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Demystifying the challenges and barriers to manage, develop, and transfer clean and green technologies in Brazilian academic research groups: Some empirical evidence

Charbel Jose Chiappetta Jabbour and Ana Beatriz Lopes de Sousa Jabbour

UNESP - Sao Paulo State University, Production Engineering Department, Bauru, Sao Paulo State, Brazil

ABSTRACT

This work presents empirical evidence of the main challenges in managing/leading academic research groups on clean and green technologies in Brazilian universities. We also present evidence about the main barriers to the effective creation of innovation and technology transfer of these clean and green technologies. Empirical evidence come from PhD researchers/academics who lead/manage official research groups on clean (environmental, green) technologies. Results show the following: (a) The main challenges of managing research groups are the lack of an innovative culture, the lack of partnership with an industrial sector, and the necessity of keeping laboratories updated; (b) the main barriers to innovation and technology transfer are difficulties in not having enough researchers and staff members, assessments of academic performance that do not consider innovation, and an uncertain national legislation on clean technology. Based on these and others' findings, we suggest that policymakers working on clean and green technologies pay attention to act and develop initiatives focusing on the following: providing direct financial support for laboratory improvement, linking academics and practitioners from the industrial sector, and providing training and development programs on clean and green technologies' legislation and financial issues, such as the payoff of clean and green technologies and opportunities from green investors.

KEYWORDS

Clean and green technologies; emerging economies; policymakers; research groups; research policy

Introduction

The current environmental context contains challenges, as climate change is positing clean and green technologies as a popular subject to be researched by universities around the world (Flamos, Georgallis, and Psarras 2010). In Brazil, it is not different; in fact, it is common to find calls for proposals and other incentives from official funding agencies attempting to support research groups on clean and green technologies based at universities. However, in this context, little is known about the following:

- The main challenges, from the perceptions of research group members, that research groups face on clean and green technologies at Brazilian universities.
- The main barriers that can hamper new and innovative clean and green technologies and how they are transferred to the market.

Thus, the main objective of this work is to present empirical evidence on the challenges of managing clean and green technologies research groups and the barriers that can hamper the innovative potential and transfer to the market. This subject is relevant not only to emerging economies (Namanya 2008) but also to developed countries aiming to transfer clean and green technologies to developing countries (Bygrave 1997).

In this research, clean (environmental) technology can be defined as the continuous improvement of processes, products, and services derived from the conservation of raw materials and energy and leading to the reduction of toxic substances, waste, and emissions within the production cycle (Kuehr, 2007).

At this moment, some authors (Clausen et al. 2012; Suzuki 2014) have tried to understand similar issues, but they are not focusing on clean and green technologies research groups, nor are they focusing on an emerging country context.

Some relevant works in the field are as follows:

- Meijer and Hekkert (2007) found that uncertainty about government policy is crucial when developing new clean and green technologies.
- Staniškis and Stasiškienė (2003) argue that establishing an effective financing mechanism is critical to develop clean and green technologies.
- According to Ockwell et al. (2008), policymakers should be aware of the challenges of development and transfer of clean and green technologies..
- Clausen et al. (2012), based on a survey and case studies, discovered that universities provide the most fertile grounds for such research units, and that external support and support from the leadership of the university are important factors behind the establishment of these research units. In

CONTACT Charbel Jose Chiappetta Jabbour prof.charbel@gmail.com UNESP - Sao Paulo State University, Production Engineering Department, Bauru, Sao Paulo State, Brazil.

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the longer term, however, attracting core (basic) finance is essential for each unit's ability to progress.

- Suzuki (2014) described barriers that hamper innovation and the transfer of technologies in developing countries. The author highlighted a lack of the enabling environment in the developing countries as a main barrier in transferring technologies at the diffusion stage. Furthermore, the author emphasized that institutional support for improving the enabling environment and enhancing the capacity of the developing countries is also essential for the successful innovation and transfer of technologies at this stage.

Adapting the work of Clausen et al. (2012), the main challenges that we consider that can challenge the management of research groups on clean and green technologies are as follows:

- Work and funding geared to the long term (C1)
- Having employees/skilled technicians (C2)
- Publishing the results of research internationally (C3)
- Attracting high-skilled students (C4)
- Establishing international partnerships (C5)
- Getting support from the university's top management (C6)
- Establishing/maintaining scientific leadership in the area (C7)
- Getting support from official funding agencies (C8)
- Establishing partnerships with the productive/industrial sector (C9)
- Reporting research results more broadly to society (general media) (C10)
- Getting support from other departments/units of the same institution (C11)
- Getting support from other leading universities/institutions (C12)
- Building a culture of innovation (C13)
- Dealing with challenges of internal communication/interpersonal relationships (C14)
- Keeping updated on forward innovations launched in the market world (trade fairs, exhibitions, shows) (C15)
- Keeping updated on forward innovations launched in the academic world (papers, books, conferences) (C16)
- Keeping updated with laboratories/equipment (C17)

Adapting from the work of Suzuki (2014), we consider the following main barriers that can hamper the innovation and transfer of clean and green technologies from universities to the market:

- Perception of high-risk financial investments (B1)
- Costs of innovation are too high (B2)
- Lack of financial availability (B3)
- Lack of staff/skilled researchers (B4)
- Lack of information on technological advances (B5)
- Lack of information on market advances (B6)
- Establishing/maintaining scientific leadership in the area (B7)
- High uncertainty about the real demand for new technologies (B8)
- High uncertainty over national legislation on new technologies (B9)
- High uncertainty about the international legislation on new technologies (B10)
- High uncertainty about the valuation of the innovative effort by the scientific world (B11)

An empirical research to discover the main challenges and barriers to clean and green technologies from the perception of Brazilian researchers was carried out, as explained below.

Research methodology

This quantitative research is based on an e-survey carried out with Brazilian PhD scholars working and heading official research groups in the field of clean and green technologies in Brazilian research-based universities.

An electronic questionnaire was created on an e-survey website. The researchers were invited to respond to the assertive C1–C17 and B1–B11 through a Likert scale with five points. In the case of challenges (C1–C17), the scale was "1 – noting challenges" to "5 – strongly challenged." Regarding barriers (B1–B11), the scale was "1 – completely disagree" to "5 – totally agree." This survey was conducted with the following details.

Searches through the Brazilian Council for Scientific Research – a database on research groups – were selected using the search terms "clean and green technologies," "green technologies," and "environmental technologies." Thus, it was possible to find the main research groups on this subject. After that, we checked whether the researchers had at least one academic publication regarding clean, green, environmental technologies or similar issues. We sent an e-mail message to more than 100 researchers inviting them to fill out the questionnaire between January and October 2014. After this time frame, we received 33 filled-in questionnaires. The data were analyzed with SPSS 22 (IBM), and we conducted descriptive analyses and Pearson's correlation analysis, as follows.

Research results

First, the results on the challenges of managing clean and green technologies research groups are presented according to the perception of 33 PhD scholars/academics who lead/work in Brazilian official research groups in Brazil. The Cronbach's alpha for challenges (C1–C17) is 0.917, which can be considered to be high (near 1.0) and to show an adequate level of data reliability. As Table 1 illustrates, the three main challenges indentified based on the average value are in the following order:

- Building a culture of innovation (C13)
- Establishing partnerships with the productive/industrial sector (C9)
- Keeping updated laboratories/equipment (C17)

Table 1. Descriptive analyses – construct: challenges.

Challenges	*N*	Minimum	Maximum	Average[a]	Standard deviation (SD)
C13	33	2.00	5.00	**4.2424**	.83030
C9	33	2.00	5.00	**4.2121**	.96039
C17	33	2.00	5.00	**4.1818**	.91701
C5	33	1.00	5.00	4.0909	1.10010
C7	33	2.00	5.00	4.0000	.93541
C8	33	2.00	5.00	3.9697	.84723
C1	33	2.00	5.00	3.9091	.94748
C3	33	2.00	5.00	3.8788	.92728
C2	33	1.00	5.00	3.8485	1.22783
C6	33	2.00	5.00	3.8182	1.01411
C14	33	2.00	5.00	3.7273	.97701
C10	33	2.00	5.00	3.7273	.87581
C12	33	2.00	5.00	3.6970	1.01504
C4	33	1.00	5.00	3.6970	1.10354
C15	33	1.00	5.00	3.6061	1.05887
C11	33	2.00	5.00	3.4848	1.12142
C16	33	1.00	5.00	3.4242	1.09059

[a]Main values are in bold.

Table 2 shows the correlations coefficients between C1 and C17, based on Pearson's correlation coefficients. Many correlations are significant.

The stronger correlations are between the following:

- "Keeping updated on forward innovations launched in the market world (trade fairs, exhibitions, shows) (C15)," and "Keeping updated on forward innovations launched in the academic world (papers, books, conferences) (C16)."
- "Getting support from other departments/units of the same institution (C11)," and "Getting support from other leading universities/institutions (C12)."
- "Dealing with challenges of internal communication/interpersonal relationships (C14)," and "Keeping updated on forward innovations launched in the market (trade fairs, exhibitions, shows) (C15)."

Regarding the barriers (B1–B11) that, from the researchers' point of view, can hamper the transfer of innovation and technology from universities to the market/industrial sector, the Cronbach's alpha can also be considered adequate (0.858). Table 3 shows the descriptive statistics and the three main barriers, which are, in the following order:

Table 3. Descriptive analyses – construct: barriers.

Barriers	N	Minimum	Maximum	Average[a]	Standard deviation (SD)
B4	33	2.00	5.00	**3.9394**	.93339
B11	33	1.00	5.00	**3.7879**	1.19262
B9	33	2.00	5.00	**3.6364**	.99430
B8	33	1.00	5.00	3.5455	1.12057
B2	33	2.00	5.00	3.5455	1.12057
B3	33	2.00	5.00	3.5455	1.06334
B1	33	2.00	5.00	3.5152	1.03444
B7	33	1.00	5.00	3.5152	1.06423
B6	33	2.00	5.00	3.4545	1.06334
B10	33	2.00	5.00	3.4242	.96922
B5	33	2.00	5.00	3.2424	1.03169

[a]Main values are in bold.

- Lack of staff/skilled researchers (B4)
- High uncertainty about the valuation of the innovative effort by the scientific community (B11)
- High uncertainty over national legislation on new technologies (B9)

Table 4 shows the correlations coefficients between B1 and B11, based on Pearson's correlation coefficients. Many correlations are significant.

The stronger correlations are between the following:

- "High uncertainty over national legislation on new technologies (B9)," and "High uncertainty about the international legislation on new technologies (B10)."
- "Perception of high-risk financial investments (B1)," and "Costs of innovation are too high (B2)."
- "Perception of high-risk financial investments (B1)," and "Lack of financial availability (B3)."

Table 2. Pearson's correlations between multiple challenges (C1–C17).

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17
C1	1																
C2	.525[a]	1															
C3	.449[a]	.258	1														
C4	.481[a]	.426[b]	.604[a]	1													
C5	.398[b]	.358[b]	.654[a]	.564[a]	1												
C6	.210	.253	.308	.173	.323	1											
C7	.529[a]	.381[b]	.216	.394[b]	.273	.165	1										
C8	.503[a]	.326	.393[b]	.525[a]	.372[b]	.248	.434[b]	1									
C9	.331	.346[b]	.240	.357[b]	.395[b]	.233	.591[a]	.469[a]	1								
C10	.308	.135	.381[b]	.494[a]	.448[a]	.189	.420[b]	.283	.331	1							
C11	.366[b]	−.081	.209	.122	.191	.382[b]	.268	.213	.221	.298	1						
C12	.588[a]	.238	.425[b]	.334	.193	.491[a]	.428[b]	.498[a]	.260	.185	**.737**[a]	1					
C13	.426[b]	.313	.364[b]	.390[b]	.215	.499[a]	.121	.277	.208	−.035	.138	.498[a]	1				
C14	.614[a]	.564[a]	.480[a]	.617[a]	.634[a]	.390[b]	.513[a]	.443[a]	.530[a]	.385[b]	.353[b]	.513[a]	.623[a]	1			
C15	.680[a]	.289	.364[b]	.430[b]	.327	.368[b]	.473[a]	.544[a]	.484[a]	.352[b]	.508[a]	.583[a]	.503[a]	**.708**[a]	1		
C16	.583[a]	.166	.454[a]	.448[a]	.410[b]	.354[b]	.306	.522[a]	.180	.321	.363[b]	.515[a]	.435[b]	.581[a]	**.772**[a]	1	
C17	.379[b]	.414[b]	.357[b]	.361[b]	.324	.373[b]	.510[a]	.691[a]	.665[a]	.297	.276	.430[b]	.187	.441[b]	.462[a]	.327	1

Main values are in bold.
[a]Significance level 0.01 (2-tailed).
[b]Significance level 0.05 (2-tailed).

Table 4. Pearson's correlations between multiple barriers (B1–B11).

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	1										
B2	**.721**[a]	1									
B3	**.674**[a]	.556[a]	1								
B4	.389[b]	.272	.475[a]	1							
B5	.406[b]	.288	.474[a]	.373[b]	1						
B6	.235	.362[b]	.327	.155	.438[b]	1					
B7	.064	.098	.158	.156	−.032	.615[a]	1				
B8	.316	.229	.110	.122	.396[b]	.153	.255	1			
B9	.461[a]	.212	.489[a]	.279	.546[a]	.545[a]	.360[b]	.408[b]	1		
B10	.430[b]	.327	.496[a]	.409[b]	.550[a]	.656[a]	.448[a]	.528[a]	**.749**[a]	1	
B11	.370[b]	.230	.291	.157	.322	.571[a]	.384[b]	.136	.486[a]	.459[a]	1

[a]Significance level 0.01 (2-tailed).
[b]Significance level 0.05 (2-tailed).
Main values are in bold.

Conclusions and policy implications

The main purpose of this research is to explore the main challenges of managing clean and green technologies research groups and the primary barriers that can hamper effective and clean innovations and transfer based on the perception of Brazilian PhD scholars working/leading such research groups.

Regarding the challenges, we discovered that it is necessary to pay attention to creating an effective culture of innovation, maintaining partnerships with the productive sector, and keeping laboratories and research equipment updated. It is also necessary to consider that some challenges are highly correlated. For example, it is a challenge to keep a focus on innovations that come from both market and academic sectors. In addition, communication and interpersonal relationships are linked with being updated on market innovations, and having updated laboratories and equipment is linked with receiving financial support from funding agencies. Based on these findings, we suggest that policies for promoting clean and green technologies research groups focus on the following: Helping to create an atmosphere in favor of innovation with real links to the market/productive sector and helping clean and green technologies research groups to get funding to improve their laboratories and equipment. Public policies should also have incentives in the form of putting together joint actions and workshops to connect both academicians and practitioners, which are practices that ultimately connect universities and the market/industrial world. This process will also require support to develop effective communication, strong leadership behavior, and interpersonal skills in the researchers.

Regarding the barriers to innovation and the effective transfer of this innovation to the market, we found that a lack of enough skilled staff and researchers, uncertainty about the valuation of the innovative effort by the scientific community, and uncertainty about the national legislation are key barriers hampering the innovation of clean and green technologies. Policies aiming to promote clean and green technologies should act to create new jobs in Brazilian universities and invest in human resources training, and development. In addition, they should create a broad scientific assessment of researchers, with a valorization of innovative effort and not only of academic publication (for example, there is a strong focus on scientific papers publication). They should also create clearer and more transparent scenarios regarding the legislation of clean and green technologies and promote the diffusion of this knowledge through websites and reports. Policymakers on clean and green technologies should consider that the uncertainty about national legislation could be likened to not having a clear understanding about the international legislation. They also need to act to supply academicians and practitioners with financial information and investment analysis tools, as they have the knowledge of when and how clean and green technologies will pay off. Finally, policymakers can promote workshops and meetings between clean and green technologies research groups, industrial sector, and green investors.

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