can entrepreneurs in Argentina, given the economic and political conditions, play their role in the transformation towards a bioeconomy, or, in other words, what are the existing factors that strengthen or weaken bioeconomic activities, and how do entrepreneurs react to these situations, i.e., how do they grasp opportunities and overcome obstacles? Secondly, what are the contributions of the bioeconomic ventures towards sustainable development processes? Thirdly, which policies are needed to strengthen the transformation towards a sustainable bioeconomy in Argentina? To answer these questions, we use a case study approach which enables us to explore the experiences and knowledge of entrepreneurs of the bioeconomy in Argentina. Case studies are well suited for answering "how"-questions [16]: in our case, how bioeconomic entrepreneurs develop their business under the Argentine business environment and how this translates into sustainability outcomes.

The paper is organized as follows: First, we describe the analytical framework of the case study; Second, we explain the methods used and give an overview of the enterprises interviewed; Third, important factors influencing the advancement of the bioeconomy are presented, and the development outcomes analyzed; Fourth, we discuss the results on pathways, factors, outcomes and the role of the entrepreneurship in the bioeconomy; Finally, we conclude and give recommendations for further research and development of the bioeconomy in Argentina.

2. Analytical Framework

The analytical framework used evolves around the concept of different pathways towards the bioeconomy, the role entrepreneurs play in this transition, the factors that might influence this transition, and the possible outcomes for sustainable development. We used the literature research from Web of Science and Google Scholar with the respective key words ("bioeconomy" OR "bio-based economy" AND "transition", "pathway", "entrepreneurship", "factors", "sustainability", "Argentina"), along with the additional sources found in the references of articles.

2.1. Bioeconomic Transition Pathways

The bioeconomy emerges as a new set of activities based on the use of biological resources. It mainly rests on three pillars: the intensive and diverse use of products of biological origin (biomass); the intensive use of innovative knowledge; and the development of a wide range of new products derived from these biological resources [17]. The Economic Commission for Latin America, CEPAL [18] defines the bioeconomy to be: (a) an economy based on the consumption and production of goods and services derived from the direct use and sustainable transformation of biological resources and the biogenic waste generated in the transformation, production and consumption processes; (b) taking advantage of the knowledge of biological processes and principles; and (c) the technologies applicable to the knowledge and transformation of biological resources and the emulation of biological processes and principles.

There have been different attempts to categorize bioeconomic sectors, visions, or pathways. For example, Kardung et al. [19] characterize natural-resource based sectors,

conventional manufacturing sectors, and novel sectors, which further process biomass. Bugge et al. [20] differentiate three bioeconomic visions, depending on whether the focus is mainly on bio-technologies, on the use of bio-resources, or on bio-ecological processes. Dietz et al. [21] distinguish four bioeconomic transformation and innovation pathways (TPs), which are influenced by the mechanisms and factors described by Börner et al. [22], and which might have different sustainability outcomes: TP1: fossil-fuel substitution; TP2: boosting primary sector productivity; TP3: new and more efficient biomass uses; TP4: low-bulk and high value applications. The pathway concept of Dietz et al. [21] is based on theoretical considerations of how techno-economic mechanisms such as factor substitutions (of fossil by renewable resources) and efficiency gains (by innovations) can play out in different ways towards a bioeconomic transition. Whereas the visions typology from Bugge et al. [20] might be useful for the analysis of bioeconomic discourses, the transition pathway categories seem more suitable to detect these different techno-economic mechanisms which drive the development and shape the outcomes of the bioeconomy [23].

Even if, as we will see, these pathways are not mutually exclusive, for analytical reasons, we use the concept suggested by Dietz et al. [21], as it allows us to better differentiate the role of innovations, influencing factors, and outcomes depending on the specific pathway. However, we added a fifth one, by differentiating pathway three into one that is focused on using existent, yet under-utilized biomass, mainly organic waste or side streams, for new purposes (still called TP3), and innovations in new bio-based products and services by locally adding value (called TP5). The creation of a fifth pathway was considered opportune as during our study, we have perceived the special importance of locally embedded initiatives strongly focused on the valorization of local resources (other than organic side streams), in the context of Argentina.

2.2. Bioeconomic Entrepreneurship

Bioeconomic ventures constitute an emerging sector with new rules of the game and new logics, where innovation and the entrepreneurial nature of the actors play a key role. The analysis of the figure of the entrepreneur has revolved around the contributions of Schumpeter [24], who considered him to be a dynamic actor, capable of generating a break from a situation of market equilibrium to move to a higher stage, through the introduction of innovations as one of the main pillars of economic development. Innovation is interpreted as a permanent modification of productive and organizational processes in search of improved efficiency and productivity, in which technologies and relations between agents play a determining role [25]. Innovation, with its collective and systemic character, has the capacity to generate positive externalities that can be exploited by other actors in the territory or sector, who manage to use the innovations, experiences and knowledge of economic actors, research organizations and governmental agencies [26].

Considering the role played by entrepreneurs with regard to innovation, and new products and processes, they are of special importance when it comes to making the transition towards a sustainable bioeconomy. As Kuckertz et al. [27] point out, the bioeconomy offers a new, promising field of innovation where enterprises perceive opportunities to create competitive advantages, but where they often also have to take higher risks. Besides the micro level, the meso level of a conducive enterprepreneurial ecosystem, i.e., networks of actors such as universities, specialized investors and established larger firms, is considered to be necessary in order to catalyze the development of the bioeconomy. Finally, the macro level, i.e., governmental support systems, based on a clear vision and bioeconomic agenda, making investments and offering programs, can foster the bioeconomy.

However, as highlighted by Korsgaard and Müller [28], although entrepreneurship is a key factor in development processes, the creation of ventures varies according to the degree of commitment of the actors to the territory, not only due to economic calculation issues, but also for identity and life project reasons; reasons that have not always been taken into account by classical economics, yet are important in local development processes. Moreover, the presence of institutions that encourage entrepreneurship, such as a culture

with an entrepreneurial profile, together with the population's disposition to take risks, can create an appropriate environment for the entry of new companies into the productive sector [29].

Adamseged and Grundmann [6] developed an analytical framework of business environments to analyze the success factors of bioeconomic enterprises in rural areas, which includes institutional development, technology and knowledge, consumers' agency, market structure, funding, resource and infrastructure, and training and education. The authors validate this framework empirically by interviewing bioeconomic enterprises in different European countries. They find that special challenges exist for entrepreneurs in the bioeconomy, for example, from complex regulations, the need of knowledge for technical and organizational innovations, and the importance of consumer awareness. The importance of factors can differ depending on the size, location and products of the firm.

In our analysis, we focus on the micro level (enterprises), although we also consider the role the meso level (networks, cooperation with R&D centers, etc.) and governmental policies play for the entrepreneurs, i.e., the interplay of the three levels described by Kuckertz et al. [27]. We also paid attention to the personal factors and reasons mentioned by Korsgaard and Müller [28] in the analysis. We also partly rely on the framework of Adamseged and Grundmann [6] for the analysis of the business environment. In addition, factors mentioned outside the specific literature on entrepreneurship, as described in the next section, were taken into account.

2.3. Factors Influencing the Development of the Bioeconomy

Despite the existence of new ventures and innovation dynamics, various authors [18,30,31] emphasize the need to satisfy four major elements, without which the construction of virtuous dynamics of productive development derived from natural resources may be limited: Firstly, the availability of such natural resources in a sustained manner over time; Secondly, the presence of a facilitating and innovative environment around these activities, i.e., a culture of entrepreneurship, the presence of business actors and networks, universities and technology centers, among others; Thirdly, the overcoming of problems derived from distance, since natural resources are often found in territories far from large cities, which represents a series of disadvantages such as a lack of human and financial resources, services and infrastructure, and proximity to markets, which may condition the success of the enterprises; Fourthly, a macroeconomic environment that provides sufficient time for the maturation of productive enterprises.

For analyzing the factors that influence the potential for sustainable bioeconomic growth, different frameworks have been developed, for example, by the European BERST [32] project. The BERST model for the operation of a regional bioeconomy includes supply and demand side factors, differentiating, on the supply side, factors of production (natural resources, labor, capital, innovation), and on the demand side, destinations (intermediate, consumer, export). The SAT-BBE project developed a driver-impact-result framework where technology and innovation, market organization, environmental change, demographics, economic development and consumer preferences constitute the (dynamic) supply and demand drivers, whereas policies, strategies, and legislation are considered as the governmental measures to influence the bioeconomic development [19]. Teräs et al. [33] examined enabling and impeding factors of the bioeconomy in different regions of five Nordic countries, which consisted mainly of natural resources, cooperation and synergies between key actors, the institutional and political framework, funding possibilities, and human resources. García-Quevedo et al. [34] group the barriers to the development of European small and medium-sized firms in the circular economy into two main categories: lack of resources and capabilities and regulations and costly administrative requirements. Börner et al. [22] conceptualize the mechanisms of a bio-based transformation: besides underlying drivers such as population growth, economic growth, climate change, technological innovations and general policies, they point out the main mediators of such a change, which are divided into change mechanisms (policy incentives, markets/trade, and

knowledge and innovation transfers) and context factors (natural resource endowment, governance effectiveness, and infrastructure). Hinderer et al. [35] found in their expert survey that political strategies, programs and standards are considered as most important for the transition to the bioeconomy, followed by aspects such as competitiveness and investment in research. The supply of biomass, technical progress and consumer awareness were rated as less important by the experts.

Considering the wide range of different factors suggested in the literature, we assume that socio-cultural, economic, technological, institutional and political factors might either enable or constrain the development of a bioeconomy by influencing the decisions of entrepreneurs, their economic opportunities and business success. However, some factors might be more important for specific pathways, while others might be valid for all of them.

2.4. Sustainability Outcomes

The ongoing debate on the impact of the bioeconomy on sustainability goals is still highly controversial between scientists and experts in the field, however there is a growing amount of literature on possible (un-) sustainable outcomes (see the reviews of [30,36–38]. However, there are few studies on the sustainability outcomes of the different pathways suggested by Dietz et al. [21]. Biber-Freudenberger et al. [30] in their literature review, show the most common benefits and risks expected for sustainability in each of the transition pathways (TPs). For TP1 (fossil fuel substitution), the main expected benefits are greenhouse gas emission reductions, and the risks are related to land use change, competition for food, and biodiversity loss. For TP2 (boosting primary sector productivity), society can benefit from innovations, increased food production and income for farmers, with less pesticides and less impact on biodiversity, although the risks associated are on ecosystem services, unequal access to knowledge and technologies, especially for smallholder farmers, and negative impacts on food security, inter alia. For TP3 (new and more efficient biomass uses), the benefits could be lower input use, lower pollution, better waste management and higher food security, although maybe at the expense of negative health and ecological effects, and higher competition for food production. For TP4 (low bulk-high value applications), increasing levels of knowledge, technologies and skills due to innovations, and also health benefits are expected, but also increasing inequalities between rich and poor countries, and between the highly and the less educated, among other things.

Stark et al. [23] discuss and give examples of possible outcomes of transition pathways 1 to 4. TP1 can, through higher demand for biomass resources, lead to (indirect) land use change in ecological sensitive regions such as forests. TP2 may, by boosting agricultural productivity, induce the expansion of the agricultural frontier into sensitive ecosystems. TP3 of new biomass uses might, if not based on side streams or waste, cause higher demand for biomass with similar consequences. Even TP4, which uses low volumes of biomass, but aggregates high value, may lead to undesirable consequences if technology risks and inadequate utilization exist.

Following the literature review and expert opinion survey of Biber-Freudenberger et al. [30] and the examples of Stark et al. [23], which are, to our knowledge, the first to try to systematize the possible outcomes of each of the transition pathways, we link the pathway characteristics to specific economic, social and environmental impacts.

3. Methods

3.1. Selection of Cases and Sample Structure

We used a case study as an appropriate approach to describe, systematize and explain dynamics in new technologies and emerging bioeconomic processes not yet widely studied and understood [16,39–41]. The investigation has a descriptive and exploratory nature, since it analyzes a wide field of activities not studied in detail in the Argentine case, and on which new information and evidence is to be built. This strategy placed much more emphasis on the quality and representativeness of the informants than on the quantity of cases to be analyzed. The research strategy was to include a diverse sample of bioeconomic

ventures to have a broad picture of the bioeconomy in Argentina, but also, to detect differences between sectors and pathways. Moreover, a diverse selection of the sample should help to increase the validity of the results by doing cross-case analysis of similarities and differences [39]. For example, if the most diverse types of companies name the same factors, one can assume that these have an important influence on the development of the bioeconomy as a whole.

As there are no consolidated databases of companies dedicated to the bioeconomy in Argentina, we had to rely on the only information available, which consists of a list from the Ministry of Agriculture and Science and Technology, with a total of 88 bioeconomic ventures. Our aim was to include ventures of all the bioeconomic pathways, and to cover sectors and regions that constitute the main actual and probably future areas of the Argentine bioeconomy (forestry in the Northeastern region, biofuels and bio-oils in the Pampean region, marine resources in the Patagonian region, food and beverages in Cuyo and other regions) and its main biomass sources, coming from the agricultural and livestock sector, the forest sector, the marine/aquatic sector, and from residual/waste management [12]. We also tried to include ventures of different size and technological levels. Based on these criteria, and with the (limited) information on the characteristics of enterprises, 23 enterprises were selected from the list for the semi-structured interviews, a number considered manageable. Subsequently, each of the ventures was contacted to explain the type of research and to schedule an interview date and time.

The structure of the sample is given in Table 1. As can be seen, overall, the cases cover a wide range of different sectors, regions, sizes, and technological levels. However, given the limited number of cases, it was not possible to include all sectors, regions, sizes, and technological levels, for each pathway. Also, the forest sector could not be included. Moreover, as mentioned above, the information on size and technological level was not very clear beforehand, and therefore these categories could only be roughly pre-estimated.

Table 1. Number of cases selected from different pathways.

TP	Nr. of Cases	Sector (Nr. of Cases)	Region (Nr. of Cases)	Size (Nr. of Cases)	Techn. Level (Nr. of Cases)
1	5	Biofuels (4), Bioplastics (1)	Pampa (5)	Small-Medium (5)	Middle-High (3) Low-Middle (3)
2	6	Inputs for Agriculture (4) Inputs for Livestock (2)	Patagonia (1) Cuyo (1) Pampa (4)	Medium-Large (3) Small-Medium (3)	Middle-High (6)
3	3	Residuals for Food Production (3)	Patagonia (1) Pampa (2)	Small-Medium (3)	Middle-High (2) Low-Middle (1)
4	2	Pharmaceuticals (2)	Pampa (2)	Medium-Large (2)	Middle-High (2)
5	7	Food production (6) Aquatic/Marine (1)	Patagonia (2) Pampa (2) Northeast (2) Northwest (1)	Small-Medium (7)	Middle-High (3) Low-Middle (4)

As can also be seen in Figure A1 of the Appendix A, the locations of enterprises are widely distributed over the vast Argentinean territory. Moreover, a short summary of the starting points, activities and development of the interviewed enterprises, differentiated per pathway, are given in Table A1 of the Appendix A. For TP1, the fossil-fuel substitution pathway, we interviewed five small and medium enterprises, three of them dedicated to biofuels, one to biogas, and one to bioplastics. For TP2, the pathway of boosting primary sector productivity, we interviewed three companies of bio-inputs for agriculture (inoculants, seeds, etc.), a company of vaccines for livestock and one of its suppliers, and a research center developing new insecticides. For TP3, the pathway of new and more efficient biomass uses, we got information from three enterprises that use different agro-industry residuals. For TP4, the pathway of low-bulk and high value applications, we conducted interviews with two medium-sized pharmaceutical companies. For TP5, the pathway of locally creating value added with new products and services, we interviewed a wide range of initiatives and enterprises, dedicated to tobacco and reptile leather manufac-

turing, fish pond recovery, pro-biotics from an Andean plant, mushrooms for haute cuisine, and pharmaceuticals and cosmetics from sea urchin eggs.

3.2. Data Collection

For triangulation purposes, a method proposed for case studies [16], we combined qualitative information from the interviews with descriptive statistics from an online survey that allowed the systematization of the information generated. At the same time, information about the companies was collected on their respective web pages in order to learn about their activities and products.

Given the conditions imposed by COVID-19, the interviews were conducted virtually through the internet, using Zoom. The interviews took place in a pleasant and trusting environment, and all the enterprise leaders agreed to record the interviews that lasted between 60 to 90 min, and were conducted between October and December, 2020. Three main open-ended questions were asked on: (1) the factors which fostered the ventures; (2) the factors which limited the bioeconomic enterprises; and (3) the outcomes for sustainable development. The interviews were recorded, which allowed us to check the information again if necessary.

The interviews were complemented by online surveys completed by the interviewees, using Google forms. In total, 78% (18 out of the 23) enterprises responded (60% from TP1, 83% from TP2, 100% from TP3, 50% from TP4, and 86% from TP5). The survey was aimed at systematizing information on the factors, impacts and needs of the different bioeconomic ventures by asking questions with pre-given answers. The variables of the questionnaire are based on the literature presented in Section 2. The online survey can be found in the Appendix B. For the first question, which asked how different factors influenced the business development, ten factors were presented and interviewees were asked how these affected the development of their venture. Secondly, we asked if the impact the enterprises had on different social, economic, and environmental outcomes was null, low or high. In the third question, we wanted to know if certain conditions for the future development of the companies are fundamental and urgent, or necessary, or no matter of concern.

3.3. Grouping of Cases and Data Analysis

The categorization of business cases into pathways is not always straightforward as some cases might belong to various pathways. In order to check this, we asked the entrepreneurs in the survey how much they contributed to the five pathways. Nearly all (16 of the 18) respondents categorized themselves into the same pathway we had put them, i.e., they stated that they contribute (a lot) to the given pathway. However, nearly all (17) enterprises also stated that they contribute to at least two other pathways. Therefore, we continued with the original grouping following the examples given in Biber-Freudenberger et al. [30] and Stark et al. [23].

For the qualitative data from the semi-structured interviews, a comparative two-step analysis was undertaken. In the first step, we made a transversal analysis of the ventures within each of the three main interview questions. A synopsis of all cases was built to facilitate the comparison of the contents of each interview and question. The vast and very diverse information obtained was then categorized around the factors and outcomes mentioned in the analytical framework. In a second step, we compared the results of the five pathways in order to detect specific characteristics, but also similarities between them.

4. Results

4.1. The Drivers of Bioeconomic Development

From the information obtained in the interviews and the survey, it was possible to analyze which were the main factors that limited or promoted the development of bioeconomic initiatives. Table 1 presents the data from the online survey, which will be described in more detail in the following paragraphs.

4.1.1. Technology Transfer and In-House R&D

An important element to consider for a knowledge-based bioeconomy is the way how companies generate or incorporate new knowledge into production processes [42,43]. In the survey (see Figure 1), 53% of enterprises consider in-house research as essential for the development of their business, and for 35%, it boosted their development. In addition, knowledge transfer from third parties such as research centers and universities is considered by two thirds of companies as a boosting factor. From the qualitative data of the interviews, three different situations that define the trajectory and evolution of companies over time could be observed:

1. The generation of knowledge takes place within the company itself; the companies have their own laboratories or research departments, with solid technical teams, equipment and the capacity to generate new research and patents. In addition to their own R&D teams, these companies are strongly linked to scientific and technological research laboratories or organizations, such as the National Institute of Agricultural Technologies (INTA) or universities, with whom they carry out joint research projects, tests and experiments. These companies correspond mostly to TP2 and TP4, i.e., those that generate products to boost agricultural development (seeds, fertilizers, agro-chemicals in general), and those that generate products of very low volume but very high value (biopharmaceutics);
2. Companies that are highly demanding in terms of R&D, yet do not have own equipment and therefore have built up relationships with research centers, generally belonging to the state. Physical proximity, and in many cases having previously participated as a technician or researcher in these organizations, has allowed the entrepreneurs to articulate scientific knowledge with business development in a stable manner over time. On many occasions, this synergy between R&D has made it possible to generate new products and processes. Most of these are new companies belonging to TP3 and TP5 and have started their development with governmental scientific and technological support.
3. Although there is high-level scientific and technological knowledge, it is not adequately articulated with productive processes. The factor limiting this articulation between knowledge generation and productive development is the existence of very different logics, processes and criteria for action between the scientific and business worlds, and the lack of effective mechanisms for transfer and cooperation. Generally, these companies belong to TP5, and are initiatives aimed at generating new products, which cannot be consolidated due to a lack of funding or business support structures.

4.1.2. The Availability of Raw Materials

Most enterprises (72%) consider the availability of raw materials to have boosted or have been essential for their business (see Figure 1), confirming what other authors have reported [9,11,44]. This is certainly the case for the biofuel industry (TP1) based on soy beans or corn, but also for the initiatives of TP3, which use agricultural waste streams and of TP5 where value is added on locally abundant plants or animals. The great richness in natural resources—from Andean plants to caimans and sea urchins, from soy and corn plantations of the Pampa to wild mushrooms in Patagonia region—can be used in bioeconomic ventures. Often small enterprises start innovations towards pathways TP3 and TP5 when raw materials are locally available and new market opportunities arise, for example, the gourmet and tourist sector for mushroom production. In general, where raw materials are an important base for processing, production is closely linked to or even vertically integrated into the industries. For example, an insect production site has been installed where organic waste from the potato industry was available. One's own production of raw materials such as medicinal plants ensures a stable supply and often lower costs. Outsourcing is also a strategy to ensure high quality supply as seen in the case of serums for the vaccine industry. Nevertheless, some enterprises also stated that availability of raw material was an important limiting factor. For example, price fluctuation

in commodities such as soy beans (paid in US$ whereas biofuels are paid in Pesos), not sufficiently compensated by the formula of the guarantee price, seems to be a problem hampering the further development of TP1. There are also some materials currently not or not easily available from national providers, such as pellets for bioplastics or herb extracts, so that they have to be imported. Finally, the prevalent agricultural production model in Argentina, with its large genetically modified (GM) crop plantations and pastures, thrives in the biotechnology sector of TP2. A highly competitive input sector, which produces seeds, inoculants, or vaccines is developed with the existing production model, and helps to foster it.

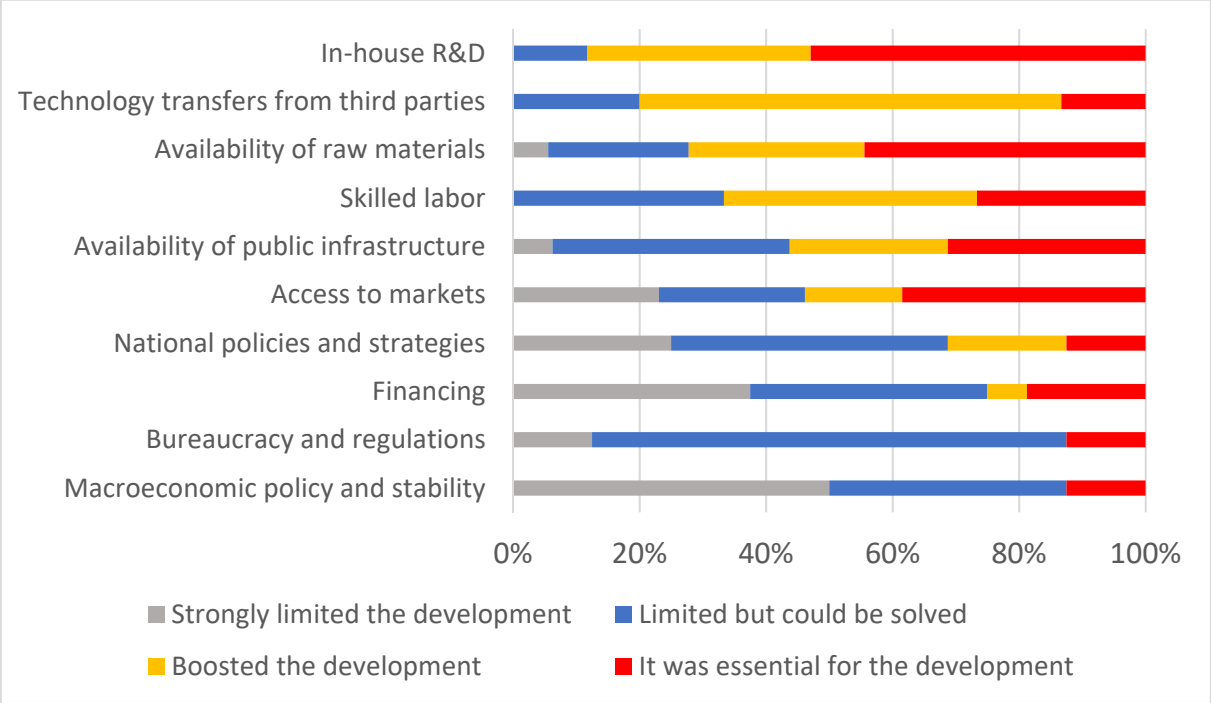

Figure 1. Limiting and enhancing factors for the development of bioeconomic ventures (%). Source: own calculations based on enterprise online survey.

4.1.3. Skilled Labor

The third major factor that drives and enables the development of the bioeconomy is the presence of actors with high levels of training and skills (66% of companies, see Figure 1). Most companies have highly trained personnel and there is a culture of continuous training, provided by the companies themselves, but also in nearby training centers and universities, with which companies maintain close relations, especially companies related to pharmaceuticals (TP4) or the production of bio-inputs for agriculture (TP2).

Without differences between pathways, a well-repeated pattern could be observed with respect to the managers or owners of the companies:

- All of them have high levels of training and professionalization, many of them come from the business or from the scientific world and have a university degree obtained in Argentina or abroad;
- They have a high level of knowledge about the activity, built from a solid working or academic career in the field. The bioeconomic ventures they manage are not the beginning of their professional careers, but rather condense many years of scientific, technological and business experiences;
- They have the capacity to build networks of dialogue with other companies, producer organizations, governments, and especially with science and technology organizations, as they try to build collaborative networks for the exchange of information and

knowledge. This situation is more frequent in companies located in the Pampas region, where there is a greater production tradition and a higher density of R&D institutions and organizations;

- Finally, they are actors with an entrepreneurial spirit, capable of understanding business dynamics and taking risks.

4.1.4. Availability of Public Infrastructure

Lack of infrastructure has been identified as a powerful limiting factor for the development of bioeconomic initiatives [45,46]. However, in our case study, only 44% of enterprises had this difficulty (see Figure 1), and differences between pathways could be observed. TP1 and TP3 companies, which depend on the supply of large volumes of biomass, require adequate infrastructures, such as a connection to major communication routes, especially paved roads that allow the transport of biomass to the plants, and access to high-powered electricity grids. These infrastructures are not available in the same way throughout Argentina; there is a greater supply in the Pampas region. The companies in these pathways that are located in territories with a greater backlog of infrastructure endowment tend to have greater problems for their development, which is why they must partner with provincial governments to build these infrastructures, often jointly. TP2 companies do not have major infrastructure and equipment difficulties, as they have set up their own laboratories and research centers for the development of their products. TP4 has very complex infrastructure and equipment requirements, but these are private and do not depend on the public sector, except for the basic infrastructure of roads, energy and communications. TP5 requirements are much the same. Thus, all ventures have a minimum of energy, road and communication needs, although this applies even more so in the case of those mobilizing large volumes of biomass. Another critical problem is the lack of quality internet connectivity in the different regions, which hampers the development of these ventures, especially those located in small towns or in areas with a dispersed rural population. This situation is more serious in the most peripheral regions, especially in Patagonia.

4.1.5. Market Access

In total, 46% of enterprises stated that market access hindered their development (very) much, while 54% thought that it was (very) helpful for their success, see Figure 1. This dichotomy might be explained by the fact that in some cases, market structures have been proven to work against new, innovative bioeconomic ventures, whereas in other circumstances, markets strongly demanded the respective products.

There seem to be some structural barriers for bioeconomic newcomers, especially in TP1. For example, it looks like the traditional plastic industry has had an adverse attitude towards bioplastic, and therefore, was not very interested in this new field, even if this has changed a bit. Also, there have been complaints that lobbying of the petroleum companies against biofuels in the country is very strong. On the other hand, for TP1, new market opportunities have been created by the biofuel law with its blending quotas.

Some enterprises heavily profited from a demand for products not sufficiently served by the market, for example in the case of reptile leather, where US importers asked explicitly for the product. Companies active in TP2 and TP4 frequently were able to benefit from international markets by exporting their products and/or by establishing subsidiaries in other countries. Yet, most of the initiatives of TP3 and TP5 are not strongly market-driven, but rather try to look for niche markets. They often serve special, conscious costumers who appreciate bio-based products, for example, the organic food industry using bio-plastics for packaging, or gourmet restaurants in Buenos Aires offering Patagonian mushrooms. This is in line with Adamseged and Grundmann [6], who stated that bioeconomic enterprises often serve niche markets and do not compete directly with other companies.

4.1.6. Macroeconomic Stability and Financing

Macroeconomic conditions, such as the volatility of the exchange rate, high levels of inflation and the general instability of the economy, have been mentioned by 88% of companies as a main limiting factor for the development of bioeconomic projects. For example, the volatile exchange rate has a negative effect on planning security and can strongly affect profitability, especially for those enterprises whose inputs are billed in dollars (such as soybeans used in TP1), or which are highly export-oriented (such as firms from TP2 and TP4). Besides, enterprises from all pathways mentioned difficulties in getting credit with reasonable interest rates. To overcome this bottleneck, many companies adopted strategies of internationalization of the firm or exit from the country, in order to solve the bottlenecks imposed by the domestic context (lack of financing, bureaucratic obstacles, high logistical costs, high fiscal costs), and thus be able to reduce costs, access stable financing at lower cost, or to plan their investments in the longer term. The companies with the greatest tendency to offshore their factories are those linked to TP2 and TP4, i.e., those that produce low-volume yet high value-added goods, especially laboratories for agricultural inputs or medicines.

4.1.7. National Policies and Regulations

The institutional context, the quality of strategies and policies, regulatory frameworks and bureaucracy are key factors for the development of bioeconomic enterprises [5,47]. Argentina's experience shows that when well-structured policies, plans and programs are combined with funds and a medium- and long-term time horizon, investments are generated, new projects are launched and the sector is developed. However, this is only true for 31% of interviewed enterprises, which were supported by national policies (see Figure 1). An example is the Renewable Energy Law, as this law defined a long-term scenario where economic actors from TP1 could operate with predictability, generating investment to produce electricity through non-conventional sources (especially biodiesel). When these policies change abruptly due to political decisions, an atmosphere of uncertainty is generated that leads to either a reduction in activities (as is currently the case with biofuels), the termination of investments, or the relocation of investments to other countries (e.g., Uruguay, the United States, Brazil, or China).

The same holds true for regulatory frameworks. When stable laws exist over time, new ventures are structured and generated, whereas when they do not exist, ventures are carried out under a framework of uncertainty that can limit or penalize the development of new investments and new projects. Faced with the lack of adequate regulatory frameworks, it has often been the companies themselves that accompanied the public sector in the creation of technical standards in order to have a regulatory framework that protects investments and initiatives. The companies most affected by this problem are those on the innovation frontier, which create new processes and products, for which there are no adequate regulatory frameworks; this problem has a big impact especially on TP2 and TP4. For example, it was mentioned from different companies that the National Scientific and Technical Research Council (CONICET) has no clear rules for patenting, and to get a patent is very complicated. A company from TP2 complained that there is no law on seeds.

Finally, excessive regulation or bureaucratic and administrative obstacles penalize the development of bioeconomic ventures (88% of enterprises). In many cases, these elements have been overcome by the companies themselves through numerous steps, however, doing so has implied high costs and requires a lot of time and, as such, this has made some of the initiatives or projects uninteresting and unprofitable.

4.2. The Contribution to Sustainable Development

In general, the interviewed enterprises see their contribution to sustainable development much more in the generation of new knowledge (72%) and employment (59% and 47%), not so much in ecological terms, such as reduction in CO_2 emissions (40%), and even less in social improvements, such as food security (33%) and rural development (31%); see

Figure 2. However, this contribution is diverse, and depends on various factors and on the different pathways. A good example is TP2, which in Argentina is strongly linked to the production model of soy beans, corn, and livestock. The transfer and dissemination of GM soy beans and corn coupled with no-tillage systems led to yield increases but also to an expansion into marginal regions. This led to various detrimental ecological and social outcomes [10], however, it has also created economic opportunities for rural regions. In parallel, enterprises of TP2 have developed into a highly innovative, competitive and internationally present sector, which allowed for further R&D and technological innovations in agriculture, making it even more productive, strengthening and deepening this bioeconomic transformation pathway. At the same time, the enterprises are also contributing to more sustainable production systems by offering more ecofriendly and efficient solutions for plant and animal production and protection.

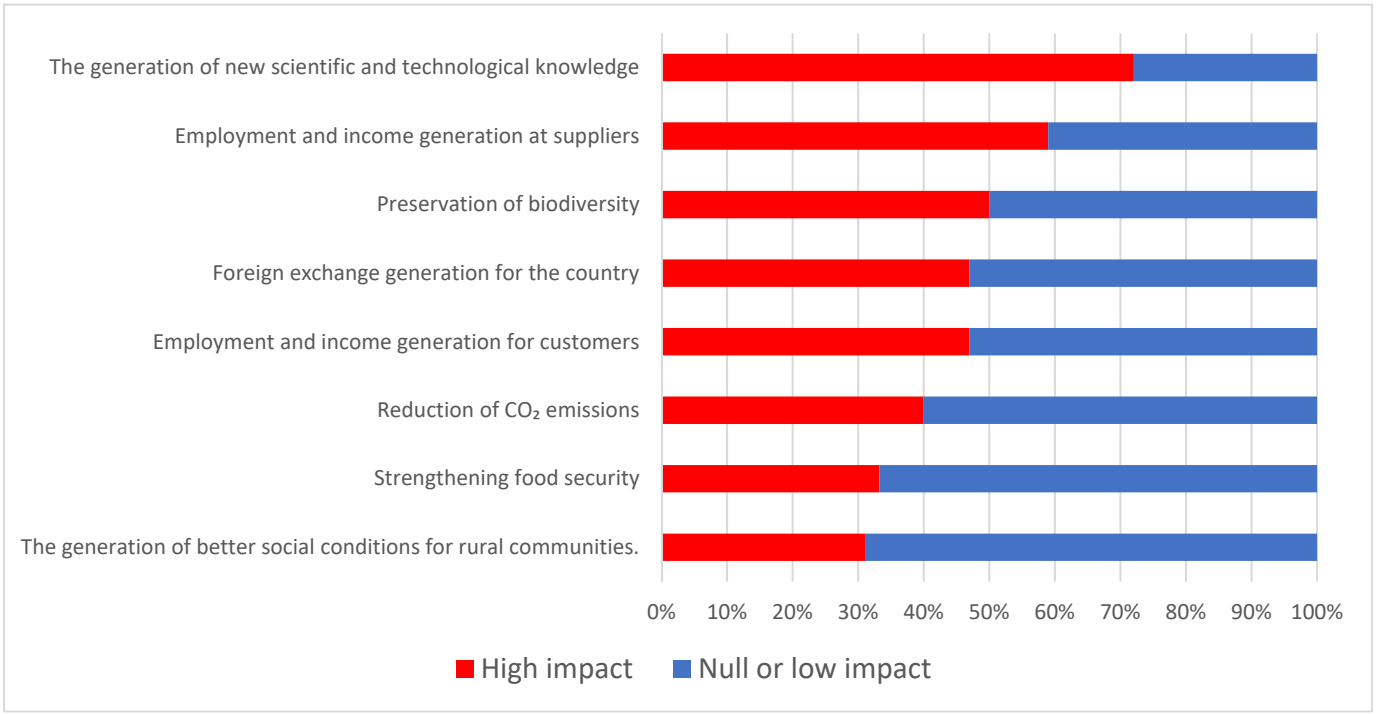

Figure 2. Impact on sustainability (%). Source: own calculations based on enterprise online survey.

The pharmaceutical enterprises of TP4 are also very much dedicated to R&D, generating jobs, income and foreign currencies, although they seem to have little impact on rural development, as their demand for raw materials is very limited. This is different in TP3 and TP5, where locally available resources are used and transformed, adding value and generating jobs, yet on a small scale. Moreover, these small-scale initiatives often explicitly follow a holistic, sustainability-oriented bioeconomy concept. For example, some initiatives aim to preserve natural resources, as in the case of the ranching system of caimans, which, coupled with economic incentives for the local population, leads to the repopulation of these reptiles in the wild. The circularity aspect is very prominent in initiatives which transform agricultural residuals into new resources, such as compost or insects. Fostering sustainable production systems such as regenerative agriculture by offering commercialization possibilities is another important aspect of some ventures.

The environmental outcomes of the fossil resources substitution TP1 have been extensively discussed in the literature, especially with respect to (indirect) land use changes [48]. We will not enter this debate here, however, we do want to mention three points that came out in our study: First, in Argentina, the use of soy bean and corn for biodiesel and bioethanol production can also be seen as part of TP5, adding value to the locally abundant,

already produced crops; Second, it can also be considered as part of TP3, as enterprises often utilize agricultural residuals to produce energy; And third, the initiatives we interviewed are mostly small to medium ones, offering new opportunities for local providers, and fostering a local, circular economy, as, for example, in the case of mini-distilleries.

R&D is crucial for most of the bioeconomic enterprises. Nearly all pathways comprise some form of innovation and generation of new knowledge. This can be patents of products and processes, which render some of the companies, mainly from TP2 and TP4, internationally competitive. However, also on a lower technological scale, new products and processes are being developed, be it new recipes for mushrooms, inulin extraction from an indigenous plant, rearing of sea urchins, micro-pulverization of rice, or use of local materials for insect production.

Social impacts on the community level seem relatively weak as only one third of enterprises expected a high impact on this level (see Figure 2). This might be explained by the fact that most enterprises have few relationships with local communities and/or are rather linked to medium and large-scale farmers. However, some initiatives, mainly from TP5, foster local development directly by providing new income opportunities for small-scale producers, such as caiman egg collectors, tobacco growers, apple producers, fish ponds owners, or mushroom gatherers. Nevertheless, these initiatives are also rather small-scaled, and would need to up-scale to have broader impacts.

In short, the fact that the major bioeconomic impacts can be found mainly on the technological and economic, less on the ecological and social side, is an expression of the overall agro-rural development trend of the past decades in Argentina. In other words: the development model followed and its path-dependency also shapes the structure, scope, dynamics and impact of the bioeconomy in a certain country.

4.3. Challenges for the Future

In view of the conditions for the development of bioeconomic ventures, the analysis was oriented to identify the main needs of entrepreneurs in order to improve their business activities, considering that these responses constitute key inputs for the development and improvement of policies in support of the bioeconomy. The responses revolve around three alternatives: First, there are needs that can be considered fundamental and urgent to solve; Second, there are other needs that must be taken into account and that must be solved; And finally, there are a series of elements that today do not constitute issues of concern. Figure 3 presents the resulting values according to the survey.

The analysis shows that there are three fundamental and urgent elements that need to be resolved. Firstly, there is a need for a clear national bioeconomic strategy with long-term objectives and well-defined and sustained rules of the game, so that companies can define their business plans and actions. Secondly, it is fundamental to have a stable and solid macro-economy in the long term, which allows investment projects to be considered. This clearly does not only concern bioeconomic ventures, but the entire productive sector in general. Thirdly, there is an urgent need to promote innovation and the generation of new knowledge. Many companies see the generation of new knowledge as a key factor of competitiveness, not only at national but also at international level. This is why there is much concern around the generation of more R&D, especially within the companies themselves, in order to increase their level of autonomy and reduce their dependence on other science and technology structures in the country as this implies greater bureaucratic processes and longer times, which limits the competitiveness of the companies.

On the other hand, there is a large set of needs, which are in the opinion of the interviewees, not of a fundamental nature, as the companies consider that they can continue to function and maintain certain levels of competitiveness even without substantial changes in these needs, or they consider that these needs can be resolved by the companies themselves through different strategies. For example, the lack of financing is an element to be solved, although many companies look for alternatives, e.g., risk investments or international financing. The permanent availability of raw materials, the lack of skilled labor and the lack

of infrastructure are also needs raised by the companies, however all of them have been solved through greater links with the public sector, strategic alliances with other companies, training of personnel within the company, among other strategies.

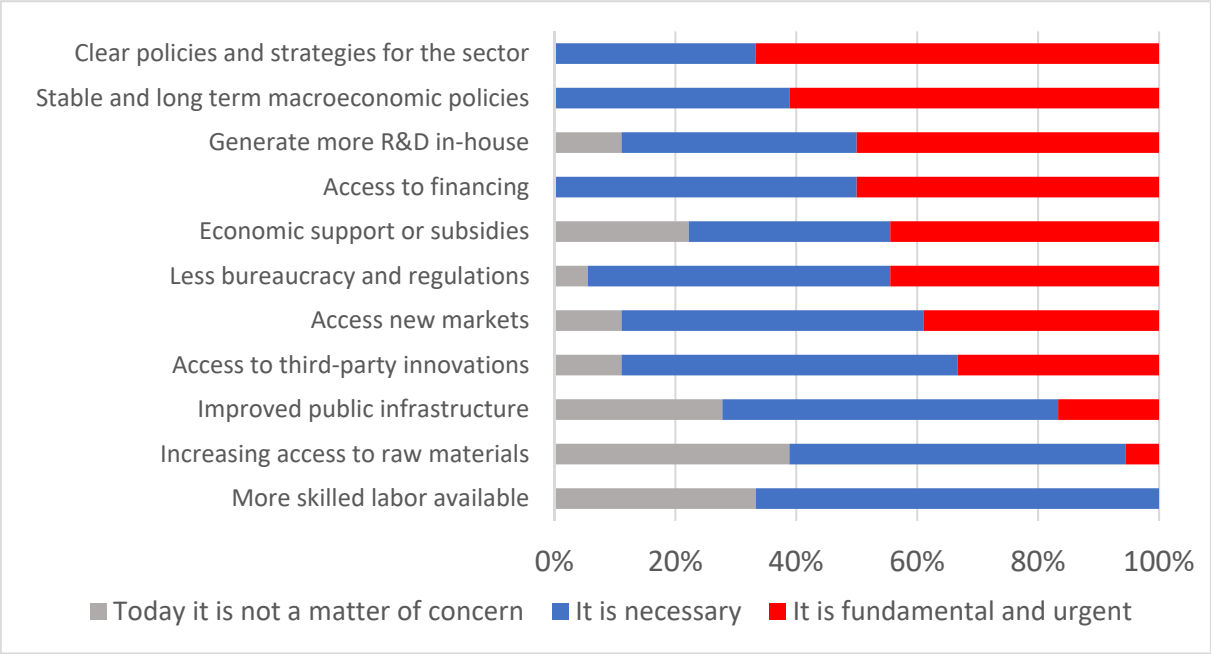

Figure 3. Needs to improve the conditions for the development of bioeconomic ventures (%). Source: own calculations based on enterprise online survey.

5. Discussion

5.1. Bioeconomic Transition Pathways

The transformation towards a bio-based economy can follow different pathways, linked to different objectives and concepts of the bioeconomy. The pathways proposed by Dietz et al. [21] have proven to be useful to categorize the Argentine bioeconomy. However, for the analysis carried out in this country an additional category has been introduced: TP5, creating new products and services with local value added. The explicit definition of this new category allows accounting for the dynamics of bioeconomic diversification in Argentina, i.e., the effort to generate new products different from the traditional productive sectors. The identification of this category not only permits a better understanding of the dynamics of bioeconomic processes in Argentina, but also points to an important trend in a country whose production systems are quite homogeneous and large-scale, highlighting efforts to build a much broader and more diverse productive fabric, supported by the strong endowment of natural resources.

This does not mean that pathway three, as defined in our study, cannot lead to more diversified productive structures and to more local value added. Indeed, the three cases included in TP3 are locally embedded new ventures, however they differ from TP5 not only in that they mainly use organic side streams, but also that they are linked to "traditional" agro-industries (of juices, potatoes, rice and soy beans) as providers of biomass. In general, there are overlaps between the different pathways, and some ventures could be classified into various categories. However, as the pathways are used as a heuristic analytical tool, the classification of bioeconomic ventures into five broad categories might be useful also for other Latin American countries with similar production structures to Argentina, for example Brazil, Colombia, or Mexico.

The different pathways are considered to be context-specific; they might need different enabling conditions and strategies, and their sustainability outcomes can also differ [30].

In the following sections, we corroborate these statements by discussing the factors and outcomes found for the distinguished pathways.

5.2. Bioeconomic Entrepreneurship

The important role of entrepreneurs for innovations in the transition towards sustainability and the bioeconomy, as stressed by some authors [2,27,49,50], could be confirmed by our study. As we have seen, entrepreneurs in Argentina are the main actors with the potential to turn innovative ideas into a new bioeconomic reality by investing in R&D, by searching for new business opportunities, by taking risks and undertaking new initiatives and investments. As described above, entrepreneurs, often in cooperation with R&D organizations, have developed new products by seizing the specific bioeconomic opportunities existing in Argentina.

This argument is even more convincing when, as in the case of Argentina, entrepreneurship has to struggle with an unstable economic and political environment representing additional business risks. The main constraints that enterprises face in Argentina are the lack of finance, unstable macroeconomic conditions, and lack of regulatory frameworks and strategies. It is interesting to note that in the face of these constraints, the companies that have been able to develop the most have not been necessarily the largest, nor the most capitalized, but those that have had the greatest flexibility to adapt to restrictive national conditions and strong international competition. Thus, the key competitiveness factor of these companies would not be given by their scale, but by the availability of highly trained human resources, the quality and competitiveness of their products in the international market, and above all the capacity and flexibility they have to adapt to different contexts and situations.

The high level of training, knowledge, entrepreneurial spirit and the capacity of building networks proved to be a decisive factor for the development of bioeconomic initiatives, since in this type of business it is not just a question of producing, but of mobilizing a more complex set of resources and capacities, linked to innovation and knowledge, confirming what other authors have reported [27,51]. Thus, these entrepreneurs are situated in a paradigm of post-Fordism and flexible and innovative work, under collaborative schemes, and not in a Fordist paradigm that emphasizes routine work and competition.

Some bioeconomic entrepreneurs follow a strategy of re-valuing local resources. They are committed to and try to contribute to the communities where they are located. It seems that these entrepreneurs which Korsgaard et al. [28] idealized as rural entrepreneurs, do not only follow profit motives, but, being embedded in the rural place, are also interested in fostering local development processes.

5.3. Factors Influencing the Development of the Bioeconomy

The factors that enhance or limit the development of bioeconomic initiatives in Argentina are similar to those identified in many other countries [31,42,43,45,52]. In this regard, Maciejczak [45] (p. 145) points out: "These new production determinants of bioeconomy are: sources of biomass, investment in R&D, competent people engaged in R&D as well as institutional arrangements of the sector." Here, we want to make clear reference to the three most important factors in the Argentinean case.

The first key factor for the development of the bioeconomy in Argentina is the strong endowment of natural resources. The same situation is raised for the case of other countries, especially in the European case [43,53]. However, the requirement of natural resources is very different according to the type of bioeconomic activity carried out, and this marks profound differences between countries [54]. In Argentina, the development of the predominant pathway one is based on the high availability of biomass. In this sense, the implementation of bioeconomic ventures is strongly determined by the large supply of natural resources, which has led Argentina to develop, over time, activities that require large volumes of biomass, or that enhance the development of existing primary activities. It can be said that there is a path-dependency on natural resources.

The second key factor, which coincides with the international experience reported by different authors [42,43,53,54] is the scientific and technological development and the training and entrepreneurial capacity of the actors. All the bioeconomic pathways analyzed have been underpinned by scientific and technological advances driven by the companies themselves or by the state, and by the presence of a dynamic academic environment, which allows for the training of company staff and the transfer of new knowledge and technologies. Successful bioeconomic ventures have a key element in common: actors with the capacity to build bridges of dialogue between the world of science, innovation and business. When the same language and interests are shared between the R&D sector and the productive sector, a virtuous circle of growth can be achieved, however, this requires that the actors involved can understand the logic and dynamics of both, science and the market. In this sense, a key element in bioeconomic initiatives is the presence of private action [18].

The third key factor is the quality of policies, economic stability and regulatory frameworks. In Argentina, these appear to be the most critical factors limiting the development of bioeconomic initiatives. Changes in the rules of the game of the economy and changes in exchange rates affect productive activities in general [52], but can particularly affect bioeconomic activities if they involve large investments in infrastructure and equipment, but also in processes and knowledge, which require sufficient maturation times [42,43]. Cyclical devaluations in Argentina and the unstable fiscal policy around the production of primary goods are notorious for affecting the profitability of such activities as there is a high dependence on the value of the dollar, either for the purchase of imported inputs or for the export of products. The lack of regulatory frameworks and excessive bureaucracy surrounding the activities has also been clearly pointed out as a strong constraint on the development of initiatives.

These results are confirmed by other studies such as Lachman et al. [15], which used a case study of different bioeconomic enterprises and initiatives in Argentina and identified five groups of drivers: costs; factors of demand; biomass availability; responses to regulatory framework; and access to and/or development of technology. Depending on the company profile, some of them were critical to initiating or intensifying bioeconomic activities. For example, nearly all of the enterprises considered in-house R&D as well as cooperation with research centers as a crucial factor. The regulatory frameworks, mainly the Biofuels Law (Ley 26.093 from 2006) and the Renewable Energy Law (Ley 27.191 from 2015), conduced some enterprises to start producing biofuels and electricity, partly from agro-residuals. Also, the availability of cheap biomass, including organic waste, played an important role in starting new bioeconomic activities. In relation to obstacles faced by the bioeconomic companies, the majority considered the lack of financing as a crucial issue, hindering new investments. Other major challenges mentioned were related to the legal framework, such as the non-actualization of the Biofuels Law and the freezing of prices, to specific regulations and controls for food, and to the legislation of protection of seeds. Other enterprises stated the unstable macroeconomic environment and the lack of government support for entering international markets as important obstacles for their business [15].

The main factors seem not very different from those found by Scheiterle et al. [55] for the case of the sugar cane industry in Brazil's bioeconomy: the good factor conditions (land, climate); the very good quality of research institutions; and the ability of firms to diversify their production portfolio and increase biomass efficiency were mentioned by key stakeholders as the main opportunities. Considering government policies, as in the case of Argentina, they fostered the sector by introducing a share of ethanol blended into gasoline and by giving incentives towards biotechnology. Whereas inconsistency of policies, legislation hurdles for startups and missing legislation for intellectual property rights have been mentioned as challenges. What seems to be missing more so in Brazil, in contrast to the views explained by our Argentinian interviewees, are high educated personnel, links between academics and the sugarcane industry, and entrepreneurship in general.

Compared to other Latin American countries such as Costa Rica and Mexico, Argentina scores high in human resources and educational levels, in innovations systems (measured by expenditures on R&D, number of scientific articles and patents) and in ICT infrastructure. Yet, it is lacking behind Costa Rica in terms of "institutional and regulatory environment conducive for the development of business activities" [56] (p. 232). Many of the factors specified here are also in line with the ranking of Argentina in the Global Competiveness Index [57]: the country scores very low in macroeconomic stability, in its financial system and in public sector performance, especially in the burden of regulations, whereas the skills of the workforce and the innovation capability, especially the research institutions, rank relatively high.

5.4. Sustainability Outcomes

In Argentina, TP2 has been quite successful in terms of increasing production and productivity, and in creating knowledge and innovations. Since the introduction of GM soy beans in 1996, innovations in Argentina's agriculture has been mainly driven by this production model, which fostered own research (e.g., on drought-tolerant seeds), new technologies (e.g., for no-tillage systems), and alliances between seed producers, breeders, input suppliers and local research institutions [58]. The biotechnology sector also offers more ecological solutions such as inoculants, bio-based seed treatments, bio-fertilization or bio-stimulants adjuvants ("eco-intensification"). The biotechnologies used in the soy bean sector have resulted in increasing yields and productivity. However, by fostering the existing soybean model ("*el modelo sojero*"), this pathway is also responsible for the expansion of GM soy bean with its highly debated negative consequences on air and water quality, land use changes, land distribution, health and employment, etc. [10].

The creation of new technologies and knowledge was mentioned by most companies as one of the important success factors, and also, as their main contribution to development. This is in line with innovation studies of natural resource-based industries: these industries, often together with their suppliers, can be drivers of innovation in developing countries by using advances in science and adapting them to local specificities. As knowledge about natural resources can often be considered idiosyncratic, there is room for and need of local-specific innovations [59]. For example, the development of new soy bean seeds has been driven by national companies in Argentina, in close cooperation with public organizations such as INTA and CONICET. In these cases, national companies can compete with multinationals, by adapting technology solutions to local conditions. Moreover, this shows that local suppliers (including services) of a traditional export commodity sector can become drivers of new knowledge and technology generation [60].

The bioeconomic model developed in Argentina is, as discussed above, conditioned by the strong availability of natural resources, which also has spatial consequences. Given that mobilizing large volumes of biomass requires large infrastructures and logistics and transport systems, and given that Argentina suffers from major limitations in this regard, bioeconomic enterprises are located and anchored in the same territories where the biomass is produced, contributing to diversifying the productive matrix and generating local employment. In this sense, bioeconomic initiatives in Argentina have a strong potential for territorial development. This has also been observed in other countries such as Brazil, but also in Spain, as a key factor for the repopulation of marginal rural areas [43].

The bioeconomy in Argentina also helps the move towards a local, circular economy. Mainly in TP3, although also in TP1 and TP5, we found examples where organic waste streams are used as inputs for biofuel production, as compost or as animal feed. Nevertheless, pathway P1 in Argentina, as in many other Latin American countries, still seems to be concentrated on biofuels based on soy bean and corn, not sufficiently exploiting other possibilities such as small-scale biorefineries, which can use different crops, produce higher quality feed and many by-products, require low investments, and can have positive impacts on local development [61]. However, with the bioenergy law in Argentina, there has been a rise in such small-to-medium scale units, and innovations and investments have

been made, for example, in "mini"-distilleries or biorefinery plants that use soy bean oil, and also recycle vegetable oils and add value producing by-products.

The bioenergy sector in Argentina has, since the Kirchner government, adopted a discourse of sustainability, innovation and development [62]. By locally adding value ("*agregado de valor en origen*"), and coupled with sustainability certifications ("Enterprise B") the sector wants to show its compromise with social and ecological development. However, using two examples of enterprises also interviewed in our case study, Toledo-López and Tittor [62] consider this only as a "green makeup" ("*maquillaje verde*"). The authors argue that the social and environmental damages and injustices allegedly caused by the enterprises are a sign that their environmental discourse is merely a strategy of the business sector that serves as an excuse for the construction of its hegemony, generation of new markets and the accumulation of capital. These examples show that it is necessary to study more thoroughly the real socio-economic and environmental impacts of the different pathways on the local level.

6. Conclusions

Before concluding, we have to acknowledge the different limitations of our research findings. Firstly, there is no statistical information available on bioeconomic companies, which, despite the efforts made, resulted in a small database on which the research was carried out. This means that the findings of this case study cannot be generalized. Secondly, the findings are strongly linked to the current situation found in Argentina. However, in a dynamic environment within a dynamic sector, changes will happen that might confirm or challenge our findings, meaning that what is considered a successful venture today, might be outdated tomorrow. Thirdly, they reflect the view of the enterprises interviewed, and therefore, might be biased towards a more optimistic or pessimistic view of the situation of the bioeconomy in Argentina; even if we conferred this with the literature, our survey is still an opinion-based one, and the actual consequences of the bioeconomic initiatives, for example, on local development, request further studies.

Having said that, we conclude by giving answers to the research questions we posed at the beginning of this paper. Firstly, entrepreneurs in Argentina, despite the unstable economic and political conditions, have played a decisive role in the transition towards a bio-based economy by using the factors which highly favor them, and mainly consist of the availability of natural resources, human capital and R&D capacities. Companies have been able to overcome, to a certain degree, adverse conditions by finding flexible solutions such as internationalization, search for private risk capital, promotion of in-house R&D, etc. Secondly, the contributions of the bioeconomic ventures towards sustainable development processes depend on the type of pathway and on the production model behind it. The agricultural commodity production is still the mainstay of the Argentinian bioeconomy, although small-scale local initiatives, which also include socio-institutional and agro-ecological innovations, are coming up. However, the main contribution of the bioeconomy in Argentina can still be seen in the generation of income, employment, and new scientific and technological knowledge. Thirdly, the policies to strengthen the transformation towards a sustainable bioeconomy in Argentina need to be predictable, with long-term objectives and well-defined and sustained rules of the game. A good example is the Renewable Energy Law, which first stimulated the sector, but is now hindering its further development.

What holds true for all pathways, but often seems to be overlooked and is not sufficiently accounted for in national strategies, is that entrepreneurship is an important element for the transformation to a bioeconomy. In Argentina, the bioeconomy strategy referring to entrepreneurs is reduced to the availability of venture capital. Yet, this seems to be not different to the bioeconomic strategies in many other countries, including Germany. However, what seems to be much more important than strategies is a conducive environment for innovative bioeconomic entrepreneurs [2].

Even if there is a discussion going on as to whether the transition to a bioeconomy should be policy-driven or if the state should only set the rules of the game and let the bioeconomic entrepreneurs do their business, it seems convincing that the support of entrepreneurs by a general and explicit vision of the state and respective policies are enhancing the probability of such a transformation [27]. Therefore, and in line with national and international documents, four main recommendations can be put forward to improve the competitiveness of the Argentinean bioeconomy:

Firstly, to define a national bioeconomic development policy, strategy and plan, with the participation of the state at different levels, private actors and their organizations, and the scientific and technological complexes. Such an initiative should lead to clear and long-term definitions in terms of scientific and technological development, human resource training, infrastructure creation and management, financing, and business promotion and support systems. As Hodson et al. [1] point out, an action plan that coordinates the activities of the public sector is needed, a plan which counts with a comprehensive vision of the different dimensions of public policies (macroeconomic, tax, commercial, agricultural, industrial, scientific-technological) and which encourages the efforts of the private sector. Other experts of the bioeconomy in Argentina, such as Rodriguez et al. [18], Bisang et al. [44], and Trigo et al. [14], move forward on the same ideas and proposals;

Secondly, to substantially improve the governance mechanisms of the bioeconomic complex and the relationship with the public sector [21]. This will involve working on the regulatory and normative frameworks, adapting them to new activities, biological risks, resource protection, protection of property rights and patents, which is a major challenge. It will also be necessary to work on the organizational logic of the state and its links with the private sector, improving synergies and coordination, for which it will be necessary to reduce the bureaucratic obstacles that limit the competitiveness of the sector [18];

Thirdly, a national strategy for the bioeconomy should pay more attention to entrepreneurship as a driver of transformations. We suggest some elements cited in Kuckertz [2] would be helpful in this respect for the case of Argentina: a legal framework encouraging bioeconomic entrepreneurship, differentiated, tailored support to technology-based bioeconomy startups as well as to small, rural entrepreneurs, and special innovation programs considering the specific needs and goals of bioeconomic initiatives;

Fourth, it is essential to build a true transition culture, that is, to educate, raise awareness and promote the transition towards new scenarios of environmental sustainability. The development of the bioeconomy will only be possible if a new national culture is built that is more inclined and focused on thinking about environmental problems and the logic of unsustainable production and consumption. If society does not adopt new perspectives and consumption practices, the bioeconomy will only be a niche activity, with little capacity to transform itself into a new paradigm and a new production logic;

Finally, further research is needed. As mentioned above, the impact on sustainability outcomes of different pathways need much more in-depth investigation, taking into account changing rules of the game. In particular, the consequences of the bioeconomy for rural development deserve much more attention in the case of Argentina. Even if not always clearly distinguishable and not always mutually exclusive, it seems that in Argentina at least two different bioeconomic implementation strategies are followed, which Priefer et al. [46] called the technological-based versus the socio-ecological approach [63]. The former is mainly based on progress in the biotechnologies and on close cooperation between policy, science and business, uses yield-enhancing inputs, new agricultural technologies, and genetic engineering for higher biomass production, and is geared towards international competitiveness and cooperation, economies of scale and global value chains; whereas the latter envisions sustainability outcomes of the bioeconomy through a multifunctional, decentralized, ecological agriculture, and a combination of scientific research and the tacit knowledge of local farmers, for the strengthening of rural areas by creation of regional value chains, and for regional autarchy in food and energy supply [46]. It would be important to more thoroughly investigate this diversity of bioeconomic approaches, and to have

a closer look at local initiatives that are not (only) based on sophisticated technologies, but also include social and agro-ecological innovations [64]. We further consider that any research initiative in this direction would benefit greatly from the methodological proposal put forward by D'Amico [65] in terms of stages to characterize bioeconomy development processes.

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Appendix A

Table A1. Description of enterprises interviewed.

TP	Nr.	Enterprise	Description
P1	1	Porta Hermanos	is a traditional enterprise of liqueurs, which, with the biofuel boom, built its own bioethanol plant, which was the start of developing so-called "mini-distilleries", a new solution for farmers, which combined centralized services with decentralized, intelligent production systems. The five already installed mini-distilleries are based on corn, and sub-products are used as feed, so that medium-sized corn and livestock producers are the main target group of this innovative system.
	2	Essential Energy Holding	founded in 2006, is a farmer-owned enterprise, which since then has invested in five plants that use soy bean oil, but also recycles vegetable oils, waste, and produce bioethanol from sugar cane and corn, mainly for the national market. It also adds value by producing sub-products such as oleic, glycerin and fatty acids.
	3	Grupo Bolzano	started in 2010 when the new Biofuels Law came into force and now has two small to medium factories producing biodiesel for the internal market, and one which transforms crude glycerin into sub products.
	4	Cleanergy renovables	is a small enterprise that started in 2016 building a biogas plant of 1.2 MW, which only uses waste (e.g., pig manure and residues of peanuts). It is one of the 70 biogas projects that have been promoted by the bioenergy law which fixed tariffs for a 20 year period.
	5	Biopsa	imports from Germany bioplastic pellets of compounds tailored to customer requirements. This allows the small enterprise to follow a business to business model, working on a sufficiently large scale. As there was no market for bioplastics and no interest from the plastic industry, the strategy was to sensitize the industry by stimulating the demand of special costumers (such as designers or organic producers) of the more expensive bio-plastics).

Table A1. *Cont.*

TP	Nr.	Enterprise	Description
P2	6	Rizobacter	started with the growing soy bean boom in Argentina, then internationalized and looked for strategic partners to get access to distribution networks, and as a way to overcome national constraints to be able to keep on growing. Cooperation with research centers and INTA/CONICET, and own research on innovative biological products led the company become world leader in inoculants.
	7	Bioceres	Was founded in 2001 by 23 farmers to have more value addition for their products. Today, the main activity of the company is drought—tolerant soy bean and wheat seed (HB4®technology). "Bioceres Crop Solution" is registered at NYSE with joint-ventures. Besides, Bioceres creates new bio-based enterprises, which work with transformation and value-addition of biomasses, for example, via use of waste to generate energy in the municipalities, use of potatoes residues for biomaterials or of straw to make panels for construction.
	8	Green Quality	is a small enterprise, out-founded from Biogénesis Bago in 1993, in a remote region. It developed together with INTA a plant growth promoter (PGBR), and inoculants that can stay 18 months without being refrigerated. They are also the only ones producing a tri-bacterial inoculant.
	9	Biogénesis Bago	is a specialized, medium-sized firm of vaccines, especially for foot-and-mouth-disease, against which vaccination is obligatory in Argentina since 2001. Biogénesis provides specialized customer services and is competing with multinationals, and has joint ventures, even in China. Cooperation with Universities and INTA/CONICET coupled with a strong own R&D department led to innovations and in-house patents.
	10	Vaccine Serum Cicloneo	is a personal spin-off from Biogénesis Bago, which had been outsourcing the provision of serum for its vaccine for foot-and-mouth-disease. Its former employee was helped with credit, know-how, and a ready market, in order to get a reliable, local provider of high quality serum.
	11	IMBECU	is a public research center which since 2011 developed micro-particle based insecticides which would allow to protecting wheat and corn in silos, substituting toxic insecticides. It functions with electric charges of aluminum oxide (which can be totally recollected after use and be reused again) that lead to the dehydration of insects. There was interest of (multinational) companies of this innovative technology, but it has not been adopted so far by any of them.
P3	12	MICRONAR	is a small enterprise which uses locally abundant products from industries, which so far have been under-used (such as broken rice) or only traditionally used (such as soy beans or lentils). After four years of technology development it started with the micro-pulverization of rice and legumes to fabric a special flour which the local meat industry uses, substituting maize or imported rice.
	13	PROCENS	is a personal initiative of two young entrepreneurs who started lately to produce black soldier fly (BSF) larvae as a more sustainable animal feed. They use a native BSF species, which is reared with a special diet based on residuals from the local potato industry.
	14	Jugos S.A.	was founded in 1976, when local small producers united and put capital for the processing of their fruits, making (concentrates) of juices (from apples and pears). The residuals (pomace) they use to make compost, which gave good results in experiments made together with INTA on apple plantations.
P4	15	NATUFARMA	a family enterprise, initially used local carrot production to extract beta-carotenes, and in 1989, after a journey to Europe got to know and started to produce pills containing extract of valerian. During the following years, it diversified its products, incorporating different extracts of herbs, most of them imported, to serve the growing market of natural pharmaceutics in Argentina.
	16	ERIOCHEM	is a national enterprise of oncological drugs, founded in 2001 of pharmacists who had been working in "classical" labs, and now wanted to have a more R&D concentrated, highly specialized enterprise investing in patents and global market access. It was then the first Argentine enterprise exporting oncological products to the US. For one of their medicaments, they use the alkaloids of a *Catharanthus* plant from Madagascar which they cultivate on 15 ha. They have internationalized their business with subsidiaries in Brazil, Mexico, Uruguay, and the US.

Table A1. *Cont.*

TP	Nr.	Enterprise	Description
P5	17	Sayri	is a small, personal enterprise, which started in 2012 to produce tobacco from traditional varieties. They do not use any additives (only native herbs), and work with the concept of "regenerative agriculture" to support the health of consumers as well as producers. It serves a niche market of quality tobacco with loyal clients, and also exports to other LA countries.
	18	Caimanes de Formosa	is a family enterprise with previous experience in leather products, which switched to reptiles when their customers in the US needed providers. Since 2003 they have been working with the "ranching" concept where the eggs of caimans are searched in the wild, but then hatched and created in the farm, and some of them afterwards freed again which serves to recover wild populations.
	19	La Esmeralda	as a Union workers investment, follows the same ranching concept of caimans to add local value for a luxury good destined to international markets.
	20	Aquaculture Apóstoles	is a project of the municipality to recover fish ponds that are out of use with the aim that small producers can add value and produce good quality fish for local people. The project give extension services and also fishings.
	21	Yacón	is a traditional Andean under-utilized plant, of which leaves and tubers can be used. The project develops value-added products such as inulin and fructo-oligosaccharide, which have a market potential for its positive health effects (against diabetes, obesity). The University of Tucumán is developing a PPP with a sugar company and CONICET for patents of pro-biotic products (cheese and yoghurt with Yacón), and also developing new products (chips, flour). National programs financing the bioeconomy were behind this applied research project.
	22	CIEFAP	is an applied research project financed by national programs and present in all of the Patagonian provinces. It included capacity building for the development of new products out of mushrooms, and created links to other sectors (tourism, gourmet), although the scaling-out and transformation to business is still limited.
	23	ARBACIA	was created when a researcher of Echinodermata joined with a specialist in the transfer of bioeconomic technologies. After having searched for practical solutions to rear sea urchins in aquaculture, the lab started to produce on a small scale, and will soon scale-up to commercial scale. The extraction of sea urchins eggs can serve as nutrition supplements, cosmetics, and pharmaceutics.

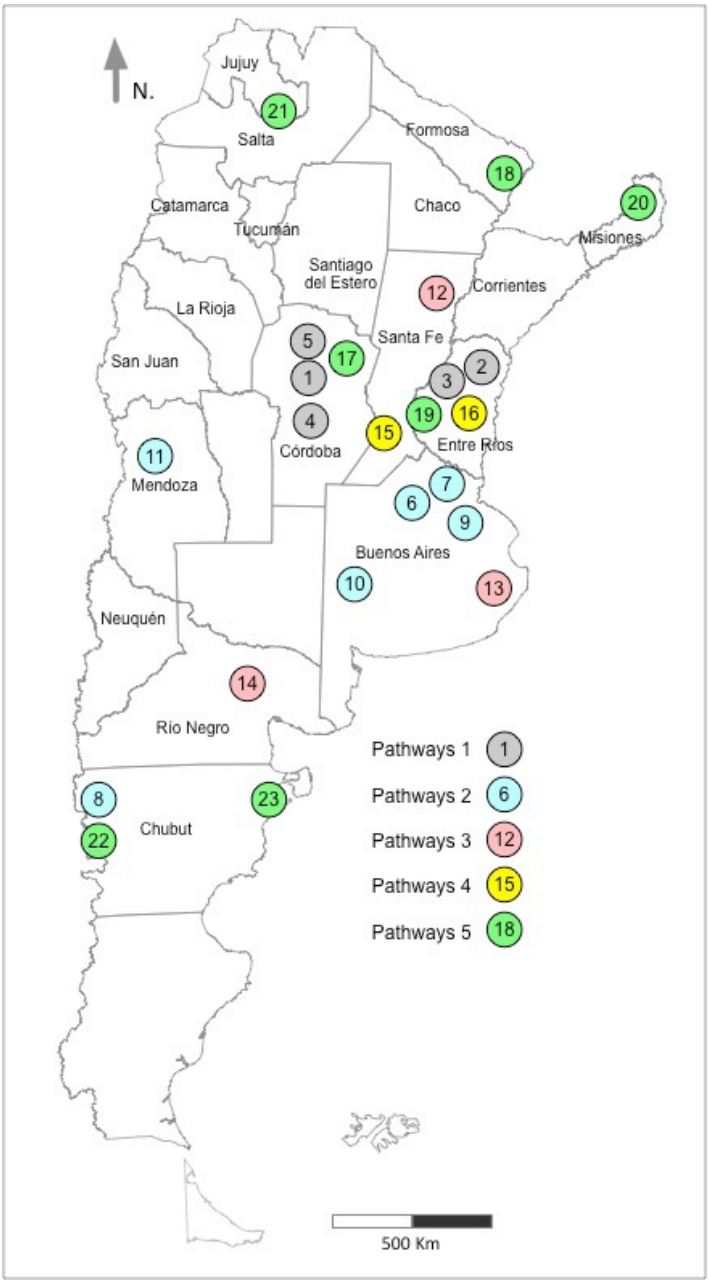

Figure A1. Location of the enterprises interviewed.

Appendix B. Online Survey Questions and Answers

(1) How much did your company contribute to the following variables?

- To the substitution of resources and fossil fuels;
- Increased productivity in the primary sector;
- To a more integral and efficient use of biomass and residues;
- Generation of very high-value, low-volume products;
- The generation of new products and higher local value added.

Possible responses:

- Contributes a lot;
- Contributes;
- Contributes little;
- Does not contribute.

(2) How did the following variables affect the development of your bioeconomic entreprise?

- Financing;
- Availability of public infrastructure (energy, communications, etc.);
- Bureaucracy and regulations;
- Skilled labor;
- Availability of raw materials;
- Transfer of technological innovations and know-how from third parties;
- Access to markets;
- In-house research and development;
- Policies and strategies in the country;
- Macroeconomic policy and country stability.

Possible responses:

- It slowed down the development of our venture;
- Limited but could be solved;
- Boosted the development of our venture;
- It was essential for the development of our venture.

(3) What was the impact of your bioeconomic venture on:

1. Generation of better social conditions for rural communities;
2. Strengthening food security;
3. Reduction in CO_2 emissions;
4. Employment and income generation for customers;
5. Foreign exchange generation for the country;
6. Preservation of biodiversity;
7. Employment and income generation at suppliers;
8. The generation of new scientific and technological knowledge.

Possible responses:

- High impact;
- Low impact;
- Null impact.

(4) What are the needs of your company to be able to develop in the future?

1. More skilled labor available;
2. Increasing access to and availability of raw materials;
3. Improve public infrastructure;
4. Increasing access to third-party innovations and knowledge;
5. Access new markets;
6. Less bureaucracy and regulations;
7. Economic support or subsidies;
8. Access financing;
9. Generate more research and development in-house;
10. Stable and long term macroeconomic policies;
11. Clear policies and strategies for the sector.

Possible responses:

- Today it is not a matter of concern;
- It is necessary;
- It is fundamental and urgent.

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