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Learning by failing. An empirical exercise on CIS data

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Abstract

The failure to innovate has been only recently recognised as one of the key elements of the firms' innovative performance, and is thus giving rise to a blooming literature. Indeed, many papers have addressed the issue of failure in innovation, highlighting several of the constraints binding firms innovative efforts.

However, this literature has focused only on the determinants of firms' failure, neglecting the role of failure in spurring also innovative activity. Indeed, failure has been recognised as a powerful mechanism for organisational learning.

In this paper, the relationship between innovative performance and failure to innovate is investigated through the use of the 2008 CIS Innovation survey.

This paper's results highlight that, first, the probability of abandoning an innovative project is decreased by organisational experience and by the utilisation of external flows of knowledge. Moreover, vicarious learning is possible insofar as it is associated to the building of absorptive capacity.

In turn, failure is a crucial element in spurring the production of innovation by firms, as it is an important element of learning, thus constituting a crucial element in determining the pace and the rate of innovation produced by European firms. However, while abandoned innovative activity is a positive determinants of innovation, when the same activity is postponed, it turns out to become a liability for innovation production.

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1 Introduction

Starting from the seminal work by Cyert and March (1963), both theoretical and empirical contributions agree that firms' learning patterns are crucial for both their innovativeness and their growth. Organisational literature (e.g. March, 1991; Levinthal and March, 1993; Levitt and March, 1988) has emphasised that, as a result of modifications of the patterns of knowledge accumulation through experience, organisational learning is a key element in determining differences in firms' performance. For firms addressing innovative behaviour it is essential to generate, maintain, and develop their capability to build and/or recognise internal knowledge. Learning is the main tool to redefine existing processes, by apprehending, refining, modifying and restructuring routines and operating procedures. Hence, on the one side, this reduces the likelihood of failure through improvements of firms' efficiency, and on the other side, it enhances the organisations resiliency, thus increasing the likelihood to survive by improving the capability to recover from eventual poor performance.

However, as innovative activity is inherently uncertain, it often results in failure. Failure is therefore seen as a problem in the economic activity of firms, as the early literature pointed out that in the wake of a failure, organisations typically pursue strategies aimed at surviving, thus engaging in activities addressing, for instance, reduction of costs, of risky investments, of organisational burden (for a survey, see van der Panne, van Beers, and Kleiknecht (2003)).

One important element that has been emphasised in this literature is related to failures in organisational activity as a positive element for organisational learning, as failure shows where and how the organisation was unable to cope with the pressure coming from the environment and thus focuses organisational attention on its inability to adapt its techno—economic effort to the needs of the market. Therefore, a subset of this literature argues that an important element of organisational learning comes from failure, emphasising that learning is strictly connected with failure as trial and error activity is one of the main elements of discovery. Organisational learning, in this case, comes through the capacity of the members of the organisation to make sense of the series of disparate and possible contradictory events coming from the environment, for which a creative answer is often the only way to cope with (Coe and Barnhill, 1967).

Moreover, in some cases, the failure of certain projects, although at first sight it can be (and usually is) evaluated negatively by the firm, afterwards (i.e. after its outcome is thoroughly investigated) it might happen that the firm itself realises that the failed project has indeed generated value. Value in terms of both new knowledge about a previously overlooked innovative neighbourhood service and of the creation of completely new projects that were not identified from the failed project. A classical example is the process of learning that resulted from the Columbia space shuttle disaster (Madsen and Desai, 2010). In such cases, the true value of the failed project escapes the evaluation tools ordinarily adopted to compare ex–post results with ex–ante targets (Elmquist and Le Masson, 2009).

The aim of this paper is to evaluate if failure in innovative projects generates a significant learning process that can be one of the main elements in the firms' knowledge and thus in firms' innovative activity. To do this, a set of empirical estimates will be performed on a large dataset of innovative firms from sixteen countries, taken from the 2008 Community Innovation Survey. A two step model will be used to estimate the patterns of failure in innovation, and subsequently if this generates useful learning patterns for innovation production.

The main results of the paper are, first, that failure is negatively correlated to the previous experience (proxies by R&D), and to the acquisition of external knowledge and positively to the firm being part of an industrial group, and producing new-to-the-market or new-to-the-firm goods. Moreover, vicarious learning has a negative impact on failure for firms engaged in R&D. As far as innovation production is concerned, failure has a positive impact, while postponed innovation activity has a negative one.

The paper is organised as follows. Par. 2 will review the theoretical literature on the subject. Par. 3 will describe the data, the variables and the econometric methodology. Par. 4 will present the results. Finally, par. 5 will conclude.

2 Literature review

The idea that learning results from experience dates back at least to Adam Smith. Learning takes place through a process of trial-and-error and happens as a result of repeated attempts to solve problems as they appear, and thus it is a dynamic process which takes place only during the development of techno–economic activities.

Failure is one of the way through which problems emerge and manifest themselves, thus triggering processes of learning. From a behavioural theory of the firm point of view (Cyert and March, 1963), learning is associated to organisational routines that happen to be stored within the organisation, because they are able to represent well (satisfyingly well) the firms' response to the challenges coming from the outer environment. Therefore, if a routine is able to copy sufficiently well the outside world, it is a well functioning routine which needs not to be changed or questioned. Once the organisational routine has reached the satisfying level, it is assumed it can be maintained unaltered until it fails repeatedly the test of correct world representation. If a routine is judged successful, it does not engender search activities, but marginal and maintenance ones.

However, if a organisational behaviour is leading to failure, it is considered to misrepresent the world, and thus a procedure (a meta routine) is implemented to understand when and where it failed and to correct it. This process of search of a new (successful) organisational routine implies a process of learning. Thus, it is likely that the perception of certain problems is more effective once they are effectively faced by the firms. To put it more clearly, problems are normally encountered (and presumably solved) by innovative firms. Moreover, the process of learning is more focused in case of failure than it would be in the case of success. Failure highlights more clearly new directions in the process of learning, as it focuses the attention and shows the critical elements that led to a subpar performance. In this sense, failure is a better ”focusing device” than success is.

The main bulk of the literature on this topic has developed from an organisational perspective with several papers addressing the issue of the ‘benefit of failure’. Indeed, Chesbrough (2010), through the analysis of Xerox business model, supports the idea that failure is able to supply and convey new ways to understand and implement innovative approaches within the organisation. By meaning failure as an experiment, new data are created, that might reveal previously unnoticed opportunities. Haunschild and Sullivan (2002) analyse the impact of airline failures on the rate of subsequent accident, and find that when accidents come from multiple causes, they induce the involved airlines to perform more careful investigations, with a consequent reduction in subsequent accidents, with respect to other airlines that experienced less complex ones. Also Madsen and Desai (2010) analyse the impact of the 2003 disaster of the Columbia Space Shuttle (see Chapter II of Collins and Pinch (1998) for a thorough analysis), and find that, following that catastrophic failure, the Columbia Accident Investigation Board, established immediately in the aftermath of it, highlighted the importance of prior failure in driving organisational learning. On the contrary, previous near–misses (i.e. small failures that eventually never translated into failure, such as the same damage suffered during the launch of the Atlantis Space Shuttle some months before), just like success, have lower probabilities to produce revisions of the organisational practices (Dillon and Tinsley, 2008). Chiou, Magazzini, Pammolli, and Riccaboni (2012) find that knowledge gained from both successes and failures in the pharmaceutical industry are elements contributing to learning. In particular, failures are important since they might uncover previously neglected routes, thus increasing the probability to find a new successful route in patenting new drugs that were previously concealed by successful ones, and that for this reason were forbidding new explorations. Similar results emerged from sectoral analysis performed, in the case of railroad accidents (Desai, 2010b; Baum and Dahlin, 2007), and the gas industry (Desai, 2010a).

Another strand of literature has focused on more extensive empirical analysis, due to the more recent availability of extensive surveys on innovative activity of the firms. However, this strand of literature is more focused on the obstacles to innovative activity, rather than to their failure. Many papers (e.g. Galia and Legros, 2004; Lhuillery and Pfister, 2009) have produced analysis based on French data, while Galia, Mancini, and Morandi (2012) make a comparison between France and Italy. Hadjimanolis (1999) analyses Cyprus, while D'Este, Iammarino, Savona, and von Tunzelmann (2012) provide evidence for UK. Other papers have dealt with particular domain, such as the financial obstacles (Mohnen, Palm, Schim Van Der Loeff, and Tiwari, 2008) or the multinational firms (Iammarino, Sanna-Randaccio, and Savona, 2009).

From the analysis of the literature some stylised facts to be empirically tested emerge. Organisations gain from their operating experience, learning from previous failures, and are thus becoming less prone to fail. This happens for several reasons. First, previous operating experience makes organisational members less likely to make mistakes in response to failure by enhancing their capacity to learn. Their learning curve is better suited to increase they ability to read situations and to interpret them “more correctly” then they would otherwise do in case of no previous experience. Second, previous operating experience allows to build a stock of knowledge, which makes organisations more pro–active with respect to the necessary search activities and to the necessity to integrate the new knowledge derived from failures.

Hence, a first testable hypothesis is that firms with higher levels of operating experience are less likely to experience failures.

Another element comes from the consideration that firms with a generalist aim build on their operating experience in such a way to be more effective at learning activities from failures with respect to firms with specialist aims. On the one side, operating experience from generalist firms constitutes a sort of buffer that is more effective for survival than that of specialist ones. On the other side, generalist firms must posses a broader knowledge, which is more helpful to understand (and thus to learn) from failures. Here, we refer to generalism as the degree of organisational complexity (not to its mere size) in terms of a wider range of products and of suppliers with respect to specialist firms. Hence, the organisational structure of a specialist firm being more complex must therefore be able to deal with multidimensional relationships, with respect to specialist firms (Desai, 2010b, p. 7).

Hence, a second testable hypothesis is that firms with more composite learning flows are more likely to learn from failure (and to reduce their rate) than firm with simpler organisational structure, distinguishing between direct knowledge flows (which come from direct knowledge of other firms experience) and vicarious learning (which comes from indirect knowledge of other firms' experience).

Finally, learning is associated to different patterns depending on the organisational routine to be have success or not. Indeed, if an organisational routine happens to be successful, it is considered to represent sufficiently well the needs of the firm and its relationships with the outer environment (i.e. it represents well the world), and thus it is considered to work well, and thus it is maintained (almost) unaltered within the organisation. Thus, we might expect that the more failure is effectively faced by a firm, the more it will react to it, and thus the more it will be involved into a alarming process that has innovation as a final result.

We thus delineate a third hypothesis: a firm that faced an experience of organisational failure is less likely to face failure again because of its learning activity and as a result it will innovate more than organisations with prior experiences of success.

3 Data, variables and methodology

This paper's empirical analysis is entirely based on data taken from the anonymised *Community Innovation Survey 2008 (CIS 2008) — The harmonised questionnaire* co–ordinated by Eurostat (for a description, see, for instance, Mairesse and Mohnen (2010)) based on the Oslo Manual (OECD/Eurostat, 2005). The Survey, which is in its sixth round, covers the years from 2006 to 2008 and includes the following sixteen countries: Bulgaria, Cyprus, Czech Republic, Germany, Estonia, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Portugal, Romania, Slovakia, Slovenia, Spain.

Firms, with at least 20 employees, answer questions primarily concerned with the nature of technological innovations, the supervision of these innovations (i.e. innovation projects), the internal and external sources (of R&D), the objectives of technological innovation, the sources of information, the cooperation to innovate, and, finally, the obstacles to innovation projects.

The econometric strategy adopted in this paper, mimics the Crepon, Duguet, and Mairesse (1998) model, in which the impact of innovative activity on firm's performance is empirically evaluated. A structural model is proposed, which sequentially estimates an R&D equation (i.e. the firm decides whether to undertake or not R&D, and its intensity) and then the predicted value of the R&D is plugged into a second step to evaluate the patterns of innovative production. This in turn constitutes the input of a, third step, productivity equation.

This paper's estimates follow this model, although they are limited to two steps: the first step, deals with the patterns of abandoned (and subsequently of postponed) innovation, while the second deals with the patterns of production of innovation. The main reasons to follow this procedure are linked, on the one side, to the possibility through this model to (more or less) instrument the estimation procedure to deal with the issues of simultaneity.

The first step is estimated through a one stage Heckman procedure (Heckman, 1979) in order to cope with selection bias. Indeed, as firms answer if they abandoned innovation or not, we collect true zeros that can be either abandoned innovation after having tried to innovate, and zeros due to absence of innovative activity.

The dependent variable ($inaba$) of the first step is constituted by a dummy variable which is 1 if the firm answered yes to the to question n. 4 "During 2006 to 2008, did your enterprise have any innovation activities that did not result in a product or process innovation because the activities were abandoned or suspended before completion?", and 0 if not.

The main co–variates for the first step are: (i) the log of R&D ($lrtot$) expenditure (from question 5.2); (ii) the variable describing where the knowledge to the a firm were coming from: from external producers ($external$), from internal production ($internal$), from joint production ($joint$). As far as the first co–variate is concerned, the expectation is that the more the stock of previous R&D performed, the higher the level of experience of the firm, and thus the less the probability of failure. This should provide an empirical test for hypothesis 1. As for the second co–variate, the intuition is that being able to draw knowledge from external sources, implies that the innovative activity of a firm is more general. Thus, the wider is the pool from which knowledge is taken from, the wider is set of competencies that the firm needs to develop in order to produce a marketable innovation. Hence, the wider the competence set, the lower the probability of failure. This should provide an empirical test for hypothesis 2.

Also vicarious learning is introduced, and is approximated by a variable ($setnaz$) that allocates the total number of abandoned innovation by sectors and by country. Firms are thus exposed to the failures in the same sectors and in the same country, from which they can eventually learn.

Vicarious learning is introduced in order to check if the knowledge flows are introduced directly within the firm (i.e. by direct experience with certain typologies of sources of information that they declare they have used in the past three years) or indirectly (i.e. through the contact with similar experiences that the firm has likely been knowing and from which it can extract useful information). This co–variate should provide additional evidence on hypothesis 2.

Another important co–variate is related to the typology of innovative activity, that is whether the innovation that the firm is trying to produce is new to the market ($newmkt$) or new to the firm ($newfrm$). In these cases, the firm is dealing with high levels of uncertainty, higher than that implied by innovative activity which is not brand new (for instance, embodied in machinery). Thus, in cases of this type a higher probability of failure is linked to these two co–variates.

Finally, a variable for being part of an industrial group (gp) is also introduced. The expectation is that being part of a group has a positive impact on the probability of failure, as, on the one side, having a broader enterprise environment allows more degrees of freedom, and on the other side, the use of innovative activity can be used in a strategic way, thus rendering innovation more prone to abandon a certain innovative project if the group decides to abandon certain avenues of research in favour of others.

The descriptive statistics are presented in Table 1 and the correlation value in Table 2.

Since a Heckman model is used because of the selectivity problem generated by the fact that only a fraction of firms abandon innovation in

Table 1: Descriptive statistics — First step

	mean	sd	min	max
inaba	0.09	0.28	0.0	1
lrtot	10.43	3.43	-0.4	22
newmkt	0.31	0.46	0.0	1
newfrm	0.41	0.49	0.0	1
gp	0.27	0.45	0.0	1
external	0.06	0.23	0.0	1
joint	0.08	0.28	0.0	1
internal	0.25	0.43	0.0	1
N	127338			

Table 2: Correlation — First step

	inaba	R&D	newmkt	newfrm	gp	external	joint	internal
inaba	1							
lrtot	-0.0291***	1						
newmkt	0.104***	0.152***	1					
newfrm	0.0212***	0.245***	-0.122***	1				
gp	0.0952***	0.290***	0.0769***	0.0485***	1			
external	-0.0828***	-0.0685***	-0.0947***	-0.0292***	-0.0711***	1		
joint	0.0359***	0.00148	0.0525***	0.0219***	0.0150*	-0.108***	1	
internal	0.0312***	0.103***	0.164***	0.183***	0.0613***	-0.305***	-0.436***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

a given period, the information used for selection must be independent of those in the previous step. In this case, firms' size ($lturn08$) is used as the relevant variable. Indeed, as the effect of firm's size on the probability to perform R&D and thus on innovativeness is a sort of standard result (as bigger firms are more likely to be willing to incur this type of sunk costs, they are better–off with respect to financing issues and to the associated risks), the literature is in agreement that the probability of abandoning an innovative project does not depend on the mere size of the organisation, but rather on its characteristics. Therefore, it seems legitimate to use size in the selection equation.

The estimation procedure for the second step is a logit that describes the probability of producing an innovation.

The dependent variable ($innotot$) for the second step is a dummy variable which is 1 if the firm answered yes to the question n. 2.1 "During the the three years 2006 to 2008, did your enterprise introduce new or significantly improved goods" and "New or significantly improved services", and 0 if not.

The predicted values taken from the first step ($pred.inaba$) should provide evidence for hypothesis 3. To this co–variate, in order to understand the role of knowledge in producing an innovation two sets of other co–variates are added. One is related to the depth and breadth of the sources of innovation (question 6.1) by building two dummies, one ($depth$) with value 1 if for any value of the answer to the question that described the importance of the information source to be "high", and another one ($breadth$) with value 1 for any positive answer to the same question. The other set of co–variates is related to answers to question 6.3 on the type of co–operation partner by location, and is a dummy variable that takes value 1 for co–operation in 'your country' ($coopYYC$), and outside it ($coopRROW$) and finally a co–variate ($impcoop$) based on the answer to question 6.4, which gives the most valuable type of partnership.

The descriptive statistics are presented in Table 3 and the correlation value in Table 4.

Table 3: Descriptive statistics — Second step

	mean	sd	min	max
innotot	0.48	0.50	0.0	1
depth1	0.25	0.43	0.0	1
breadth1	0.36	0.48	0.0	1
coYYC	0.11	0.31	0.0	1
coRROW	0.06	0.24	0.0	1
impcoop	0.11	0.32	0.0	1
size08	0.48	0.67	0.0	7
N	127338			

Table 4: Correlation — Second step

	innotot	depth1	breadth1	coYYC	coRROW	impcoop	size08
innotot	1						
depth1	0.566***	1					
breadth1	0.715***	0.773***	1				
coYYC	0.341***	0.418***	0.410***	1			
coRROW	0.248***	0.307***	0.284***	0.560***	1		
impcoop	0.349***	0.434***	0.431***	0.919***	0.645***	1	
size08	0.181***	0.186***	0.177***	0.180***	0.192***	0.186***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4 Results

4.1 The probability to fail

The first step of the empirical exercise is presented in Table 5. The Heckman procedure proves to be correct, as the ρ coefficient is significant indicating the presence of a selection bias. Also the LR test (conducted in this particular case on estimate n. 5, but it is the same for all the estimates) of independent equations $(\rho = 0) : \chi^2(1) = 7.19 \; Prob > \chi^2 = 0.0073$, confirms the rejection of the null hypothesis of no correlation, and hence of no selection bias. Finally, the variable used for the selection procedure (turnover in 2008) appears to be statistically significant, and as already discussed represent a proper selection instrument.

From Table 5 it emerges that the probability to abandon an innovative project is negatively related to the level of R&D, which confirms hypothesis 1 about the necessity to build–up a certain level of absorptive capacity also with respect to the abandonment of innovative project. In this sense, the level of R&D has the effect of increasing the stock of knowledge and thus to increase the rate of learning that the organisation can engender also with respect to failure.

Also the capacity to learn from external sources of knowledge has a positive role in decreasing the probability to abandon an innovative project (it is in fact negatively correlated and statistically significant). The same does not hold when the firm builds its knowledge stock both completely and partially internally. In this case, both coefficient are statistically significant but positive.

The same holds true for the other co–variates, that have a positive impact on the abandonment of innovative projects. In particular, a firm, being part of an industrial group, run the risk to abandon an innovative project for strategical reasons, linked to the 'division' of innovative labour within the group. Also, when a firm is engaged in highly innovative projects, that are new to the market and/or new to the firm, the likelihood of abandoning an innovative project increases.

The effects of vicarious learning (Table 6) is a quite interesting example of how the process of learning follows patterns that are far from 'linear'. Indeed, if the variable $setnaz$ is considered by itself, it turns out to be positively related to the probability of abandoning an innovative project and significant. However, once it is interacted with the main co–variates, it remain positive and significant in interaction with being part of an industrial group, looses significance in interaction with external knowledge, and becomes negative if interacted with R&D. This seems to confirm that vicarious learning has a complementary role, which is significant in relation to the stock of existing technological knowledge (the R&D): if we select the firms investing in R&D, then this investment is an element that allows them to enhance (or start) a process of learning. In turn, this gives the possibility to comprehend what happens in the outer environment that is not directly linked to the necessities of the organisation. The opposite holds if a firm is part of an industrial group, which builds its linkages predominantly within the group and thus finalises strategically the learning process, making, so–to–say, the firm blind to the outer environment. Also in this case the Heckman procedure is justified by the statistical tests.

4.2 The probability to innovate

The probability to innovate is shown in Table 7, where the prediction from the previous estimate is plugged into the logistic estimation of the probability to innovate. This predicted value turns out to be positive and significant, confirming hypothesis three on the role of failure in enhancing the innovative capabilities of the organisation through a process of "learning by failing". All the controls have the expected signs, influencing positively the probability to innovate. Hence, cooperative attitude has a positive impact. Size, turns out to be negatively related once depth is considered, but is not significant if breadth is instead considered.

4.3 Postponed innovation

A final interesting test is performed to assess whether there is a different pattern behind postponing an innovative project with respect to definitely abandoning it (Table 8). Also in this case a Heckman procedure is performed (for which also in this case all the statistical test are satisfactory), showing that in this case the higher the R&D, the higher the probability of postponing a project, which seems pretty obvious as the bigger is the organisation experience, the higher the probability that in the process new elements emerge that necessitate further investigations and thus further time. The probability of postponing an innovative project is negatively related to the external and the internal knowledge acquisition procedures, hinting at a dual role of knowledge production, and thus to the fact that accessing new knowledge (independently from inside or outside the organisation) allows to understand and thus to reduce the likelihood of postponing a project. Again, being part of a group and producing innovation new to market/to the firm has a positive impact on postponing innovative project as it may be, on the one side, strategically worth, and on the other side, that tuning with the market might require more second thoughts.

An interesting result emerges from the second step, when both the probability to abandon and to postpone an innovative activity are included (Table 9). Indeed, the impact on the innovative activity of the two types of failure is completely different, with the proper failure (abandoning an innovative project) which enhances the probability to produce an innovation, while the minor failure (postponing an innovative project might result from a rescheduling of the agenda or from minor failures that slow down the production process) have a negative effect on innovative activity.

These results are in accordance with the previously cited literature related to the problems encountered by the Space Shuttle Program (Madsen and Desai, 2010). Indeed, the problems leading to the catastrophic event of the Columbia Shuttle where experienced also previously (by the Atlantis Shuttle), but were considered as minor failures that only postponed the mission, but as they did not impede the success of the mission, they did not engendered a process of revision leading to an innovation (that in this case would have avoided the catastrophic follow–up).

5 Conclusion

This paper has shown that the idea that failing in innovative activity might turn to be a positive element for the firms' organisation is far from absurd. Indeed, if firms are thought as learning organisations, their patterns of learning are surely more solicited is they are put under stress from persistent negative results. Indeed, several articles have consistently shown that within a behavioralist framework, firms typically persist in their organisational routines if they happen to be successful, that is if they happen to correctly represent the outside reality.

If this is correct, then, the only case in which the organisational routine are investigated in order to understand how to improve on their performance is when they fail systematically to produce a certain level of satisfying performance. And this case can only happens when a project fail to deliver a certain performance. Therefore, failure is seen as a crucial element to spur innovative behaviour within the organisation, to revise the operating routines and to change them in radical ways.

This paper has furnished an empirical investigation on two related levels: on the one side, the elements influencing both positively and negatively the failure of an innovative project, and, on the other side, the role of failure in spurring innovative activity. The main results are consistent with the scanty literature on the issue, and stress the positive role of the accumulated experience of the firm and of its degree of generality in dealing with knowledge flows. Moreover, once failure is incorporated into an innovative equation, it turns out to positively affect the production of innovation. If the innovative activity is only postponed (rather than abandoned) the estimation clearly show that the learning activity connected to this other, less radical, way of failing is completely different, and that, as far as its determinants are concerned, the accumulated experience acts positively to postpone innovative projects, as maybe in the process new discoveries slow down the pace of the original project by opening–up new avenues of research. Moreover, the impact on innovation production is negative, as innovation production is affected by these minor failures since they work to enlarge and widens the innovative effort of the firm, thus weakening its efforts.

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Table 5: Heckman regression, probability of abandoning an innovation

	(1)	(2)	(3)	(4)	(5)
lrtot	-0.0103***				-0.0104***
	(-11.32)				(-11.44)
external		-0.0422***			-0.0966***
		(-7.36)			(-10.47)
joint			0.0668***		0.0156*
			(15.74)		(2.24)
internal				0.0557***	-0.0145
				(14.08)	(-1.93)
gp	0.107***	0.0585***	0.0591***	0.0583***	0.104***
	(18.38)	(17.55)	(17.77)	(17.51)	(17.83)
newmkt	0.0979***	0.156***	0.145***	0.136***	0.0943***
	(17.90)	(45.35)	(41.78)	(37.16)	(16.81)
newfrm	0.0467***	0.117***	0.105***	0.0890***	0.0471***
	(8.02)	(35.80)	(32.05)	(24.14)	(7.86)
cons	0.247***	0.0340***	0.0300***	0.0212***	0.266***
	(19.44)	(5.47)	(4.84)	(3.39)	(19.25)
Sector dummies	yes	yes	yes	yes	yes
select					
gp	-0.144***	-0.179***	-0.178***	-0.178***	-0.144***
	(-7.32)	(-10.02)	(-10.02)	(-10.02)	(-7.33)
lturn08	-0.117***	-0.141***	-0.141***	-0.141***	-0.117***
	(-32.41)	(-44.45)	(-44.45)	(-44.45)	(-32.40)
cons	2.922***	3.556***	3.556***	3.555***	2.923***
	(53.87)	(74.96)	(74.97)	(74.97)	(53.86)
athrho					
cons	-0.114***	-0.0444*	-0.0465**	-0.0460*	-0.112**
	(-3.34)	(-2.45)	(-2.61)	(-2.57)	(-3.27)
lnsigma					
cons	-0.830***	-1.066***	-1.068***	-1.067***	-0.832***
	(-186.45)	(-345.23)	(-345.77)	(-345.63)	(-187.15)
N	31825	57092	57092	57092	31825

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Vicarious learning

	(1)	(2)	(3)	(4)
setnaz	0.0000655***	0.0000671***	0.000129***	0.0000596***
	(14.95)	(14.92)	(9.45)	(11.36)
external	-0.0948***	-0.0852***	-0.0939***	-0.0949***
	(-10.31)	(-7.76)	(-10.23)	(-10.33)
setnaz x external		-0.0000193		
		(-1.58)		
lrtot	-0.00895***	-0.00896***	-0.00501***	-0.00897***
	(-9.71)	(-9.72)	(-4.09)	(-9.74)
setnaz x lrtot			-0.00000555***	
			(-4.92)	
group	0.103***	0.103***	0.103***	0.0945***
	(17.72)	(17.71)	(17.59)	(12.91)
setnaz x gp				0.0000144*
				(2.02)
joint	0.0194**	0.0196**	0.0187**	0.0192**
	(2.78)	(2.80)	(2.68)	(2.75)
internal	-0.0211**	-0.0208**	-0.0207**	-0.0212**
	(-2.82)	(-2.78)	(-2.77)	(-2.83)
newmkt	0.0910***	0.0909***	0.0907***	0.0910***
	(16.28)	(16.26)	(16.22)	(16.28)
newfrm	0.0472***	0.0472***	0.0486***	0.0471***
	(7.92)	(7.91)	(8.13)	(7.89)
cons	0.255***	0.254***	0.211***	0.259***
	(18.49)	(18.42)	(12.74)	(18.59)
Sector dummies	yes	yes	yes	yes
select				
gp	-0.144***	-0.144***	-0.144***	-0.144***
	(-7.34)	(-7.34)	(-7.35)	(-7.34)
lturn08	-0.117***	-0.117***	-0.117***	-0.117***
	(-32.36)	(-32.36)	(-32.34)	(-32.35)
cons	2.923***	2.923***	2.923***	2.923***
	(53.79)	(53.79)	(53.75)	(53.78)
athrho				
cons	-0.102**	-0.102**	-0.0974**	-0.101**
	(-2.84)	(-2.84)	(-2.63)	(-2.80)
lnsigma				
cons	-0.837***	-0.837***	-0.837***	-0.837***
	(-188.78)	(-188.79)	(-189.20)	(-188.88)
N	31825	31825	31825	31825

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: Logit estimation of the probability of producing an innovation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
pred. inaba	0.313**	0.308**	0.323**	0.582***	0.580***	0.596***	0.524***
	(3.10)	(3.07)	(3.23)	(5.70)	(5.65)	(5.84)	(5.04)
depth	1.201***	1.253***	1.243***				0.513***
	(12.87)	(13.48)	(13.32)				(4.82)
breadth				4.227***	4.286***	4.315***	3.785***
				(18.90)	(19.19)	(19.37)	(15.88)
coYYC	0.790***			0.530***			0.866**
	(6.41)			(4.17)			(3.28)
coRROW		0.703***			0.312		0.300
		(3.92)			(1.55)		(1.42)
impcoop			0.576***		0.267	0.367**	-0.556*
			(4.64)		(1.91)	(2.87)	(-1.96)
lsize08	-0.229*	-0.214*	-0.210	0.283*	0.284*	0.307*	0.242*
	(-2.13)	(-1.99)	(-1.95)	(2.33)	(2.33)	(2.52)	(1.98)
cons	5.489***	5.607***	5.546***	5.805***	5.820***	5.865***	5.745***
	(11.94)	(12.19)	(12.04)	(12.45)	(12.43)	(12.54)	(12.27)
Sector dummies	yes	yes	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes	yes	yes
N	13081	13081	13081	13081	13081	13081	13081

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: Heckman — Postponed innovation

lrtot	0.0373***
	(43.30)
external	-0.138***
	(-14.26)
joint	0.0165*
	(2.47)
internal	-0.0216**
	(-3.07)
gp	0.0408***
	(6.77)
newmkt	0.0833***
	(14.24)
newfrm	0.0279***
	(4.88)
cons	0.115***
	(8.55)
Sector dummies	yes
select	
gp	0.0934**
	(2.73)
lturn08	0.0251***
	(3.56)
cons	1.328***
	(11.63)
athrho	
cons	3.721***
	(17.04)
lnsigma	
cons	-0.758***
	(-179.37)
N	28276

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9: Logit estimation of the probability of producing an innovation

	(1)	(2)	(3)
pred. inaba	8.017***	8.002***	7.991***
	(9.96)	(9.95)	(9.92)
pred. postp	-1.914***	-2.004***	-1.840**
	(-3.33)	(-3.50)	(-3.23)
depth	0.505***	0.488***	0.502***
	(4.70)	(4.54)	(4.66)
breadth	3.890***	3.797***	3.886***
	(15.90)	(15.44)	(15.86)
coRROW	0.354		
	(1.89)		
coYYC		0.444***	
		(3.40)	
impcoop			0.253
			(1.93)
lsize08	0.295*	0.286*	0.294*
	(2.20)	(2.12)	(2.18)
cons	4.172***	4.148***	4.105***
	(7.83)	(7.80)	(7.72)
Sector dummies	yes	yes	yes
Country dummies	yes	yes	yes
N	13091	13091	13091

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$