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Utilities: Innovation and Sustainability

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Abstract: Pro-market reforms have disrupted the playing field and strongly affected the innovative behavior of electricity, gas and water utilities. Beyond a significant reduction in sectoral R&D investments, very little is known about how these firms accomplish their innovation strategies in this new scenario. Given this gap in the literature, the first aim of this paper is to identify the internal determinants of both the product and process innovation of utilities in a liberalized environment. Additionally, there is another external force that is also disrupting the specific landscape of utilities: the sustainability challenge. Therefore, the second aim of this paper is establishing whether sustainability-orientation is a driver of innovation in the utilities industries. The empirical study is carried out on a panel of 82 Spanish electricity, gas and water utilities over the period 2005–2012 (Technological Innovation Panel dataset (PITEC)). The main findings are: (i) the acquisition of disembodied knowledge does not play a relevant role for utilities; (ii) non-formal search processes are central to product innovation; (iii) some markets for technology –external R&D and technology embedded in equipment—are determinant factors for process innovation; (iv) sustainability orientation increases the likelihood of generating both, product and process innovations. These firm-level results are novel contributions to the field of utility management.

Keywords: utility; electricity; gas; water; liberalization; innovation; sustainability; PITEC

1. Introduction

Electricity, gas and water utilities face the challenge of digital transformation [1]. The smart grid is just the most obvious example of this huge but promising technological undertaking [2,3]. However, this paper focusses on two other external forces that are shaping the environment of utilities—liberalization and sustainability—and how these forces interact with their innovation strategies.

On the one hand, liberalization and other pro-market reforms have changed the playing field of utilities [4]. As a result, the former centralized and cooperative systems of sectoral innovation have passed away. Moreover, in the old monopoly days, innovation in the utilities industries was a relatively peripheral phenomenon [5]. This is no longer the case. Innovation is now a central issue for the different stakeholders of electricity, gas and water utilities [6]. Regulators, for example, are highly concerned about how to encourage innovation in the industries under their supervision, while ensuring the interests of consumers are protected [7]. Paradoxically, our understanding of how utilities undergo the innovation process in a liberalized environment is very limited. Herein lies the motivation for studying the internal determinants of product and process innovation for utilities. On the other hand, energy and water lie at the heart of the sustainability problem. Therefore, utilities must be essential actors in the transition to a sustainable future [5,8]. Innovation is considered a precondition to progress in this path. For this reason, the second aim of this research is establishing whether sustainability-orientation is a driver of innovation in liberalized utilities industries.

It should be stressed that this is an exploratory study for an under-researched issue. Previous literature is scarce [9,10]. No theories are tested, because the purpose of this paper is to generate empirical evidence regarding a highly relevant decision for utilities.

The remainder of the paper is structured as follows. Section 2 describes how utilities have undergone innovation under traditional monopolistic environments and the changes that pro-market reforms have introduced. It also discusses whether sustainability-orientation is a driver of innovation in the utilities industries, and research questions to be addressed in the paper are formally stated. Section 3 carefully describes the data, variables and models of the empirical study. Section 4 presents the results, and finally Section 5 discusses the main contributions.

2. Innovation and Sustainability in a Liberalized Environment

2.1. Internal Determinants of Innovation

Under traditional monopolistic environments, electricity, gas and water utilities deployed innovation strategies characterized by incrementalism and path dependencies. Far-reaching technological changes occurred, but they were usually driven by external stimuli [11]. Rate-of-return regulation, direct public intervention and public ownership situated the risk on the customer's side [4,12]. Not surprisingly, in comparison to firms operating in non-regulated environments, utilities showed a low propensity to introduce product innovations. However, process innovations were much more common and were considered a technical issue. Markard, Truffer and Imboden describe this technological regime for the specific case of the electricity supply industry [13] (pp. 204–205): "in monopoly times, decision making was mainly oriented at the technical quality and the security of supply. Investments into the grid, for instance, were carried out according to a fixed, regular schedule and companies tried to achieve the best available technical standard. Costs or financial returns rather played a minor role. Electricity consumers were mainly regarded from a technical point of view". As far as the inputs of the innovation process were concerned, governments led long-term R&D programs, while utilities co-operated in the development of new knowledge through joint technology centers, demonstration projects and different collaborative arrangements [14–16]. New technologies embedded in equipment and advanced services produced a vast array of supplier-driven incremental innovations. Finally, learning-by-doing and the exchange of best practices among utilities were common non-formal search methods [17].

Liberalization processes have disrupted the playing field of traditional electricity, gas and water utilities. Sectoral restructuring, privatization, new regulatory regimes and competition in or for the market have transferred the bulk of the risk from customers to owners. All these pro-market reforms have strongly affected the innovative behavior of utilities [11]. The new scenario eliminates many previous barriers and rewards firm innovation. Therefore, industry-wide cooperation has collapsed, economic issues have gained a central role, projects with shorter payback periods are preferred and customer-oriented product innovations have flourished [18]. Moreover, several authors have consistently confirmed a significant reduction in sectoral R&D investments in different jurisdictions after liberalization experiences [19–26]. However, very little is known about how utilities accomplish their innovation strategies at the firm level in a liberalized environment; i.e., which activities (inputs) are needed to generate innovations (outputs). As stated above, academic attention has been focused almost exclusively on analyzing the changes in the sectoral volume of R&D resources. Paradoxically, the role of both R&D and non-R&D knowledge acquisition activities at the utility level has been almost neglected [27]. Given this gap in the literature, the first research question this paper addresses is as follows:

RQ1. What innovation activities do utilities engage in to generate innovations in a liberalized environment?

2.2. Sustainability-Oriented Innovation

However, there is another external force that is also disrupting the specific landscape of utilities: the sustainability challenge. Energy and water supply utilities find themselves in the midst of a sustainability transition: a long-term, multi-dimensional, and fundamental transformation through which the established socio-technical systems are shifting to more sustainable modes of production and consumption [28].

Pressures to adapt to the new situation come from almost all relevant stakeholders: governments and regulators, non-governmental organizations (NGOs), local communities, investors, employees, suppliers or customers. Harvey and Schaefer [29] point out that green stakeholders with an institutional power base—government via legislation, environmental and industry regulators—appear to be the most influential. In the last decades, the legal framework has emphasized the importance of making both the energy and water sectors greener. The well-established energy policy goals of the European Union not only include security of supply and competitiveness, but also environmental protection [30]. The transition to a low-carbon world is now assumed by almost all stakeholders of the energy industries. Regarding the water sector, the European Union implemented the Water Framework Directive to address both water quality and quantity challenges, with the explicit aim of improving water security and pollution [31]. NGOs now have a direct influence on governments and firms, but they also exert a hidden indirect influence on sustainability issues through national and transnational multi-stakeholder standardization bodies [32]. Sustainability compliance and reporting are becoming key communication mechanisms with investors and the general public [33–35]. Liberalization has empowered customers. They are more aware, have more freedom to shop around and are more demanding. They could even become partners under a new paradigm of citizen utilities. This is already happening in the electricity industry, as the sharp cost reduction of solar photovoltaics technology is changing the traditional unidirectional power grid [36].

Product and process innovation are available tools to cope with such profound transformation. Successful product design for green products may provide utilities with a competitive advantage [37]. At the operational level, economic and environmental goals quite often converge: process innovation is usually incremental and is primarily focused on increasing technical efficiency or quality [8]. The initial narrow eco-innovation practices have slowly evolved into a more comprehensive approach under the label of sustainability-oriented innovation [38]: making intentional changes to firm's products or processes to create social and environmental value, in addition to economic returns [39]. Sustainability-oriented innovation aims to alleviate tensions between the environmental, social and financial goals the firm [40,41].

The conventional wisdom is that sustainability-orientation is associated with higher innovation [42]. Utilities increasingly integrate sustainability goals in their innovation processes. However, it remains an open question whether, in the specific case of utilities, this sustainability-orientation is propelling the innovation output. The existing evidence from the utilities' field is limited, based on case studies and far from conclusive [10]. Thus, the second research question can be stated as follows:

RQ2. Is sustainability-orientation a driver of innovation in the utilities industries?

3. Data, Variables and Models

3.1. Data

The empirical study will be developed for the Spanish case. Two reasons support this choice. On the one hand, the regulatory framework governing Spanish utilities clearly evolved towards the liberalized paradigm at the end of the 20th century. Both the Electricity Sector Act (Law 54/1997) and the Hydrocarbons Sector Act (Law 34/1998) restructured and deregulated power and gas markets. Although no equivalent regulatory discontinuity was introduced in the water industry, liberalization forces also affected water utilities: privatizations and public-private partnerships spread across the country under the provisions of the Local Government Act (Law 7/1985). On the other hand, firm-level data availability reinforces the choice of Spain for our empirical study. The dataset from the Technological Innovation Panel (hereafter PITEC) contains annual information about the innovation activities of around 12,000 Spanish firms from 2003 onwards. This wide coverage allows disaggregated analyses for certain industries. As far as econometrics is concerned, PITEC provides a viable sample of Spanish firms whose main activity is in the electricity, gas or water supply value chains.

The data are available on a consistent basis for the period 2005 to 2012. According to a recent strand of literature on innovation barriers [43–47], only the subset of potentially innovative firms should be considered. Innovating is not the only viable competitive strategy, and therefore some firms could rationally decide not to innovate, even if no relevant barrier were in place. Following a similar procedure to Costa-Campi, Duch-Brown and García-Quevedo [9], firms that meet three conditions are excluded from the sample: (i) firms that have not introduced product or process innovations, (ii) firms that state that there is no significant need to innovate, and (iii) firms that do not perceive any significant cost, knowledge or market barrier to innovation. After data cleaning, the final sample contains 429 observations from 82 electricity, gas and water utilities. As will be explained below, all independent variables are lagged one year in the causal model. Hence, the observed interval for the dependent variable is limited to seven years (2006–2012) and 349 observations.

Unfortunately, due to statistical secrecy, there is no obvious way to identify in the dataset whether an observed utility is an electricity, gas or water utility. Therefore, it is not possible to disaggregate the sample into different subsamples according to the main activity of the firm. Previous studies using PITEC data that attempted to focus on energy industries (for instance, [9]) fell short of covering all energy activities and only energy activities.

3.2. Variables

Variables are defined according to the Oslo Manual [48] and measured as follows.

- Product or process innovation (INNit) (binary variable 0–1): This variable will take the value 1 if utility i has introduced a new product or process in the year t or in the two previous years. The innovation will always be new for the utility, but not necessarily for its industry or market. In some models, this variable will be split into two: product innovation (INNPTit) and process innovation (INNPCit);
- Research & Development (R&Dit) (binary variable 0–1): This variable will take the value 1 if utility i has carried out internal or external research and development activities during the year. These will be, in any case, creative actions focused on increasing the stock of knowledge and its application to develop new or improved products and processes. In some models, this variable will be split into two: internal R&D (IR&Dit) and external R&D (ER&Dit);
- Acquisition of machinery and equipment (EQUIit) (binary variable 0–1): This variable will take the value 1 if utility i has acquired advanced machinery, equipment, hardware or software intended for the production of new products or processes during the year. This category only includes the acquisition of capital goods for innovation that is not included in R&D activities;
- Acquisition of external knowledge (EXKit) (binary variable 0–1): This variable will take the value 1 if utility i has acquired external knowledge for innovation, such as licenses, patents, disclosures of know-how, trademarks, designs or other inventions during the year;
- Non-formal search processes (NFSit) (binary variable 0–1): This variable will take the value 1 if utility i has (i) trained its personnel for innovation activities, (ii) carried out technical operational preparations not included in R&D, or (iii) performed exploratory market research activities for new or significantly improved products during the year;
- Size (SIZEit) (positive decimal number): This variable will take the value of the log of the average number of employees in utility i during the year;

- Business group affiliation (GROit) (binary variable 0–1): This variable will take the value 1 if, during the year, utility i is part of a group as either the parent company, a subsidiary, a joint-venture or an associate;
- Foreign ownership (FOWit) (binary variable 0–1): This variable will take the value 1 if, during the year, 50% or more of the capital of utility i is owned by foreign firms;
- Sustainability goals (SGit) (binary variable 0–1): This variable will take the value 1 if, during the year, utility i classifies as highly relevant the innovation goals of mitigating environmental impact and/or complying with environmental/health and safety regulations.

3.3. Models

In order to answer the first research question (RQ1), the causal model of Equation (1) is proposed.

$$\text{INNit} = f\,(\text{R\&Dit-}_1;\ \text{EQUIit-}_1;\ \text{EXKit-}_1;\ \text{NFSit-}_1;\ \text{SIZEit-}_1;\ \text{GROit-}_1;\ \text{FOWit-}_1) \quad (1)$$

The generation of product or process innovations is the dependent variable and two types of explanatory variables are considered (Equation (1)). On the one hand and according to the Oslo Manual [39], four variables that describe the innovation strategy of the firm are considered: (i) research and development, including both internal and external activities; (ii) acquisition of machinery and equipment; (iii) acquisition of external knowledge; and (iv) other non-formal search processes. On the other hand, three control variables which capture firm characteristics that may influence the innovation process are considered: (v) size, (vi) business group affiliation, and (vii) foreign ownership. In order to strengthen the causality link, all the independent variables are lagged one year vis-à-vis the dependent variable.

The dependent variable has a dichotomous nature and, therefore, a binary response model is chosen. A logistic regression or LOGIT has been used, as it is considered the most adequate for the distribution of data [49]. In addition, the model is estimated with a panel data set (random effects). This allows us to control for unobservable individual heterogeneity: firm-specific characteristics that could influence the dependent variable and were not included in the model [50]. It is worth noting that panel data also makes possible the introduction of lagged explanatory variables, while cross-sectional studies based on a one-wave innovation survey cannot [51]. Year dummy variables have been included in the model in order to control for the potential year effect.

The second research question (RQ2) is addressed with the causal model of Equation (2).

$$\text{INNit} = f\,(\text{R\&Dit-}_1;\ \text{EQUIit-}_1;\ \text{EXKit-}_1;\ \text{NFSit-}_1;\ \text{SIZEit-}_1;\ \text{GROit-}_1;\ \text{FOWit-}_1;\ \text{SGit-}_1) \quad (2)$$

The difference in relation to Equation (1) is the inclusion of "sustainability goals" as an explanatory variable. A utility with a sustainability-oriented innovation process would assign high relevance to the innovation goals of mitigating environmental impact and/or sustainability compliance. As in the previous case, (i) independent variables are lagged one year, (ii) year dummy variables are included, and (iii) LOGIT regression is used for model estimation.

Computations have been done using the software package STATA V12 (StataCorp LLC, Texas, TX, USA).

4. Results

4.1. Inputs of the Innovation Process

Table 1 shows the correlation coefficients for the independent variables of Equation (1). Furthermore, variance inflation factors (VIFs) reveal no evidence of multicollinearity among the variables, as all of them are under the threshold of 2 (full results not shown).

Table 1. Correlation matrix (models 1 to 4). IR&D: internal R&D; ER&D: external R&D; EQUI: acquisition of machinery and equipment; EXK: acquisition of external knowledge; NFS: non-formal search processes; SIZE: size; GRO: business group affiliation; FOW: foreign ownership.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. R&D	1								
2. IR&D	–	1							
3. ER&D	–	0.50 ***	1						
4. EQUI	0.13 ***	0.09 **	0.04	1					
5. EXK	0.19 ***	0.12 ***	0.23 ***	0.11 **	1				
6. NFS	0.33 ***	0.26 ***	0.25 ***	0.18 ***	0.16 ***	1			
7. SIZE	0.30 ***	0.37 ***	0.31 ***	0.115 ***	0.14 ***	0.14 ***	1		
8. GRO	0.16 ***	0.16 ***	0.24 ***	0.12 ***	0.13 ***	0.13 ***	0.41 ***	1	
9. FOW	0	0.03	0.03	0.15 ***	−0.08	−0.03	−0.03	0.27 ***	1

n = 349.

To begin with, four models are estimated using logistic regressions on the full sample of 82 utilities and 349 observations (Tables 2 and 3). Some common issues will be presented before describing the results of the different models. Firstly, the coefficients of year dummy variables are not reported for brevity. Secondly, Wald tests indicate that the four models are significant at the 99% confidence level. Thirdly, we have also tested and rejected that the panel-level variance components are unimportant for these four models (LR test of Rho). Therefore, panel data are preferred to pooling models in all cases. Finally, we have estimated identical models using PROBIT instead of LOGIT. As expected, the results (not shown) were almost the same.

Table 2. Inputs of innovation process.

Variables	**Model 1: INN**	**dy/dx**	**Model 2: INN**	**dy/dx**
R&D	2.200 *** (0.54)	0.22 ** (0.11)	-	-
IR&D	-	-	1.40 ** (0.71)	0.11 (0.07)
ER&D	-	-	1.34 ** (0.67)	0.10 * (0.06)
EQUI	4.40 *** (1.42)	0.20 *** (0.07)	4.58 *** (1.42)	0.21 *** (0.07)
EXK	1.02 (1.78)	0.05 (0.07)	1.14 (1.8)	0.06 (0.06)
NFS	1.94 ** (0.97)	0.10 * (0.05)	1.93 ** (0.95)	0.10 * (0.05)
SIZE	0.25 (0.25)	0.02 (0.02)	0.20 (0.25)	0.02 (0.02)
GRO	1.78 ** (0.81)	0.16 (0.10)	1.63 ** (0.79)	0.15 (0.10)
FOW	−0.08 (1.30)	−0.01 (0.11)	−0.13 (1.28)	−0.01 (0.11)
Constant	−4.35 *** (0.63)	-	−3.91 *** (1.39)	-
Year effect considered	Yes	Yes	Yes	Yes
Goodness of fit statistics				
Log-likelihood	−121.18		−121.33	
Wald (χ^2)	35.88 ***		35.52 ***	
Sigma_u	2.57		2.50	
Rho	0.67 ***		0.66 ***	
Z_1	31.33 ***		31.02 ***	
Z_2	17.27***		15.43**	
No observations	349		349	
No firms	82		82	

(Standard errors) ***, **, *: Significant at 1%, 5% and 10%; Z1 is a Wald test for the reported coefficients of the explanatory variables, asymptotically distributed as χ2 under the null hypothesis of no relationship for all the explanatory variables; Z2 is a Wald test of the joint significance of the time dummies, asymptotically distributed as χ2 under the null hypothesis of no relationship.

Model 1 represents the general case: the innovation outcome (product or process) depends on the innovation activities and the control variables. Here, R&D is included as an aggregate variable, without discriminating between internal and external categories. All innovation activities but one have been proven to be determinants for generating innovations. The exception is the acquisition of external knowledge (EXK). It seems that utilities do not rely on this source of disembodied technology. Conversely, just one of the coefficients of the control variables is positive and statistically significant: group affiliation (GRO).

Model 2 explores whether splitting the aggregate R&D variable into in-house and outsourced R&D introduces any change. The new variables are named internal R&D (IR&D) and external R&D (ER&D). However, results are very similar. Internal and external R&D coefficients are positive and statistically significant. Again, the acquisition of capital-embodied technology (EQUI) prevails over the purchase of disembodied knowledge (EXK). Downstream non-formal search processes (NFS) keep complementing the other of innovation activities.

As far as marginal effects (dy/dx) for Model 2 are concerned, the acquisition of machinery and equipment (EQUI) is the input with the strongest significant impact on the generation of innovations (0.21). Non-formal search processes (NFS) and external R&D (ER&D) show much lower coefficients (0.10).

This amalgamated view of the internal determinants of innovation in utilities could be hiding a more complex reality. To be more precise, it could be expected that managers will establish different innovation strategies when the desired outcome is either a new product or a new process. Models 3 and 4 follow this approach (Table 3).

Table 3. Inputs of product and process innovation process.

Variables	Model 3: INNPT	dy/dx	Model 4: INNPC	dy/dx
IR&D	1.11 ** (0.47)	0.20 ** (0.08)	0.85 (0.59)	0.14 (0.10)
ER&D	0.59 (0.44)	0.10 (0.08)	1.46 ** (0.59)	0.21 ** (0.09)
EQUI	0.60 (0.44)	0.11 (0.09)	3.29 *** (0.84)	0.33 *** (0.08)
EXK	−0.81 (0.86)	−0.11 (0.09)	1.23 (1.68)	0.14 (0.12)
NFS	2.71 *** (0.51)	0.57 *** (0.10)	1.50 ** (0.72)	0.18 ** (0.08)
SIZE	0.27 (0.19)	0.05 (0.03)	0.22 (0.22)	0.04 (0.04)
GRO	0.13 (0.57)	0.02 (0.10)	1.13 (0.71)	0.19 (0.13)
FOW	1.05 (0.79)	0.22 (0.18)	−2.03 * (1.21)	−0.43 * (0.25)
Constant	−5.05 *** (1.12)	-	−3.64 *** (1.26)	-
Year effect considered	Yes	Yes	Yes	Yes
Goodness of fit statistics				
Log-likelihood	−152.30		−140.38	
Wald (χ^2)	49.77 ***		39.34 ***	
Sigma_u	1.55		2.32	
Rho	0.42 ***		0.62 ***	
Z_1	47.21 ***		34.81 ***	
Z_2	10.06		14.32**	
No observations	349		349	
No firms	82		82	

(Standard errors) ***, **, *: Significant at 1%, 5% and 10%; Z_1 is a Wald test for the reported coefficients of the explanatory variables, asymptotically distributed as $\chi 2$ under the null hypothesis of no relationship for all the explanatory variables; Z_2 is a Wald test of the joint significance of the year dummies, asymptotically distributed as $\chi 2$ under the null hypothesis of no relationship.

In Model 3, the dependent variable is the generation of product innovations (INNPT). In this case, the innovation activities that come out positive and statistically significant are internal R&D (IR&D) and non-formal search processes (NFS). Product innovation in utilities is not based on external contracts: neither ex-ante contracts for R&D, nor ex-post contracts for existing technology. Next, model 4 takes process innovation (INNPC) as the dependent variable. Now, external R&D (ER&D) and acquisition of machinery and equipment (EQUI) come out positive and statistically significant at 1%. Again, non-formal search processes (NFS) complete the portfolio of relevant innovation activities. Among the control variables, foreign ownership (FOW) is the only statistically significant variable, though with a negative sign.

The need for a disaggregated analysis is reinforced when examining the marginal effects (dy/dx), as they behave very differently in Models 3 and 4. Marginal effects provide relevant information about the influence of individual inputs in the dependent variable. In the case of product innovation, non-formal search processes (NFS) show the highest positive coefficient (0.57), while internal R&D (IR&D) follows with a coefficient of 0.20. However, capital-embodied technology (EQUI) achieves the highest positive coefficient (0.33) among the inputs of product innovation, while foreign ownership (FOW) has a strong negative impact (−0.43).

4.2. Sustainability-Orientation as a Driver of Innovation

To address the second research question, a subsample of 71 utilities (86.6% of the total sample) with 262 observations (76.4% of the total sample) was selected. This subsample contains observations of utilities that answer the section of the questionnaire related to sustainability innovation goals. Missing values in this section in a particular year imply that the observation for this utility in this year is not considered.

Table 4 shows the correlation coefficients for the explanatory variables of Equation (2) and 262 observations. Again, to deal with the issue of multicollinearity, the variance inflation factors (VIFs) were examined, and the highest value was 1.38 (other results not shown). Therefore, multicollinearity does not constitute a problem in our data.

Two additional LOGIT models are estimated for product and process innovations (Table 5). As explained in Section 4.1, (i) the coefficient of year dummy variables are not reported, and both models are significant at the 99% confidence level (Wald tests); (iii) panel data models are preferred over pooling models (LR test of Rho); and (iv) the PROBIT and LOGIT estimation results are almost the same. In Model 5, the dependent variable is the generation of product innovations (INNPT). In this analysis, the innovation activities that come out positive and statistically significant are internal R&D (IR&D) and non-formal search processes (NFS). Marginal effects for these variables are 0.23 and 0.62, respectively. The variable sustainability goals (SG) offers a positive and significant coefficient in the logistic regression, but the marginal effect for sustainability goals is not significant. In Model 6, the dependent variable is process innovation (INNPC). The innovation inputs that the model reveal as significant are the acquisition of capital-embodied technology (EQUI) and non-formal search processes (NFS). Marginal effects are low for both internal innovation activities: 0.14 for EQUI and 0.08 for NFS. The variable sustainability goals (SG) shows positive and significant coefficients in both the logistic regression and the marginal (0.08).

Finally, to establish the robustness of these results of sustainability orientation, model 5 (product innovation) and model 6 (process innovation) were re-estimated using a lower threshold for the binary variable sustainability goals (SG_{it}). This variable takes now the value 1 if, during year t, utility i classifies the innovation goals of mitigating environmental impact and/or complying with environmental/health and safety regulations at least as "relevant" (instead of "highly relevant"). The new results (not shown) did not differ from those already presented in Table 5.

Table 4. Correlation matrix (models 5 and 6).

	1	2	3	4	5	6	7	8	9
1. SG	1								
2. IR&D	0.05	1							
3. ER&D	0.17 ***	0.50 ***	1						
4. EQUI	−0.03	0.09 **	0.04	1					
5. EXK	−0.10 *	0.12 ***	0.23 ***	0.11 **	1				
6. NFS	0.02	0.26 ***	0.25 ***	0.18 ***	0.18 ***	1			
7. SIZE	0	0.37 ***	0.30 ***	0.15 ***	0.15 ***	0.13 ***	1		
8. GRO	0.05	0.16 ***	0.24 ***	0.12 ***	0.13 ***	0.13 ***	0.41 ***	1	
9. FOW	−0.14 **	0.03	0.03	0.15 ***	−0.08	−0.03	−0.03	0.27 ***	1

n = 262.

Table 5. Effect of sustainability orientation in product and process innovation.

Variables	Model 5: INNPT	dy/dx	Model 6: INNPC	dy/dx
SG	0.97 * (0.57)	0.22 (0.14)	1.54 * (0.83)	0.08 * (0.04)
IR&D	1.15 ** (0.58)	0.23 ** (0.10)	0.15 (0.70)	0.01 (0.05)
ER&D	−0.15 (0.51)	−0.03 (0.11)	0.46 (0.63)	0.03 (0.05)
EQUI	0.23 (0.48)	0.05 (0.11)	2.97 *** (0.94)	0.14 ** (0.06)
EXK	−0.59 (1.00)	−0.12 (0.17)	0.14 (1.72)	0.01 (0.10)
NFS	2.92 *** (0.56)	0.62 *** (0.09)	1.57 ** (0.77)	0.08 * (0.04)
SIZE	0.21 (0.21)	0.05 (0.05)	0.31 (0.26)	0.02 (0.02)
GRO	0.52 (0.69)	0.11 (0.14)	0.25 (0.82)	0.02 (0.06)
FOW	1.25 (0.89)	0.30 (0.21)	−1.54 * (1.13)	−0.17 (0.19)
Constant	−4.70 *** (1.28)	-	−2.47 ** (1.39)	-
Year effect considered	Yes	Yes	Yes	Yes
Goodness of fit statistics				
Log-likelihood	−121.92		−98.16	
Wald (χ^2)	40.36 ***		26.38 **	
Sigma_u	1.66		2.17	
Rho	0.46 ***		0.59 ***	
Z_1	36.21***		19.10 **	
Z_2	13.10 **		13.41 **	
No observations	262		262	
No firms	71		71	

(Standard errors) ***, **, *: Significant at 1%, 5% and 10%; Z_1 is a Wald test for the reported coefficients of the explanatory variables, asymptotically distributed as $\chi 2$ under the null hypothesis of no relationship for all the explanatory variables; Z_2 is a Wald test of the joint significance of the year dummies, asymptotically distributed as $\chi 2$ under the null hypothesis of no relationship.

5. Discussion

This paper has identified the internal determinants of the product and process innovation of utilities operating in a liberalized environment. It has also highlighted the propelling role of sustainability orientation to generate these innovations. These are significant contributions to the field of utility management. As a matter of fact, it is the first quantitative causal paper that considers the full menu of knowledge acquisition activities for innovation as defined by the Oslo Manual [48]. Moreover, it is also worth mentioning that the PITEC questionnaire is aligned with the Community Innovation Survey (CIS). Therefore, the country (Spain) and sectoral (electricity, gas and water utilities) results are directly comparable with a large body of international/multi-industry empirical innovation literature. The main findings will be discussed below.

5.1. Regarding Identification of the Inputs of the Innovation Process

First, the acquisition of external disembodied knowledge—licenses, patents, and other inventions—does not play a relevant role for utilities. Paradoxically, however, Jamasb and Pollit [52] have identified a growth in electricity-related patenting activity in the post-liberalization period due to the increased commercialization of the sector. Marino, Parrotta and Valletta [53] have found similar results for countries that have experienced a relatively weak deregulation process. Therefore, inventions are increasingly patented in liberalized environments, but utilities are not acquiring disembodied knowledge as such.

Second, the remainder innovation activities—R&D, acquisition of machinery and other non-formal knowledge search methods—are important inputs for the success of the innovation process. This result holds for both product and process innovation.

Third, as far as the dichotomy product versus process innovation is concerned, utility managers use different combinations of activities. Product innovation demands internal R&D capabilities and downstream non-formal search processes. The marginal effect is much higher for these unformalized, soft, downstream activities. Take the examples of green power labeling or dual-fuel (electricity and gas) offers—product innovations that could be design just from reverse engineering. On the contrary, some markets for technology—external R&D and technology embedded in equipment—are determinant factors for process innovation. According to the marginal effects, the acquisition of equipment has a higher capacity to generate process innovations. For example, investments in technical equipment and IT infrastructure are needed for the deployment of smart grids and networks. All in all, Vega-Jurado, Gutiérrez-Gracia and Fernández-de-Lucio [54] posed a similar idea for manufacturing firms: product and process innovations may be independent of each other and, even more importantly, they could be associated with different knowledge-sourcing strategies.

Fourth, there is no clear evidence supporting the complementarity hypothesis between internal R&D and external knowledge acquisition. Product innovation relies on in-house capabilities. Process innovation, on the contrary, demands knowledge from outside the firm. All in all, there could be complementarity effects between them, but they are not obvious from the data; a stream of innovation literature claims that internal R&D increases the absorptive capacity [55] of the firm to incorporate external knowledge [56,57].

5.2. Regarding the Propelling Role of Sustainability Orientation

Given the external pressures from the different stakeholders, sustainability orientation is considered by many authors to be a key driver of firm innovation [58–60]. Our study confirms that sustainability orientation does increase the likelihood of generating innovations. As mentioned in the sensitivity analysis, utilities declaring that sustainability goals are relevant or highly relevant tend to be more innovative. Electricity, gas and water utilities activate innovativeness when searching for solutions that (i) mitigate environmental impact or (ii) comply with environmental and health and safety regulations. However, marginal effects indicate that sustainability orientation is not the most important driver. This holds for both product and process innovation.

5.3. Limitations and Future Research

The paper has several limitations, but also sets the foundations for some future research lines. First, we have already mentioned in Section 3.1 that it is not possible to disaggregate the utilities sector into three different industries—electricity, gas and water. Although the three exhibit common features of network industries, they have different technological and regulatory characteristics. Therefore, a separate study for each industry would be valuable, but must be based on other information sources. Second, the database PITEC does not allow the researchers to identify the firms. Therefore, it is not possible to complement the information of the firm with other sources for refining the analysis. Third, the paper has focused on product and process innovation. Marketing, organizational and even business model innovations are other areas that could be worth exploring. Fourth, external determinants of innovation were not considered. For example, subsidies and other support mechanisms strongly affect the willingness to innovate. Thus, including external factors could enrich the results. Finally, due to their traditional monopolistic organizational cultures, utilities are relative newcomers in the open innovation paradigm [61]. Nevertheless, many large utilities are now common players in the external corporate venturing market. They actively seek for ideas and startups that could complement their knowledge portfolio. This new reality opens a promising window for future research.

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