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Driving Forces for Research and Development Strategies*

An Empirical Analysis Based on Firm-level Panel Data

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Abstract

This paper investigates empirically different ways to organise R&D within Swiss firms. Based on a longitudinal data set comprising three cross sections (1999, 2002, and 2005) of the Swiss innovation survey, four different types of R&D strategies could have been separated; firms combine in-house R&D with R&D co-operations (coop), or in-house R&D with external R&D (buy), or they conduct in-house R&D, external R&D and R&D co-operations (mixed), or they exclusively rely on in-house R&D (make). It is the aim of this paper to understand what drives firms to go for different strategies. Based on econometric estimations controlling for correlations between the dependent variables and endogeneity among the independent variables it was found that concepts related to the absorptive capacity, incoming spillovers and appropriability, the importance of different knowledge resources, the competitive environment, costs and skill aspects as well as technological uncertainty are essential factors to determine firm's decision to choose a specific way to organise R&D.

1. Introduction

There is a great public interest that firms engage successfully in R&D (Research and Development) activities and thus provide timely solutions to urgent needs. However, as already has been stated by Arrow (1985), information is a very important impact for R&D but it is subject to classical “market failure”. On the one hand this causes a number of public measures to promote private R&D activities and on the other hand firms are conducting several strategies to minimise outgoing spillovers and to maximise incoming spillovers and appropriability. It is the aim of this paper to investigate empirically the main driving and hindering forces for several R&D strategies, using a comprehensive cross-sectional time series data set for Switzerland. This way we hope to understand better why firms choose a certain strategy and how R&D activities can be better promoted from a policy point of view.

So far, empirical analysis about important drivers for R&D strategies mainly focusing on a single overall strategy like R&D co-operations or R&D contracts, and rarely compares differences between determinants for R&D co-operations, R&D contracts (buy) or in-house R&D activities (make). Empirical studies from Cassiman and Veugelers (2002), Belderbos et al. (2004), Bönte and Keilbach (2004), and Dachs et al. (2004) investigated R&D co-operations and found that the meaning of theoretically important factors like incoming spillovers and appropriability depends on the type of co-operation partner. For instance, higher incoming spillovers positively effects the probability to cooperate with public research institution, while better appropriability results in a higher propensity to cooperate with customers/suppliers (see Cassiman, Veugelers 2002). Also R&D contracts (buy) and in-house activities (make) have been subject to several empirical investigations. Beneito (2003), Veugelers and Cassiman (1999) and Veugelers (1997) have detected several determinants that are responsible for a firms decision to make or to buy or both, make and buy innovations. Beneito (2003) found that an intensive competitive environment, a sound financial basis of the firm, large markets and medium firm size are decisive characteristics for in-house organisation of R&D.

The paper at hand investigates empirically differences in theoretically important drivers for the organisation of R&D. Based on comprehensive panel data comprising three cross-sections (Swiss Innovation Survey 1999, 2002, and 2005) we can distinguish between four different strategies, i.e. to run R&D co-operation, to access external R&D, to combine R&D co-operations with external R&D in addition to in-house R&D or exclusively rely on in-house R&D. Our modelling framework helps us to identify important factors for firms’ strategic R&D decisions. We understand that an intensive competitive environment favours in-house R&D and absorptive capacity is essential for external strategies. Knowledge flows from universities or patents are essential for R&D co-operations. ‘Buy’ firms emphasise the knowledge input from consultants, while customers are an important knowledge source for firms exclusively relying on in-house R&D. We also learnt that incoming spillovers are best generated through R&D co-operations. Costs and risk aspects as well as lack of skills are factors that help us to understand firms' decision about R&D organisation as well. Following some theoretical notions we could confirm empirically that uncertainty and technological complexity fosters firms to contact external strategies rather than relying exclusively on in-house R&D. These results help us to better understand why firms follow different R&D strategies and that in turn contributes to improve innovation policy making.

This study contributes to existing empirical investigations in several ways. Firstly, we can investigate jointly several R&D strategies, i.e. R&D co-operation (coop), in-house R&D (make), external R&D (buy), and a combination of 'buy' and 'coop' (mixed). Secondly, we apply a comprehensive panel data set enabling us to conduct several econometric tests on the validity of our results and furthermore the data allows for statements of more general validity. Thirdly, this is the first study on this topic for Switzerland.

This paper is organised as follows. In section 2 we present the modelling framework for our empirical investigation. In section 3 we present our data. In section four we analyse different R&D strategies in greater detail. In section 4 we introduce the main hypotheses and specify the empirical model. Section 5 deals with the empirical methods used in this study. In section 6 we present our estimation results and section 7 contains the summary and the main conclusions.

2. Modelling framework

Economic theory provides us with some notions of what may cause a firm to choose in-house, 'buying' R&D or co-operations as an efficient way to organise their R&D activities. More theoretical investigations emphasise transaction costs (Williamson 1985) or property rights aspects (Hart and Moore 1990) in order to understand firms' decisions to carry out a task internally or to buy it through the market or to engage in any type of co-operation. Both approaches do not fully comply with more specific requirements in the field of R&D. They do not explicitly address important aspects of learning, technological characteristics or environmental factors and thus remain too general for the purpose of this paper. In contrast, Leiponen (2005) – building on the Athey and Schmutzler (1995) model – analyses the relationship between investments in learning and the organisation of R&D (internal, external and/or co-operation) in a changing technological or institutional environment. Meaningful for the purpose of this paper it was found that firms' incentive to invest in learning – that in turn would increase the probability for successful innovations – decreases with the frequency of technological change (technological uncertainty), as it can be seen in the case of information and communication technologies or biotechnology. Lower investments in learning activities also impact the organisation of R&D. Following the reasoning of Leiponen (2005) firms have incentives to organise R&D or innovation activities internally, if the *depreciation of knowledge* is low and thus investments in learning are likely to be profitable. In case knowledge depreciates very quickly then firms have incentives to organise R&D externally (buy) or to co-operate, since their internal learning investments are confronted with high technological uncertainty.

In the empirical oriented literature a number of further factors (environmental and firm specific) can be found that provide us with a better understanding why firms chose a specific R&D strategy.

We know that the *absorptive capacity* (Cohen and Levinthal 1989) of a firm is an important precondition to successfully capitalise on externally generated knowledge, i.e. knowledge generated by competitors, suppliers, customers, and/or public research institutions. Firms with well educated staff and permanent research activities are supposed to have higher absorptive capacity than firms lacking such characteristics. On the one hand this makes them a valuable partner for co-operation and may be a driving force to seek competent co-operation partners. On the other hand Abramovsky et al. (2005) detected some ambiguity in the effect of absorptive capacity on the motivation to co-operate. Firms that better access and understand public available knowledge may benefit from this knowledge for free and might have lower incentives to co-operate. Nevertheless they are also in a position to benefit more from co-operation projects than partners with less internal knowledge and lower absorptive capacity.

The concept of *incoming spillovers* (see Cassiman and Veugelers 2002) indicates the 'amount' of beneficial external knowledge flows for the firm. Certainly, from a firm perspective absorptive capacity is decisive to detect and assess external available knowledge. Thus, this concept is strongly related to the absorptive capacity of a firm. From a more general perspective incoming spillovers are indicated by e.g. the importance of external knowledge sources (competitors, suppliers, customers, science institutions). While incoming spillovers may motivate a firm to seek R&D co-operations, *outgoing spillovers* exert the opposite effect, i.e. they hinder co-operative activities in a way that co-operating firms run a certain risk to cause knowledge spillovers for competitors especially by forming explicit collaboration relationships.

The negative effects of outgoing spillovers are attenuated through several *appropriability mechanisms* that are a third important concept in understanding firms R&D behaviour (see e.g. Spence 1984, D'Aspremont and Jacquemin 1988). However, there is a twofold incentive problem. On the one hand, the existence of imperfect appropriability increases the incentives to acquire external knowledge through R&D co-operation, because of profits resulting from internalising external losses caused by imperfect appropriability (see e.g. De Bondt 1997). On the other hand, imperfect appropriability also increases the incentives to utilise spillovers resulting from R&D investments of co-operation partners and encourages free-riding on external R&D efforts (see e.g. Shapiro and Willig 1990, Greenlee and Cassiman 1999). However, when co-operation partners are not direct competitors (e.g. suppliers of complementary goods), or when one partner is a science institution, imperfect appropriability of the benefits of generated knowledge is not an important issue (see Veugelers and Cassiman 2005). In a strategic way firms seek to limit outgoing spillovers through secrecy measures or greater complexity of developed products and benefit from the lead time on competitors. Furthermore firms try to internalise outgoing spillovers by ensuring property rights (e.g. patents) or through collaborations with potential competitors.

The market environment of a firm as well as some firm-specific circumstances has an influence on the chosen R&D strategy. Beneito (2003) found that especially an intensive competitive environment, large markets, a sound financial basis of the firm and medium firm size influences firms decision in favour of in-house R&D. Sakakibara (1997) investigated motives for R&D co-operations and found that the relative importance of cost sharing motive increases when participants capabilities are homogeneous or projects are large and that the relative importance of the skill sharing motive increases with heterogeneous capabilities. Our data set also provides us with information on important hindering factors for R&D and several control variables, like firm-size or industry affiliation. However these are ad-hoc variables without a specific theoretical reference. Nevertheless it can be instructive to see whether they have some explanation power to distinguish between different strategies and may inspire future theoretical work.

3. Data

Our empirical investigation about the main determinants of distinguished forms of organising R&D activities is based on comprehensive panel data (firm-level) covering three cross-sections, i.e. 1999, 2002 and 2005 (see Donzé 1998 for a detailed description of the firm-panel). The data were collected in the course of three postal surveys using a rather comprehensive questionnaire, which included questions on firm characteristics, the market environment, innovation activities, R&D activities and IPR (Intellectual Property Rights). The surveys were based on a (with respect to firm size) disproportionately stratified random sample of firms with at least 5 employees covering all relevant industries of the manufacturing sector, the construction sector and the service sector as well as firm size classes (on the whole 28 industries and within each industry three industry-specific firm size classes with full coverage of the upper class of large firms).

Table 1 provides us with an overview of the different surveys. We received answers from 1470 firms (33.8%), 1938 firms (39.6%), and 2555 firms (38.7%) for the years 1999, 2002, 2005 respectively. In sum the firm panel covers 5963 observations. Since we had to delete some conflicting, non-plausible answers, 5627 observations could have been used for econometric estimations. Our investigation only focuses on R&D active firms, therefore the panel estimation (see table 2) is based on 2777 observations.

Insert table 1

4. Organisation of R&D: Make, Buy, Co-operations

Modes of organising R&D

An efficient organisation of the R&D process should support the innovative behaviour of a firm and should ease the development of new innovative products and processes. In a more traditional view R&D was conducted **in-house (make)** and followed a rather sequential pattern. After some technological problems could be solved and a prototype was built one was thinking in production, marketing and sales. It was thought that successful innovation requires control on all levels of R&D and especially preventing leakage of information. For a long period in R&D history this model worked very well and led to substantial innovations and still in-house R&D is an important precondition (see Cohen and Levinthal 1990) for other ways to organise R&D processes, like **buying R&D** results from other firms (Beneito 2003, Veugelers and Cassiman 1999), **outsourcing of R&D** activities (Mol 2005), **R&D co-**

operations or looser contacts within **R&D networks** (see Pisano 1990, Arora and Gambardella 1990, Powell et al. 1996) including the more recent phenomenon of **open innovations**. The later combine the communication advantages of newer ICT (information and communication technologies) and innovation activities. This way it is possible to incorporate remote sources of information into the innovation process while keeping transaction costs low (see Chesbrough 2003, or for a case study Dodgson et al. 2006).

Make

Certainly, there is not such as an overall model of "best practice" in organising R&D. Firms adapt to and influence the economic, technological and in some cases regulatory environment (see Schnee 1979) of an industry through their R&D behaviour. Although technology changed and also management models of R&D changed, there are many firms that mainly or exclusively rely on their in-house R&D capabilities (make). From a very general point of view we know that greater transaction costs compared to organisational costs (Williamson 1985) may cause this organisational regime. More concretely, property rights issues, secrecy and the risk that research results can not be appropriated adequately hinder firms to build R&D co-operations or take part in R&D networks. Also knowledge characteristics of the technology field may direct firms' decision towards in-house R&D. This is the case if useful knowledge is dominated by tacit components (e.g. basic research activities). It is impossible to separated it from its bearer and thus difficult to trade and to transfer (see Antonelli 2006). In contrast, codified knowledge (e.g. patents, licenses) allows for more market related transactions. Firms may buy and sell knowledge components and can assemble them in-house. However, very frequently knowledge consists of both tacit and codified components. Following Antonelli (2006) a kind of constructed interactions (technological clubs, coalitions) or more or less tied co-operations (long-term co-operations, sponsored spin-offs) would best address this knowledge environment.

Make and co-operation

In fact, it is very likely that firms **combine** different organisational forms. They conduct R&D in-house and at the same time take part in R&D co-operations or buy (codified) R&D in the technological market. In-house R&D increases the likelihood that a firm is perceived as an interesting R&D partner. It increases the bargaining power for appropriating the research results. It definitely alleviates to scan the environment for adequate partners and helps also to play a central role in an R&D network (Arora and Gambardella 1990). Nevertheless performing in-house R&D is not a sufficient condition for successful R&D co-operations. Caloghirou et al. (2003) found that the chances of successful R&D partnerships increase if cooperative research is close to the in-house R&D efforts of the partner. This way they also clearly signalise their competences in the co-operation (Miles and Snow 1992) that lowers the risk of failure. Caloghirou et al. (2003) further stated that the success rate of R&D co-operations clearly improves if partners make a combined effort to learn and to solve the question about knowledge appropriation. More general, Jarillo (1993) listed a number of rules to overcome possible opportunistic behaviour that cause a likely failure of co-operations. Following the tit-for-tat strategy (A. Rapaport), Jarillo (1993) emphasised that a possible repetition of the co-operation, authentic threat of brake-up, and threat of sanctions in case of short-term collaborations without the perspective of extension, may alleviate opportunistic behaviour. In our firm sample 11% of R&D active firms do both, conducting R&D in-house and run R&D co-operation.

Make and buy

The 'buy' and 'make' option is a valid alternative to R&D co-operations. Veugelers and Cassiman (1999) found that 73% of 439 (responding) innovative firms follow a 'make' and 'buy' strategy and only 10% and 17% pursue exclusively 'buy' or 'make' respectively. In the investigation at hand we only focus on 'make' and 'buy' option and neglect the few firms following only the 'buy' option. Certainly, 'make' and 'buy' strategies and here especially the 'buy' component only works efficiently, if knowledge is available in a codified form and thus workable technology markets exist. One may think in a kind of "off-the-shelf approach", where the innovation process is mainly characterised through combining existing codified technologies. However even codified knowledge e.g. embodied in a patent, maybe subject to some modification in order to fit with existing technological components and that this kind of modification or adaptation to different R&D environments can be challenging and causing significant delay in programmed development times, we have learnt already from Schnee (1979). Nevertheless Veugelers and Cassiman (1999) found that an effective technology protection mechanism and organisational resistance against externally induced change make it more likely that both strategies, 'make' and 'buy' are embarked. If competitors are an important source of information the 'buy' option is more likely.

Empirical evidence based on our firm-level data

Based on our data we could separate four different strategies, i.e. 'make', 'buy', co-operation and a 'mixed' type of strategy comprising firms that follow the 'make' and the 'buy' and the co-operation strategy (see table 2). As to the empirical evidence of the distinguished strategies it was found that 341 firms chose the 'make' strategy to organise their R&D activities in 1999. The absolute figure as well as the share of firms following this strategy increased in 2002 to 455 or 42.3% of the R&D active firms. In 2005 the absolute as well as the relative number decreased to the level of 1999. The 'buy' strategy shows a similar development, i.e. an increase in frequency between 1999 and 2002 and again a drop on the 1999 level in 2005. The share of firms conducting the 'mixed' strategy decreased from 1999 (27.8%) to 2002 (16.9%) and increased to 25.2% in 2005. Essentially the co-operation strategy shows a quite different development. It steadily increased in absolute numbers as well as in relative shares of R&D active firms from 9.7% in 1999 to 10.3% and 12.9% in 2002 and 2005 respectively (see table 2). Certainly it is the purpose of this paper to find out what drives firms' decision to prefer one to the other strategy.

Insert table 2

5. Hypotheses and model specification

Following the modelling framework in chapter two and taking into account some data restrictions, it is possible to formulate the following empirical models.

$$y_{ikt} = \beta_0 + \beta_1 TPOT + \beta_2 HEDU + \beta_3 COPY + \beta_4 NCOMP(2to5) + \beta_5 PCO + \beta_6 NPCO + \beta_7 KCUST + \beta_8 KSUP + \beta_9 KCON + \beta_{10} PATUNI + \beta_{11} KCONSULT + \beta_{12} UNCT + \beta_{13} COST + \beta_{14} LSKILL + \beta_{15} LPSUP + \beta_{16} LEMPL + \beta_{17} MANU + \beta_{18} SERV + \beta_{19} TDUM02 + \beta_{20} TDUM05 + e_{it}$$

Our dependent variables (y_{ikt}) represents the R&D strategy $(k = 1.....4)$ of R&D active firm i in time t (1999, 2002 or 2005). Like mentioned above four different strategies could be distinguished, i.e. make, buy, co-operation, and a mixed one. The strategies are represented through binary variables indicating whether a firm follows a certain strategy or not (1/0). Certainly, firms that follow a buy strategy are also conducting in-house R&D (make). The same is true for co-operation and the mixed strategy. Firms with R&D co-operations also conduct in-house R&D but they do not apply the buy or mixed strategy. Firms choosing the mixed strategy have in-house R&D, buy activities and co-operate with R&D partners. At time (t) a firm is assigned to a single type of strategy, although all firms have in-house R&D activities (see table 3).

Insert table 3

The vector of independent variables (see table 4) consists of a variable representing the complexity of external knowledge that might be useful for R&D activities and innovations. TPOT may be also an indicator for the importance of incoming spillovers for the R&D activities of a firm (see Veugelers and Cassiman 2002). We assume that a greater technological potential (TPOT) goes along with greater importance of buy, coop, or the mixed R&D strategy.

HEDU (share of employees with higher education) represents the human capital of a firm and thus indicates its absorptive capacity (see Cohen and Levinthal 1989). It is assumed that a greater share of HEDU makes it more likely that a firm conducts the buy, coop or mixed strategy rather than the make strategy.

COPY indicates how easy it is to copy innovations. If it is very easy to copy innovations it is assumed that firms emphasise secrecy and other appropriability mechanisms (e.g. patents) in order to protect their new ideas and products and prevent leakages from outgoing spillovers. Thus, it can be assumed that outgoing spillovers or a greater value for COPY would prevent firms from taking part in loose co-operations or follow a mixed or buy strategy. Instead it could be assumed that firms focus on in-house R&D. However, knowing that it is easy to copy innovations might be an incentive to co-operate as well, especially if the number of potential competitors is quite limited. This way one can be sure that the costs for innovations are shared too not only the benefits. Co-operation with competitors is one possibility to internalise – at least partly – outgoing spillovers. Thus, it is assumed that COPY might be insignificant or even show a positive sign for R&D co-operations.

Insert table 4

NCOMP and PCO or NPCO represent the market environment. NCOMP2 to NCOMP5 tells us the number of essential competitors in the firm's main market. Following Beneito (2003) it is assumed that a more competitive environment increases the likelihood that firms follow the make strategy. PCO (price competition) and NPCO (non-price competition) indicate the importance of the price or non-price parameters, like quality or service. We do not have any a priory assumption for the effects of these variables on R&D strategies.

COST represents the costs of innovations. Following Sakakibara (1997) it is assumed that higher costs should encourage firms to conduct R&D co-operations instead of the make or buy strategy. Following this notion one can also assume that lack of skilled people (LSKILL), or lack of public support (LPSUP) may also force firms into collaborations.

We could apply several variables representing the importance of distinguished external knowledge resources. In addition to their single meaning for the chosen strategy, they should also indicate the amount of incoming spillovers (see Cassiman and Veugelers 2002). It is assumed that a greater variety of knowledge resources increases the likelihood of incoming spillovers and thus encourages firms to follow external oriented R&D strategies. It is assumed that especially the mixed strategy should be driven by the importance of several external knowledge resources.

KCUST (knowledge resource customers), KSUP (knowledge resource suppliers), KCON (knowledge resource concern internal), PATUNI (knowledge resource patents and/or universities), and KCONSULT (knowledge resource consultant firms) represent very important external and internal knowledge resources for the R&D activities of a firm. It is assumed that strategies focusing on in-house organisation of R&D activities do not bring importance to external knowledge resources. In contrast firms are forced to external strategies (coop, buy, mixed) if they appreciate supplies, customers, universities etc. as valuable knowledge resources. Thus we expect a positive impact of these resources on external strategies and a negative on as to the make strategy.

UNCT represents the degree of technological uncertainty of the firms R&D projects. Following Leiponen (2005) we would assume that firms confronted with greater technological uncertainty would be more likely to conduct R&D co-operations or the mixed strategy. Thus, it is assumed that UNCT has a positive impact on the buy, coop and mixed strategy and a negative impact on the make one.

Certainly, we have some dedicated control variables in our function, LEMPL (number of employees) represents the firm size and MANU (manufacturing sector), SERV (service sector) and CONSTR (construction sector; reference sector) control for sector affiliation of a firm, and we also apply three time dummies TDUM99 (reference), TDUM02, TDUM05 for the years 1999, 2002 and 2005 respectively.

6. Econometric procedure and estimation results

Econometric procedure

Since we are focusing on R&D active firms and obviously not all of our panel firms are active in R&D, there is a risk of a selectivity bias. A Heckman procedure (see Heckman 1976) was applied to detect a possible bias. Following Wooldrige (2002) the selection equation and the strategy equation are identically specified with the difference of one variable. The selection equation has one variable more. In fact for all dependent variables no selection bias could have been detected[1]. The chi2 test on the correlation of the two error-components (for the selection specification and for the intensity specification) was not significant. The Wald test of independent equations (rho = 0) shows prob. > chi2 = 0.1895, prob. > chi2 = 0.3177, prob. > chi2 = 0.9185, and prob. > chi2 = 0.1304 for the make, buy, coop and mixed strategy respectively. The Heckman-calculations are not presented in this paper.

Furthermore the results are also not affected by multicollinearity (see correlations in table A1). In order to investigate a possible autocorrelation bias, the Wooldridge test for autocorrelation in panel data was applied (see Wooldrige 2002, p. 282–283) using STATA software; no significant serial correlation could have been detected (H0: no first-order autocorrelation, prob. > F = 0.2500, prob. >F = 0.6258, prob. > F = 0.7130, prob. >F = 0.7063 for the make, buy, coop and mixed strategy respectively)[2].

[1] STATA software has been used (heckprob procedure)
[2] Estimations are not shown in this paper.

We applied a multivariate probit estimator, since the disturbances of our strategy regressions (make, buy, coop, and mixed) are correlated. Following Greene (2003, pp. 710) the multivariate probit is an efficient estimator in this case. The estimation results (based on the pooled data) are presented in table 5.

Endogeneity

Endogeneity could be a further source of inefficient estimations. Based on the results of López (2006) we supposed the following variables to be endogenous, i.e. variables representing the knowledge resources (KSUP, KCUST, KCON, KCONSULT, PATUNI), the variable representing the technological potential (TPOT), the variable for appropriability (COPY), and the cost variable (COST). We built a number of instruments in order to apply the Wooldridge (2002, p. 472) test for endogeneity as implemented by STATA (H0: residuals of the structural form of the equation and the reduced form of the equation are uncorrelated) and found in the case of the coop and mixed strategy endogenous variables. In the coop equation KSUP and KCON turned out to be endogenous and in the case of mixed TPOT, PATUNI, and KCONSULT were endogenous. Please notice that in the 'make' and 'buy' equation we could not detect endogenous variables. As to the validity of our instruments please refer to table A2 and A3. All instruments are valid, i.e. they are not correlated with the dependent variable of the structural equation and they are not correlated with the residuum, but they are significantly correlated with the endogenous variable (see table 6 and 7) and they pass the joint significant test.

In order to consider endogeneity we again applied multivariate probit estimations following the procedure of Greene (1998). In this paper Greene suggests a simpler way to take into account the endogenous character of variables. Since we found endogeneity in two (coop, mixed) out of four strategy estimations, the Greene (1998) way to consider endogeneity is conducted only for the 'coop' and 'mixed' strategies (see table 6 and table 7).

Estimation results

Based on the multivariate probit procedure considering endogeneity of some factors we present the following results (see table 5, 6 and 7):

The competitive environment impacts firm's decision on its R&D strategy in favour of the 'make' strategy. A more intensive competitive environment - indicated by a greater number of important competitors (NCOMP) - increases the likelihood that a firm focuses on internal R&D activities rather than seeking for external R&D results or pursuing the 'mixed' strategy. This result is supported by all economic procedures as to the 'make', the 'buy', and the 'mixed' form. In the 'coop' case we see that the endogenous character of KSUP may bias the results slightly, since the multivariate probit model considering endogeneity in the 'coop' equation (see table 6) shows that intense competition is also fostering co-operations. However the differences between the table 5 and table 6 (considering endogeneity) are minor; the coefficient of NCOMP5 rises from 0.153 to 0.181 (std. error remains practically the same).

In case the market environment is characterised through non-price competitive factors, like quality or service, firms prefer the ‘buy’ option rather than the ‘make’ option or ‘mixed’ option if TPOT is endogenised. In contrast, if price is the relevant competitive factor, firms tend to follow the ‘coop’ strategy.

Incoming spillovers are a further factor that influences firm’s decision about its R&D strategy. TPOT represents the importance of incoming spillovers. If the technological base of a firm has great technological potential, it is more likely that the firm runs R&D co-operations rather than following a ‘buy’ strategy in order to make use of incoming spillovers for their own R&D activities. These results are based on the multivariate probit estimation (table 5). Considering the endogeneity of TPOT in the ‘mixed’ equation (table 7) shows that TPOT is not significant for the ‘mixed’ strategy anymore. Anyway TPOT remains significant in the endogenised ‘coop’ equation (table 6). Thus we keep with our result stating that great technological potential goes along with the ‘coop’ strategy.

External knowledge resources may also act as an indicator for the importance of incoming spillovers. In addition they tell us which type of knowledge is considered as useful by a firm. In case customers are seen as an important source for R&D activities, firms are likely to follow the ‘make’ strategy and it is very unlikely that they pursue a ‘mixed’ approach. PATUNI is the most important knowledge source for firms conducting the ‘coop’ strategy and the ‘mixed’ strategy. ‘Make’ firms predominantly do not rely on university knowledge or identify patents as useful knowledge resources. Furthermore ‘make’ as well as ‘coop’ firms do not appreciate consultants as important knowledge resources.

The advice of consulting firms is more frequently appreciated by firms conducting the ‘buy’ and by firms following the ‘mixed’ strategy. The positive effect on the ‘mixed’ strategy is slightly weakened if we control for endogeneity. Universities and patents as well as concern internal knowledge flows are important resources for firms pursuing the ‘mixed’ strategy based on the multivariate estimation.

Absorptive capacity is another distinguishing factor. Firms with greater absorptive capacity are more likely to pursue the ‘mixed’ strategy and they are hardly to be found among the firms following a ‘make’ strategy. This indicates that higher absorptive capacity as measured by HEDU goes along with external R&D strategies. Appropriablity is hardly a discriminating factor. COPY - our proxy for appropriability - does not show any significant sign. Only the coefficient in the ‘buy’ equation is next to the significant threshold of 10% indicating that if it is easy to copy research results, firms refrain from the ‘buy’ strategy.

Technological uncertainty was expected to make external R&D strategies more likely than internal ones. In fact, firms confronted with UNCT more often pursuing the ‘mixed’ strategy rather than the ‘make’ one. Thus, the theoretical statement of Leiponen (2005) can be confirmed empirically. However the results for the ‘mixed’ strategies turn out to be significant only if endogeneity is considered.

Firms complaining about too high costs of innovation (COST) are less likely to be found in the ‘coop’ category This effect results if we consider endogeneity in the ‘coop’ equation (see table 6).

Especially firms pursuing the ‘make’ strategy are less often complaining about lack of skills in R&D (LSKILL) based on the multivariate probit estimations. Firms conducting the ‘coop’ strategy emphasise lack of public support (LPSUP).

Positive size effects could be only detected in the ‘mixed’ category and negative size effects could be found in the ‘make’ category. Firms affiliated to the manufacturing sector are less likely to follow the ‘make’ strategy and firms in the service sector are more likely to follow the ‘coop’ strategy compared to firms in the construction sector (reference).

In sum we arrive at a rather heterogeneous picture of distinguishing factors. We saw that a competitive environment suggests internal R&D organisation rather than external R&D activities. Non-price competition in the case of ‘buy’ and technological uncertainty in the case of ‘mixed’ as well as price competition in the case of ‘coop’ suggests external R&D activities. With the exemption of customers, external knowledge resources are more appreciated by firms following the ‘buy’, ‘coop’ or ‘mixed’ option rather than the ‘make’ one. Lack of public support and high costs of innovations are put forward more frequently by firms following the ‘coop’ strategy that firms focusing on the internal one. A higher absorptive capacity may be also found in firms with a ‘mixed’ strategy rather than within firms pursuing the ‘make’ option.

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7. Summary and Conclusions

This paper investigates driving factors for four different ways to organise R&D. We could distinguish firms that exclusively conduct R&D in-house from firms that additionally ‘buy’ R&D. Moreover we found firms that complemented in-house R&D with R&D co-operations and it was also possible to find a group of firms that had in-house R&D, R&D co-operations and also buy R&D. Our search for driving and distinguishing factors for R&D strategies was guided by a conceptual framework; it mainly stated that technological uncertainty or knowledge characteristics, the absorptive capacity, incoming and outgoing spillovers together with appropriability mechanisms and cost as well as necessary skills impact firms' decision for one of the four ways to organise R&D. Rather than a closed theory of driving forces for R&D strategies, we have a patchwork of single valuable concepts. This way we aim to get some valuable insights into the changing importance of one or the other concept for decisions on R&D strategy; we wanted to know if our conceptual framework helps us to understand why firms conduct the 'make', the 'buy', the 'coop', or the 'mixed' strategy based on a comprehensive longitudinal data, comprising three cross sections (1999, 2002, and 2005). And in fact we found a number of distinguishing factors.

Based on econometric estimations it becomes clear that we can identify factors that are responsible for firms' strategic choice about how to organise their R&D. We see that our conceptual framework helps us to identify essential parameters for distinguishing R&D strategies. These results should increase our understanding of the innovation behaviour of firms and help us to better foresee the likely consequences of economic policy making (e.g. in the field of competition policy or innovation policy).

We have learnt that a greater number of immediate competitors indicating a more intense competitive environment according to market theory direct firms' decision to conduct R&D exclusively in-house. In contrast, in-house R&D is complemented by R&D co-operation or/and by R&D contracts if firms see themselves confronted with a rather low number of essential competitors and the market structure is oligopolistic rather than polypolistic. We also learnt that incoming spillovers are best generated through R&D co-operations. Clearly, especially in specialised markets, with a few numbers of competitors, incoming spillovers from other firms or research institutions are important. This way firms maintain the market overview and are most likely well informed about competitors R&D developments.

It also could be confirmed that the absorptive capacity is more important for external R&D. Firms' need a strong knowledge base to absorb R&D activities and information flows from other firms or institutions. Thus, it is also not surprising that essentially firms' conducting the 'mixed' strategy show a strong knowledge base. It also becomes clear that 'coop' and 'mixed' firms assess knowledge flows from universities essential for their R&D activities. In contrast, the 'buy' strategy seems to be very frequently conducted by firms that rely heavily on the advice of consulting firms. 'Buy' firms emphasise less frequently the importance of knowledge from universities or patents. The relatively lower absorptive capacity of firms that exclusively rely on in-house R&D comes along with the fact that customers are the most important knowledge source. They might have problems to identify the meaning of external research knowledge for their own R&D activities or their research field is very specific and they fear information leakage and competitive disadvantages. They are also exposed to intensive competition, they do not suffer from lack of skills and they do not complain about lacking public funding. These facts point at firms with relative autonomous research activities focusing on strong/intense customer relationships and innovations maybe less technological oriented. Some R&D active firms in the construction, low-tech or traditional service sector may fit with this profile.

Technological complexity is a further characteristic that help us to understand the R&D behaviour of firms. Following Leiponen (2005) we can empirically confirm that greater technological complexity directs firms to conduct external R&D strategies ('mixed'). Especially a high depreciation of knowledge and risky investments in learning are some reasons for this theoretical as well as empirical fact.

For the future research it would be interesting to investigate whether firms innovation or overall economic performance is affected by the way R&D is organised. Furthermore it would be beneficial to know if our results are country specific or if they are shared by other countries as well. Certainly, some theoretical work points at a more general validity. However it would be interesting to see some empirical confirmation based on longitudinal data. Some shortcomings of this paper can be detected as well. First of all and most importantly, we learnt that endogeneity is a great challenge in empirical work and especially in the field of R&D or innovation equations. The results of the instrumented equations are strongly related to the 'quality' of the instruments. Certainly, they have to fulfil the econometric criteria but furthermore they should explain the endogenous variable very well (high Rsquare). To meet both, validity and explanatory power is very difficult in empirical data, especially if one takes into account the permanent lack of valid instruments.

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Table 1: Number of observations (1996, 1999, 2002)

	Observations			
	t(1-3)	t1 (1999)	t2 (2002)	t3 (2005)
Manufacturing	*3192*	*822*	*1108*	*1262*
Food/Beverage	253	62	84	107
Textile	101	30	40	31
Clothing/Leather	33	14	9	10
Wood processing	110	29	40	41
Paper	81	20	32	29
Publishing	202	56	75	71
Petroleum/Chemicals	216	52	70	94
Rubber/Plastic product	149	41	60	48
Other non-metallic mineral products	123	36	43	44
Metal	73	19	24	30
Metalworking	418	110	156	152
Machinery	554	136	188	230
Electrical machinery	157	39	48	70
Electronic/Instruments	321	69	110	142
Watches	113	39	28	46
Vehicles	63	14	22	27
Other Manufacturing	114	31	44	39
Energy/Water	111	25	35	51
Construction	*591*	*163*	*167*	*261*
Services	*2180*	*485*	*663*	*1032*
Wholesale	481	128	154	199
Retail trade	372	72	122	178
Hotels and restaurants	197	38	69	90
Transport/Telecommunication	316	78	87	151
Banking/Insurance	237	36	59	142
Real estate / Renting	31	6	10	15
Computer services	124	26	37	61
Business services	385	94	109	182
Personal services	37	7	16	14
Total	**5963**	**1470**	**1938**	**2555**

Table 2: R&D active firms and frequency (share) of make, buy, co-operation and mixed strategies respectively (1999, 2002, and 2005)

Years	*R&D*	*Make*	*Buy*	*Co-operation*	*Mixed*
1999	909	341 (37.5%)	227 (25.0%)	88 (9.7%)	253 (27.8%)
2002	1075	455 (42.3%)	327 (30.4%)	111 (10.3%)	182 (16.9%)
2005	989	328 (33.2%)	284 (28.7%)	128 (12.9%)	249 (25.2%)
Total	**2973**	**1124** **(37.8%)**	**838** **(28.2%)**	**327** **(11.0%)**	**684** **(23.0%)**

Due to missing values in some of our explanatory variables we could use 2777 observations instead of 2973.

Table 3: Dependent variables

Dependent Variables	*Description*
Make	Dummy variable; 1 represents firms that conduct in-house R&D exclusively, 0 represents firms that combine in-house R&D with other types of strategies, e.g. buy, co-operation, mixed.
Buy	Dummy variable; 1 represents firms that conduct in-house R&D and buy R&D from other firms/organisations, 0 represents firms that solely have in-house R&D or combine in-house R&D with R&D co-operations or follow the mixed strategy.
Coop	Dummy variable; 1 represents firms that conduct in-house R&D and they have R&D co-operation(s) with other firms or organisations, 0 represents firms that solely have in-house R&D or combine in-house R&D with buying R&D from other firms/organisations or follow the mixed strategy.
Mixed	Dummy variable; 1 represents firms that conduct in-house R&D and buy R&D from other firms/organisations and have R&D co-operations with other firms/organisations, 0 represents firms that solely conduct in-house R&D or follow the buy or coop strategy.

Table 4: Determinants of firm's R&D strategy (make, buy, coop or mixed)

Determinants	*Description*	*Impact on (buy, coop or mixed)*
Absorptive capacity		
HEDU	Share of employees with tertiary-level vocational education (universities, universities of applied sciences, other business and technical schools at tertiary level)	+
Outgoing spillovers (appropriability)		
COPY	Easiness to copy innovations. Firms were asked to assess the easiness to copy there innovations on a five-point Likert-scale (1 hard to copy …. 5 easy to copy). In case a firm gives 4 or 5, COPY receives 1 otherwise 0 (binary variable).	?
Incoming Spillovers (technological potential, knowledge resources)		
TPOT	General technological potential, i.e. scientific and technological knowledge relevant to the firm's R&D or innovation activity (on a five point Likert-scale; 1 very low, 5 very high technological potential). In case a firm assesses the technological potential high, i.e. four or five on the Likert-scale, TPOT receives a 1 otherwise 0 (binary variable).	+
KCUST	Knowledge resource customer. Based on a five-point Likert scale firms assess the importance of customers as an external knowledge res. (1 not important ….. 5 very important). In case a firm gives 4 or 5, KCUST receives 1 or otherwise 0 (binary variable)	+
KSUP	Knowledge resource supplier. Based on a five-point Likert scale firms assess the importance of supplier as an external knowledge res. (1 not important ….. 5 very important). In case a firm gives 4 or 5, KSUP receives 1 or otherwise 0 (binary variable)	+
DIFF_KSUP	Industry mean of importance of knowledge resource supplier. Industry means of the assessment of importance of supplier as an external knowledge resource (1 not important … .. 5 very important).	Instrument
DIFF_KCUST	Industry mean of importance of knowledge resource customer. Industry mean of the assessment of importance of customer as an external knowledge resource (1 not important … .. 5 very important).	Instrument
KCON	Knowledge resource own concern. Based on a five-point Likert scale firms assess the importance of the own concern as a knowledge res. (1 not important ….. 5 very important). In case a firm gives 4 or 5, KCON receives 1 or otherwise 0 (binary variable)	+
PATUNI	Patents or universities as knowledge resource. Based on a five-point Likert scale firms assess the importance of universities and of patents as an external knowledge res. (1 not important ….. 5 very important). In case a firm gives 4 or 5 to either patents or universities, PATUNI receives 1 or otherwise 0 (binary variable)	+
KCONSULT	Knowledge resource consulting firms. Based on a five-point Likert scale firms assess the importance of consulting firms as a knowledge resource (1 not important ….. 5 very important). In case a firm gives 4 or 5 to either patents or universities, PATUNI receives 1 or otherwise 0 (binary variable)	+

Table 4: continued

Competitive environment		
NCOMP	Concentration measure based on the number of principal competitors in the world (product) market (dummy variables: CONC1 = less than 5; CONC2 = 5 to 10; CONC3 = 11 to 15; CONC4 = 16 to 50; CONC5 = more than 50. CONC1 is the reference group.	-
PCO	Intensity of price competition in the product market	?
NPCO	Intensity of non-price competition in the product market (e.g. quality, service)	?
Technological Uncertainty		
UNCT	Based on a five-point Likert scale firms assess the importance of technological uncertainty for their innovation behaviour (1 not important … 5 very important). In case a firm marks 4 or 5, UNCT receives 1 or otherwise 0 (binary variable)	+
Selected obstacles		
COST	Based on a five-point Likert scale firms indicate the importance of high costs for their innovation behaviour (1 not important … 5 very important). In case a firm marks 4 or 5, COST receives 1 or otherwise 0 (binary variable)	+
LSKILL	Based on a five-point Likert scale firms indicate whether lack of R&D staff hinder their innovation activities (1 not important … 5 very important). In case a firm marks 4 or 5, LSKILL receives 1 or otherwise 0 (binary variable)	+
LPSUP	Based on a five-point Likert scale firms indicate how important would be public support for their innovation behaviour (1 not important … 5 very important). In case a firm marks 4 or 5, LPSUP receives 1 or otherwise 0 (binary variable)	+
OORG	Based on a five-point Likert scale firms indicate whether they have difficulties to organise their innovation process (1 no difficulties … 5 great difficulties)	Instrument
OTAX	Based on a five-point Likert scale firms indicate whether difficulties are caused by taxes (1 no difficulties … 5 great difficulties)	Instrument
OREG	Based on a five-point Likert scale firms indicate whether difficulties are caused by market regulation (1 no difficulties … 5 great difficulties)	Instrument
OFUND	Based on a five-point Likert scale firms indicate whether difficulties are caused lack of third party funding (1 no difficulties … 5 great difficulties)	Instrument
Control variables		
LEMPL	The size of firms is measures through the number of employees expressed in full-time equivalents (LEMPL).	+ (Instrument)
MANU	A firm is affiliated to the manufacturing sector (binary variable). Reference sector = CONSTR	+ (Instrument)
SERV	A firm is affiliated to the service sector (binary variable). Reference sector = CONSTR	+ (Instrument)
TDUM99, TDUM02, TDUM05	Time dummies for the years 1999 (TDUM99), 2002 (TDUM02), and 2005 (TDUM05). TDUM99 is the reference.	-

Table 5: Estimation results (pooled data; multivariate probit)

Multivariate probit (MSL, # draws = 5) — Number of obs = 2777

Wald chi2(100) = 533.21

Log pseudolikelihood = - 4622.3254 — Prob > chi2 = 0.0000

(Std. Err. adjusted for 1992 clusters in UBANR)

	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z
	make			**buy**			**coop**			**mixed**		
TPOT	-0.088	0.0544	0.104	-0.092	0.0571	0.107	0.160	0.0698	0.022	0.177	0.0660	0.007
HEDU	-0.007	0.0017	0.000	0.001	0.0018	0.473	-0.001	0.0022	0.541	0.007	0.0021	0.000
COPY	0.048	0.0596	0.420	-0.104	0.0637	0.104	0.097	0.0764	0.202	-0.031	0.0720	0.666
NCOMP2	0.091	0.0624	0.143	-0.158	0.0651	0.015	0.046	0.0817	0.575	0.040	0.0752	0.592
NCOMP3	0.134	0.0827	0.105	-0.033	0.0852	0.701	0.054	0.1055	0.610	-0.242	0.1106	0.029
NCOMP4	0.099	0.0825	0.229	-0.229	0.0863	0.008	0.173	0.1056	0.101	0.015	0.0966	0.880
NCOMP5	0.314	0.0839	0.000	-0.287	0.0912	0.002	0.153	0.1066	0.152	-0.207	0.1067	0.053
PCO	-0.064	0.0555	0.246	0.022	0.0585	0.711	0.173	0.0753	0.021	-0.064	0.0683	0.348
NPCO	-0.117	0.0503	0.020	0.091	0.0518	0.080	-0.013	0.0655	0.840	0.019	0.0605	0.758
KCUST	0.091	0.0511	0.073	0.024	0.0524	0.642	-0.054	0.0653	0.412	-0.171	0.0658	0.009
KSUP	0.059	0.0546	0.277	-0.011	0.0570	0.841	-0.021	0.0703	0.761	-0.064	0.0680	0.350
KCON	-0.053	0.0594	0.371	-0.060	0.0626	0.339	0.055	0.0776	0.482	0.161	0.0767	0.036
PATUNI	-0.463	0.0585	0.000	-0.024	0.0604	0.694	0.149	0.0752	0.047	0.442	0.0646	0.000
KCONSULT	-0.414	0.0832	0.000	0.343	0.0840	0.000	-0.303	0.1181	0.010	0.232	0.0978	0.018
UNCT	-0.285	0.0781	0.000	0.120	0.0800	0.132	0.111	0.1029	0.279	0.131	0.1141	0.252
COST	-0.082	0.0531	0.124	0.076	0.0559	0.174	-0.114	0.0712	0.110	0.028	0.0659	0.675
LSKILL	-0.109	0.0645	0.091	0.047	0.0644	0.462	-0.082	0.0861	0.340	0.068	0.0745	0.364
LPSUP	-0.157	0.0887	0.076	-0.021	0.0973	0.833	0.238	0.1098	0.030	0.029	0.0983	0.765
LEMPL	-0.124	0.0202	0.000	0.026	0.0198	0.185	-0.024	0.0245	0.318	0.116	0.0266	0.000
MANU	-0.261	0.1335	0.050	0.041	0.1382	0.765	0.304	0.2041	0.136	0.155	0.1598	0.332
SERV	-0.085	0.1397	0.541	-0.050	0.1444	0.727	0.402	0.2113	0.057	-0.070	0.1698	0.679
TDUM02	0.085	0.0574	0.141	0.146	0.0589	0.013	0.032	0.0797	0.685	-0.363	0.0744	0.000
TDUM05	-0.190	0.0628	0.002	0.108	0.0654	0.098	0.195	0.0826	0.018	-0.073	0.0726	0.314
CONS.	0.840	0.1762	0.000	-0.750	0.1803	0.000	-1.763	0.2508	0.000	-1.456	0.2190	0.000
/atrho21	-0.608	0.0309	0.000									
/atrho31	-0.309	0.0262	0.000									
/atrho41	-0.467	0.0377	0.000									
/atrho32	-0.117	0.0194	0.000									
/atrho42	-0.357	0.0317	0.000									
/atrho43	-0.092	0.0256	0.000									
rho21	-0.543	0.0218	0.000									
rho31	-0.299	0.0239	0.000									
rho41	-0.436	0.0305	0.000									
rho32	-0.116	0.0191	0.000									
rho42	-0.342	0.0280	0.000									
rho43	-0.092	0.0254	0.000									

Likelihood ratio test of rho21=rho31=rho41=rho32=rho42=rho43=0

chi2(6) =1868.06; Prob>chi2=0.0000

Table 6: Multivariate Probit Model to consider endogeneity in the COOP equation

Multivariate probit (MSL, # draws = 5) — Number of obs = 2777

Wald chi2(100) = 217.22

Log pseudolikelihood = - 4107.6661 — Prob > chi2 = 0.0000

(Std. Err. adjusted for 1992 clusters in UBANR)

	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z
	coop			**KSUP**			**KCON**		
TPOT	0.141	0.0693	0.042						
HEDU	-0.001	0.0023	0.586						
COPY	0.106	0.0773	0.171						
NCOMP2	0.062	0.0824	0.455						
NCOMP3	0.057	0.1078	0.600						
NCOMP4	0.167	0.1079	0.122						
NCOMP5	0.181	0.1061	0.089						
PCO	0.189	0.0765	0.014						
NPCO	-0.009	0.0657	0.890						
KCUST	-0.043	0.0649	0.512						
KSUP	0.116	0.1371	0.399						
KCON	-0.019	0.1372	0.891						
PATUNI	0.161	0.0741	0.030						
KCONSULT	-0.342	0.1195	0.004						
UNCT	0.114	0.1015	0.262						
COST	-0.127	0.0710	0.074						
LSKILL	-0.065	0.0878	0.458						
LPSUP	0.241	0.1086	0.026						
LEMPL	-0.022	0.0252	0.390	0.046	0.0185	0.012	0.223	0.0212	0.000
MANU	0.302	0.2030	0.136	-0.017	0.1282	0.893	-0.178	0.1594	0.263
SERV	0.420	0.2112	0.047	-0.349	0.1358	0.010	-0.014	0.1537	0.925
TDUM02	0.069	0.0798	0.389						
TDUM05	0.240	0.0834	0.004						
OORG				0.074	0.0254	0.004			
OREG				0.065	0.0239	0.006	0.047	0.0265	0.078
DIFF_KCUST							1.007	0.3273	0.002
CONS.	0.840	0.1762	0.000	-0.828	0.1656	0.000	-2.135	0.2053	0.000
/atrho21	-0.608	0.0309	0.000						
/atrho31	-0.309	0.0262	0.000						
/atrho32	-0.117	0.0194	0.000						
rho21	-0.543	0.0218	0.000						
rho31	-0.299	0.0239	0.000						
rho32	-0.116	0.0191	0.000						

Likelihood ratio test of rho21=rho31=rho32=0

chi2(3) =25.0198; Prob>chi2=0.0000

Table 7: Multivariate Probit Model to consider endogeneity in the MIXED equation

Multivariate probit (MSL, # draws = 5) Number of obs = 2777

Wald chi2(100) = 417.01

Log pseudolikelihood = - 5559.622 Prob > chi2 = 0.0000

(Std. Err. adjusted for 1992 clusters in UBANR)

	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z
	mixed			**TPOT**			**PATUNI**			**KRCONSULT**		
TPOT	0.108	0.1351	0.422									
HEDU	0.007	0.0021	0.000									
COPY	-0.017	0.0670	0.796									
NCOMP2	0.059	0.0714	0.409									
NCOMP3	-0.208	0.0977	0.033									
NCOMP4	0.039	0.0959	0.685									
NCOMP5	-0.226	0.0960	0.018									
PCO	-0.051	0.0641	0.429									
NPCO	0.036	0.0579	0.539									
KCUST	-0.142	0.0579	0.014									
KSUP	-0.043	0.0616	0.488									
KCON	0.135	0.0665	0.042									
PATUNI	0.577	0.1762	0.001									
KCONSULT	0.393	0.2248	0.081									
UNCT	0.152	0.0881	0.085									
COST	0.071	0.0596	0.235									
LSKILL	0.101	0.0704	0.152									
LPSUP	0.040	0.1026	0.695									
LEMPL	0.123	0.0258	0.000	0.098	0.0189	0.000	0.160	0.0214	0.000	0.161	0.0239	0.000
MANU	0.109	0.1769	0.538	0.268	0.1375	0.051	0.254	0.1504	0.091	-0.205	0.1619	0.205
SERV	-0.098	0.1838	0.595	-0.140	0.1650	0.397	-0.331	0.1836	0.072	0.030	0.1943	0.876
TDUM02	-0.347	0.0640	0.000									
TDUM05	-0.037	0.0687	0.594									
DIFF_KSUP				-2.374	0.5553	0.000	-3.161	0.6176	0.000	-1.915	0.7108	0.007
OFUND				0.085	0.0202	0.000	0.092	0.0218	0.000			
OTAX										0.090	0.0301	0.003
CONS.	-1.594	0.2159	0.000	-0.374	0.2571	0.145	-0.593	0.2869	0.039	-1.418	0.3330	0.000
/atrho21	-0.001	0.0769	0.993									
/atrho31	-0.074	0.0985	0.453									
/atrho41	-0.093	0.1062	0.379									
/atrho32	0.352	0.0333	0.000									
/atrho42	0.236	0.0394	0.000									
/atrho43	0.111	0.0410	0.007									
rho21	-0.001	0.0769	0.993									
rho31	-0.074	0.0979	0.452									
rho41	-0.093	0.1053	0.376									
rho32	0.338	0.0295	0.000									
rho42	0.232	0.0373	0.000									
rho43	0.111	0.0405	0.006									

Likelihood ratio test of rho21=rho31=rho41=rho32=rho42=rho43=0

chi2(6) =166.798; Prob>chi2=0.0000

Appendix

Table A1: Correlations between determinants (coefficients and level of significance)

	TPOT	HEDU	COPY	NCOMP2	NCOMP3	NCOMP4	NCOMP5	PCO	NPCO	KCUST	KSUP	KCON	PATUNI	KCONSULT
TPOT	1.000													
HEDU	0.111	1.000												
	0.000													
COPY	-0.007	-0.017	1.000											
	0.715	0.357												
NCOMP2	0.032	-0.012	-0.017	1.000										
	0.083	0.538	0.354											
NCOMP3	-0.055	-0.046	0.031	-0.261	1.000									
	0.003	0.015	0.098	0.000										
NCOMP4	0.010	-0.010	0.011	-0.258	-0.146	1.000								
	0.595	0.608	0.563	0.000	0.000									
NCOMP5	-0.021	-0.034	0.034	-0.267	-0.151	-0.148	1.000							
	0.262	0.072	0.068	0.000	0.000	0.000								
PCO	0.028	-0.032	0.052	0.039	0.058	0.042	0.021	1.000						
	0.124	0.092	0.005	0.037	0.002	0.025	0.268							
NPCO	0.130	0.031	0.007	0.036	-0.022	-0.028	0.038	-0.045	1.000					
	0.000	0.101	0.706	0.050	0.244	0.137	0.040	0.013						
KCUST	0.096	0.073	0.057	0.063	-0.025	-0.017	-0.017	0.023	0.079	1.000				
	0.000	0.000	0.002	0.001	0.170	0.366	0.370	0.211	0.000					
KSUP	0.092	-0.088	0.105	0.014	0.013	0.022	0.007	0.066	0.066	0.130	1.000			
	0.000	0.000	0.000	0.453	0.487	0.240	0.701	0.000	0.000	0.000				
KCON	0.064	0.051	-0.002	0.036	-0.022	-0.035	-0.054	0.055	0.016	0.093	0.096	1.000		
	0.001	0.007	0.917	0.054	0.236	0.063	0.004	0.003	0.371	0.000	0.000			
PATUNI	0.255	0.112	0.010	0.030	-0.028	0.002	-0.051	0.029	0.087	0.106	0.101	0.126	1.000	
	0.000	0.000	0.573	0.102	0.128	0.906	0.006	0.112	0.000	0.000	0.000	0.000		
KCONSULT	0.126	0.019	0.061	0.003	-0.036	0.004	0.031	-0.009	0.072	0.063	0.045	0.048	0.082	1.000
	0.000	0.322	0.001	0.870	0.052	0.826	0.095	0.643	0.000	0.001	0.015	0.009	0.000	
UNCT	0.102	0.024	0.057	0.014	0.043	0.003	-0.030	0.013	0.030	0.047	0.063	0.050	0.131	0.063
	0.000	0.200	0.002	0.443	0.020	0.887	0.101	0.496	0.102	0.011	0.001	0.007	0.000	0.001
KOSTEN	0.119	0.080	0.152	0.003	0.002	-0.007	-0.002	0.087	0.026	0.088	0.031	0.027	0.104	0.080
	0.000	0.000	0.000	0.865	0.903	0.704	0.896	0.000	0.164	0.000	0.089	0.143	0.000	0.000
LSKILL	0.105	0.056	0.095	0.016	-0.016	-0.020	-0.001	0.023	0.046	0.084	0.082	0.048	0.111	0.050
	0.000	0.003	0.000	0.392	0.403	0.286	0.967	0.219	0.012	0.000	0.000	0.009	0.000	0.006
LPSUP	0.074	0.028	0.115	-0.041	0.019	0.045	0.026	0.015	0.005	0.041	0.027	0.008	0.051	-0.011
	0.000	0.135	0.000	0.027	0.318	0.014	0.158	0.423	0.797	0.026	0.135	0.648	0.005	0.548
LEMPL	0.100	-0.077	-0.092	0.091	-0.023	-0.026	-0.074	0.118	0.079	0.058	0.049	0.219	0.172	0.130
	0.000	0.000	0.000	0.000	0.211	0.157	0.000	0.000	0.000	0.002	0.008	0.000	0.000	0.000

Table A1: Correlations between determinants (continued)

	TPOT	HEDU	COPY	NCOMP2	NCOMP3	NCOMP4	NCOMP5	PCO	NPCO	KCUST	KSUP	KCON	PATUNI	KCONSULT
MANU	0.042	-0.096	0.002	0.092	0.020	-0.053	-0.164	0.030	0.036	0.067	0.088	-0.005	0.070	-0.123
	0.023	0.000	0.924	0.000	0.281	0.005	0.000	0.103	0.050	0.000	0.000	0.767	0.000	0.000
SERV	-0.029	0.110	-0.018	-0.065	-0.033	0.020	0.135	-0.054	-0.003	-0.061	-0.102	0.005	-0.059	0.127
	0.117	0.000	0.336	0.000	0.074	0.286	0.000	0.003	0.890	0.001	0.000	0.789	0.001	0.000
TDUM02	0.000	-0.025	0.015	-0.045	0.024	0.043	0.009	-0.016	-0.020	0.047	0.058	-0.007	0.008	-0.031
	0.987	0.192	0.410	0.016	0.195	0.022	0.628	0.398	0.271	0.010	0.002	0.714	0.658	0.094
TDUM05	-0.048	0.073	0.001	-0.010	-0.016	-0.041	-0.056	0.030	-0.033	-0.045	-0.076	0.005	-0.028	-0.033
	0.009	0.000	0.958	0.574	0.378	0.027	0.002	0.106	0.071	0.015	0.000	0.783	0.134	0.069

Table A1: Correlations between determinants (continued)

	UNCT	COST	LSKILL	LPSUP	LEMPL	MANU	SERV	TDUM02	TDUM05
UNCT	1.000								
KOSTEN	0.191	1.000							
	0.000								
LSKILL	0.158	0.156	1.000						
	0.000	0.000							
LPSUP	0.098	0.132	0.137	1.000					
	0.000	0.000	0.000						
LEMPL	0.025	-0.027	0.045	-0.076	1.000				
	0.169	0.144	0.015	0.000					
MANU	0.024	0.049	0.037	0.025	0.041	1.000			
	0.194	0.007	0.044	0.166	0.027				
SERV	-0.024	-0.033	-0.040	-0.029	-0.048	-0.902	1.000		
	0.188	0.075	0.029	0.120	0.008	0.000			
TDUM02	0.151	-0.008	0.021	-0.007	-0.062	0.034	-0.020	1.000	
	0.000	0.652	0.247	0.716	0.001	0.063	0.271		
TDUM05	-0.273	0.011	-0.066	-0.026	0.027	-0.019	0.024	-0.531	1.000
	0.000	0.564	0.000	0.165	0.136	0.311	0.190	0.000	

Table A2: Validation of instruments: Results of the regressions of the instruments on the generalised residuals for the endogenized estimations

	mixed									coop					
	TPOT			PATUNI			KCONSULT			KSUP			KCON		
Instruments	Coef.	Std.Err.	P>z	Coef.	Std.Err.	P>z	Coef.	Std.Err.	P>z	Coef.	Std.Err.	P>z	Coef.	Std.Err.	P>z
DIFF_KSUP	0.131	0.235	0.575	0.230	0.208	0.269	0.178	0.211	0.399						
DIFF_KCUST													0.117	0.167	0.485
OFUND	-0.008	0.014	0.530	-0.009	0.012	0.441									
OTAX							-0.001	0.014	0.924						
OORG										0.025	0.016	0.117			
OREG										0.012	0.015	0.407	0.005	0.017	0.767
OENVL															
CONS	0.696	0.078	0.000	0.843	0.069	0.000	0.782	0.071	0.000	0.857	0.041	0.000	0.624	0.089	0.000
	N = 2'777			N = 2'777			N = 2'777			N = 2'777			N = 2'777		
	F(2, 2774) = 0.33			F(2, 2774) = 0.85			F(2, 2774) = 0.36			F(2, 2774) = 1.89			F(2, 2774) = 0.29		
	R2 = 0.0002			R2 = 0.0006			R2 = 0.0003			R2 = 0.0014			R2 = 0.0002		

Table A3: Validation of instruments: Results of the regressions of the instruments on the dependent variables coop and mixed

	mixed (TPOT, PATUNI)			mixed (KCONSULT)			coop (KSUP)			coop (KCON)		
Instruments	Coef.	Std.Err.	P>z	Coef.	Std.Err.	P>z	Coef.	Std.Err.	P>z	Coef.	Std.Err.	P>z
DIFF_KSUP	-0.549	0.336	0.102	-0.532	0.336	0.114						
DIFF_KCUST										-0.197	0.287	0.493
OFUND	-0.010	0.020	0.633									
OTAX				-0.035	0.023	0.131						
OORG							-0.016	0.030	0.598			
OREG							-0.040	0.030	0.185	-0.044	0.030	0.135
CONS.	-0.549	0.112	0.000	-0.508	0.113	0.000	-1.126	0.079	0.000	-1.057	0.152	0.000
	N = 2973			N = 2973			N = 2973			N = 2973		
	LR chi2(2) = 2.99			LR chi2(2) = 5.06*			LR chi2(2) = 2.39			LR chi2(2) = 2.58		
	Pseudo R2 = 0.0009			Pseudo R2 = 0.0016			Pseudo R2 = 0.0012			Pseudo R2 = 0.0013		