FACULTY CONSULTING: QUANTITATIVE EVIDENCE ON A TRADITIONAL GOVERNMENT-INDUSTRY-UNIVERSITY LINKAGE

Primary Sub-theme: Triple Helix study (S2)
Secondary Sub-theme: University-industry-government linkages (S2.2)

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ABSTRACT

Based on a survey of 2590 researchers in engineering and natural sciences, this paper explores the determinants of three forms of academic consulting: 1) revenue-driven consulting: consulting activities generating income opportunities; and two forms of learning-driven consulting activities: 2) consulting activities through providing expertise or technical support, without being paid, to help companies solve technical problems; 3) consulting activities through providing expertise or technical support, without being paid, to help government agencies solve technical problems. The results of the regression models show that overall, full professors in engineering of large-sized research universities who rely on private funding for the success of their research projects and on larger research units (or laboratories), who invest more time in the technical validation of knowledge and in the protection of their discoveries and inventions, while having stronger ties with companies or government agencies, are more engaged than their colleagues in consulting activities. Moreover, to a larger extent, the same factors tend to explain paid and unpaid consulting engagements. Academic consulting is a knowledge transfer mechanism that is under-exploited.

Key words: academic consulting, engineering, natural sciences, regression models, paid consulting, unpaid consulting

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1. Introduction

Most studies on relationships between government, industry and universities deal with collaborative research, research contracts, patents and university spin-off companies. Although significant, we do not know much about academic consulting, which is a form of knowledge and technology transfer largely under-documented and under-studied (Bercovitz and Feldman, 2006; Cohen et al., 2002). Perkmann and Walsh (2008: 1884) suggest that «academic consulting is perhaps practiced in different forms and for different reasons». This paper addresses this issue by differentiating three forms of academic consulting: 1) revenue driven consulting: consulting activities generating income opportunities; and two forms of learning-driven consulting activities: 2) consulting activities through providing expertise or technical support, without being paid, to help companies solve technical problems; 3) consulting activities through providing expertise or technical support, without being paid, to help government agencies solve technical problems.

This paper addresses three questions: What is the extent of engagement of university researchers in natural sciences and engineering in these three forms of consulting activities with government and industry? Do academics engage simultaneously in these three forms of consulting activities? Are there differences in the determinants of these different forms of consulting activities?

Much of the literature on academic consulting implicitly assumes that consulting is a discretionary behaviour involving faculty motivated by personal income opportunities (Boyer and Lewis, 1984; Rebne, 1989). The evidence of the extent of such a form of academic consulting and its determinants are still scanty. As for unpaid academic consulting taking the form of informal advice involving academics motivated by the desire to learn about problems and challenges met by companies or government organizations (Perkmann and Walsh, 2008), it has been explored at the theoretical level. To the extent of our knowledge, there are no studies documenting the extent and determinants of unpaid academic consulting. This paper aims to shed new light on the extent of these forms of academic consulting by focusing attention on resources and other factors that are under the control of university researchers. It will also advance knowledge by testing some of the propositions formulated in the conceptual framework developed by Perkmann and Walsh (2008).

2. Differentiating formal and informal academic consulting activities

In this paper, we define academic consulting as the provision of services by an academic to external organizations such as companies and government agencies. Such a provision of services can either result into formalized contractual arrangements between academics and external organizations or result into informal arrangements between individuals and consulting organizations. Informal consulting arrangements describe cases where individual academics provide expertise or technical support, without being paid, to help companies or other types of organizations solve technical problems.

By comparison to other types of university-industry linkages like collaborative research and research contracts, which are performed collectively and formalized into commercial contractual arrangements managed at the university level (Schmoch, 1999), consulting tends to be provided individually by academics (Perkman and Walsh, 2008). In countries like Canada and the United States, many universities allow up to 20% of their faculty members' time for outside activities thus providing opportunities for the provision of expertise to a large variety of organizations and a large diversity of formal and informal arrangements.

There is evidence suggesting that consulting is widely practiced (D'Este and Patel, 2007; Meyer-Krahmer and Schmoch, 1998; Abramson et al., 1997). However, the level of engagement of academics into formal and informal consulting activities is under-documented, first, because most studies do not differentiate between formal and informal consulting, and second, because some consulting activities may be disclosed to university administrators while others are not. Moreover, in many universities, academics are not required to disclose their consulting activities if they do not involve more than 20% of their work time. This study attempts to advance knowledge on academic consulting by taking into account disclosed and undisclosed consulting activities, as well as paid (formal) and unpaid (informal) consulting activities. To collect data on this issue, we conducted a survey in which we asked academics in engineering and natural sciences the following three questions:

1. « How frequently have you provided, over the past 5 years, expertise or technical support, without being paid, to help solve technical problems for private firms?» where 1= never and 5= very often.
2. « How frequently have you provided, over the past 5 years, expertise or technical support, without being paid, to help solve technical problems for government agencies or organizations?» where 1= never and 5= very often.
3. «Approximately what percentage of your personal income was generated from consulting activities in 2006? »

3. Explaining academic consulting activities

As pointed out by Perkmann and Walsh (2008), academic consulting activities represent discretionary activities, and different factors explain the engagement of academics in such activities. We assume that the engagement of academics in consulting activities can be explained from a resource-based perspective (Barney, 1991), and one of its refinements, the knowledge-based perspective (Kogut and Zander, 1992; Grant, 1996; Meeus et al., 2004; Landry et al., 2006; Landry et al., 2007). Such a perspective suggests that academics integrate knowledge and other resources to create expertise and problem solving capabilities that are deployed and mobilized for the provision of expert advice and services to companies and government agencies. We hypothesize that different types of consulting will be explained by the recourse to different types of resources. The conceptual framework and hypotheses developed in this paper are related to four categories of resources that are likely to influence engagement in different forms of academic consulting: financial resources, organizational resources, knowledge resources and relational assets. Academic ranks and research fields were used as control variables. The operational definitions of the dependent and independent variables are presented in Appendix 1.

4. Data and descriptive statistics

4.1 Data collection

The population of the present study consists of the population of university researchers funded by the Natural Sciences and Engineering Research Council of Canada (NSERC). A random sample of 3908 university researchers was prepared by NSERC for this study in order to represent seven research field categories. All researchers included in the sample were funded by NSERC during the 2003 and 2007 period.

The questionnaire was developed from a literature review on knowledge transfer and commercialization, and in collaboration with the program evaluation officers of NSERC. The questionnaire asked the respondents to focus on their knowledge transfer activities, the linkages they have with potential research users, the adaptation of research results for potential users, the context of potential users, the funding of research projects, their endeavors to protect intellectual property, and publications. Most of the items in the questionnaire used 5-point Likert-type scales.

The data were collected with a web-based survey. In order to improve the response rate, the survey was designed according to the following principles (Gaddis, 1998; Dillman, 2000; Dillman et al., 1998, Dillman et al., 2001): 1) the questions were pretested before they went online; 2) an introduction was written for the survey in order to incite cooperation from participants; 3) filtering questions were used; 4) the survey was divided in sections; 5) the questionnaire did not have any open-ended questions; 6) a personalized e-mail signed by an NSERC agent was sent to each researcher with a personalized password to get access to the questionnaire; 7) finally, two follow-up reminders by e-mail signed by an NSERC agent were sent to each researcher. The survey was launched at the beginning of February 2007 and closed at the end of April 2007.

Of the 3908 researchers included in the sample, 2590 participated and completed the questionnaire for a participation rate of 66.2%. The possibility of non-response bias was verified by comparing the number of respondents to that of the original population sample for 7 categories of research fields. Every research field category is statistically well represented in the completed questionnaires.

4.2. Descriptive Statistics

The upper part of Table 1 presents the descriptive statistics of the three dependent variables considered in this study: unpaid consultation for private firms, unpaid consultation for government agencies or organizations, and paid consultation for private firms and government agencies or organizations. The distribution of researchers with regard to the unpaid consultation for private firms shows that 58.1% of them *never* or *rarely* provided expertise or technical support, without being paid, to solve technical problems for private firms, whereas 14.5% provided *often* or *very often* such unpaid consulting service activities. Likewise, with regard to unpaid consultation for government agencies or organizations, 68.2% of the researchers indicated that they *never* or *rarely* provided expertise or technical support, without being paid, to solve technical problems for government agencies or organizations, whereas 11.9% of them indicated doing so *often* or *very often*. For paid consultation, the descriptive statistics indicate that 62.2% of the researchers generated 0% of their personal income from consulting activities. The average percentage of researchers' personal income generated from consulting activities was 2.29%, with a standard deviation of 6.80%. The lower part of Table 1 reports the descriptive statistics of the explanatory variables considered in this study.

[Table 1 about here]

5. Methods

5.1. The determinants of unpaid and paid consulting services provided by researchers

In this econometric section, we focus on the determinants of the unpaid and paid consulting services provided by researchers to private firms, government agencies or organizations associated with their research field. Two different econometric models were specified. Firstly, an ordered logit regression was used to model the researcher's unpaid consulting services. We distinguished between a researcher's unpaid consultation activities to private firms and a researcher's unpaid consultation activities to government agencies or organizations. In both cases, the dependent variable has a categorical and ordinal nature and it is measured on a Likert scale of frequency ranging from 1= *Never* to 5= *Very often* of the involvement of the researcher in the provision of expertise or technical support, without being paid, to help solve technical problems. Secondly, the paid consultation was measured as the percentage of personal income generated from consulting activities to private firms or/and to government agencies or organizations. This dependent variable can take only the non-negative integer values {0, 1, 2, 3, ...} and it does not follow a normal distribution. Moreover, a zero value is a usual outcome of this variable, as confirmed by the descriptive statistics reported in Table 1 that indicate that 62.2% of the researchers generated 0% of personal income from consulting activities to private firms or/and to government agencies or organizations. Hence, in this case, a specification that considers the count data models was preferred to a linear regression model estimated by the ordinary least square method (Cameron and Trivedi, 1998; Landry et al., 2007).

5.2. The measures of the independent variables

The explanatory variables included in the three are regrouped in five categories: 1) financial assets; 2) organizational assets; 3) attributes of knowledge assets; 4) relational assets; and 5) control variables. The definitions of dependent and independent variables included in these models are presented in Appendix 1.

5.3. The determinants of unpaid consulting services

As indicated previously, the consulting services provided by researchers to private firms, and to government agencies or organizations associated with their research field (respectively CONS_FIRM and CONS_GVT) were modeled as an ordered logit model. A more detailed statistical description of the ordered logit models is presented in Amara et al. (2004).

To study the impact of the explanatory variables on the unpaid consulting services, we developed the following ordered logistic regression model:

$$\text{CONS\_(FIRM/GVT)} = \beta_0 + \beta_1 \text{INTFUND} + \beta_2 \text{PRIFUND} + \beta_3 \text{SQUNIT} + \beta_4 \text{SQTEACH} + \beta_5 \text{SMALL} + \beta_6 \text{MEDIUM} + \beta_7 \text{TTO} + \beta_8 \text{SQPUB} + \beta_9 \text{POP} + \beta_{10} \text{PIP} + \beta_{11} \text{TIES\_(FIRM/GVT)} + \beta_{12} \text{GRANTEE} + \beta_{13} \text{ASSIST} + \beta_{14} \text{ASSOC} + \beta_{15} \text{EMERITUS} + \beta_{16} \text{CHEM} + \beta_{17} \text{COMPU} + \beta_{18} \text{EARTH} + \beta_{19} \text{LIFE} + \beta_{20} \text{MASTA} + \beta_{21} \text{PHYSPA} + \varepsilon$$

β_i (i= 0…….22) are parameters to be estimated, and ε is an error term.

FIRM refers to private firms while GVT refers to government departments/agencies.

The estimations of the original two models with the five initial categories exhibited low classification accuracies, as measured by the percentages of correct predictions (47.31% and 54.10% for unpaid consultation to private firms and unpaid consultation to government agencies or organizations, respectively). In order to enhance the classification accuracy of the two models, we have collapsed categories 1 and 2 (*Never*; *Rarely*) of the dependent variable (now category 1), as well as categories 4 and 5 (*Often*; *Very often*) (now category 3). In doing so, the classification accuracies of the two models were significantly enhanced (62.56% and 69.49% for unpaid consultation to private firms and unpaid consultation to government agencies or organizations, respectively).

The results of estimating the two ordered Logit models with three categories of outcomes are presented in Table 2. The average weights of the independent variables are the Logit estimates. The threshold variables (α) are also estimated.

To assess the «goodness of fit» of the two models, we used, firstly, the Chi-square which tests the joint hypothesis that all the coefficients of the explanatory variables are zero, with higher Chi-square statistics indicating better overall model fits. For the two models, the Chi-squared statistics reject the restricted (constant only) models at the 1% level (Likelihood Ratio Chi-square of 522.46 and 473.99 with 21 degrees of freedom, respectively for unpaid consultation to private firms and unpaid consultation to government agencies or organizations). Secondly, the «predictive power», as measured by the percentages of correct predictions of the two models, appears to be acceptable (62.56% and 69.49% respectively). Thirdly, the Nagelkerke R^2 values for the two models are respectively .309 and .285, which is quite acceptable for models with qualitative dependent variables. Finally, in the two models, $\alpha_1 < \alpha_2$ and both are significant. Hence, the computation of these measures of goodness of fit leads us to conclude that our models are well behaved.

The results regarding the impact of explanatory variables on the dependent variables (unpaid consulting services to private firms and the unpaid consulting services to government departments/agencies) reported in Table 2 suggest that research unit size, validated knowledge, being affiliated with a large-sized research university rather than a small-sized research university, and being in the engineering field instead of other research fields, were explanatory variables that were significantly and positively related to a higher level of the researcher's involvement in consulting service activities to private firms, and to government agencies or organizations associated with his research field (PANEL A and PANEL B).

The financial support from private firms, the protected knowledge, the strength of ties between the researcher and representatives of private firms, being a full professor rather than an assistant professor or associate professor, were explanatory variables that were significantly and positively related to a higher level of the researcher's involvement in consulting service activities to private firms (PANEL A).

Likewise, teaching activities, the number of articles published in scholarly journals, the strength of ties between the researcher and representatives of government departments/agencies, and being a grantee researcher or emeritus professor rather than a full professor, were explanatory variables that were significantly and positively related to a higher level of the researcher's involvement in consulting service activities to government agencies or organizations (PANEL B).

Finally, the other two variables included in the model – internal funding from a researcher's university, and utilization of services provided by a researcher's university TTO– were neither related to the level of a researcher's involvement in consulting service activities to private firms nor to government agencies or organizations.

[Table 2 about here]

5.4. The determinants of paid consulting services

Paid consultation was measured as the percentage of personal income generated from consulting activities to private firms or/and to government agencies or organizations. This dependent variable can take only the non-negative integer values {0, 1, 2, 3, ...} and it does not follow a normal distribution. Moreover, a zero value is a usual outcome of this variable, as confirmed by the descriptive statistics reported in Table 1 that indicate that 62.2% of the researchers generated 0% of personal income from consulting activities to private firms or/and to government agencies or organizations. Hence, in this case, a specification that considers the count data models was preferred to a linear regression model estimated by the ordinary least square method (Cameron and Trivedi, 1998; Landry et al., 2007). In econometric modeling, such dependent variables are handled by using the Poisson regression. The central assumption of the Poisson process is the equality of the first two moments, namely, the mean and the variance. This implies that there is no heterogeneity in the data. In our case, this assumption is violated. There is a high frequency of zeros in the dependent variable, 62.2%. Second, our data is cross-sectional, an inherent characteristic of which is unobserved heterogeneity. In fact, the standard deviation for the dependent variable is very different from the mean (6.8 *vs* 2.29). We therefore relax the assumption of the equality of the mean and the variance, and allow instead for these two moments to differ from each other, i.e., we allow for overdispersion in the data. The NB distribution accounts for such overdispersion by modeling the Poisson mean as a Gamma random variable and by introducing an extra dispersion parameter α (Poch and Mannering, 1996; Cameron and Trivedi, 1998, Cheung, 2002). Hence, for a discrete random variable Y with a NB distribution:

$$\Pr(\mathrm{Y} = y) = \binom{y+k-1}{y}\left(\frac{k}{\mu+k}\right)^{k}\left(\frac{\mu}{\mu+k}\right)^{y},\ y = 0,1....$$

where $k > 0$, and $\mu = E(Y)$

[Equation 1]

From Equation 1, it can be shown that $Var(\mathrm{Y}) = \mu + \alpha\mu^2$, where $\alpha = 1/k$ is the dispersion parameter. Therefore, unlike the Poisson distribution which imposes the equality between the mean and the variance, in the NB distribution, $Var(\mathrm{Y})$ is allowed to exceed μ. The statistical significance of the parameter α indicates the inappropriateness of the Poisson model relative to the NB model (Carrivick et al., 2003; Rose et al., 2005).

As shown in Table 3, the choice of the NB model is confirmed by the econometric results which indicate that the value of the parameter α is 7.58 and it is significant at the 1% level, implying the presence of overdispersion in the data (Cameron and Trivedi, 1998; Carrivick et al., 2003).

The Negative Binomial regression results are presented in Table 3 (PANEL C). The overdispersion parameter alpha is 7.58 and it is significant at the 1% level, confirming that the data are overdispersed and that the Negative Binomial rather than the Poisson model is the appropriate model.

However, before concluding our empirical analysis, we proceeded to the verification of the presence of the zero-inflation problem. Indeed, the Negative Binomial regression results become no longer valid when the number of observed zeros exceeds significantly the number of zeros expected under the Negative Binomial distribution assumptions (Rose et al., 2005). In the presence of the zero-inflation problem, we should use the Zero-Inflated Negative Binomial regression (ZIP) rather than the Negative Binomial regression. Therefore, the ZIP model incorporates extra variation than the Poisson and the NB models (Gupta et al., 1996; Carrivick et al., 2003).

The model selection criterion is the Vuong statistic that was initially proposed by Vuong (1989) and was then adapted by Green (1994) for testing the appropriateness of the Zero-Inflated Negative Binomial model versus the Negative Binomial model. While dealing with this statistic that has a standard normal distribution, large positive values (> 1.96) favor the Zero-Inflated model, large negative values favor the non zero-Inflated model, and values close to zero favor neither model (Long, 1997).

The last column of Table 3 (Panel D) shows the results obtained under the Zero-Inflated Negative Binomial model. The value of the Vuong statistic (i.e., 9.12) favors statistically the NB model. Nevertheless, the results obtained under the Zero-Inflated Negative Binomial model are very close to those obtained under the Negative Binomial model. The unique difference between the results of the two models, obviously without taking into account the differences in the values of the variables' coefficients and significant thresholds, is the negative significant impact of the variable Medium-sized research university (MEDIUM), which implies that being affiliated with a large-sized research university rather than a medium-sized research university enhances the percentage of researcher's personal income generated from consulting activities. All the other results remain unchanged, hence showing the robustness of our findings.

[Tables 3]

6. Conclusion, discussion and implications

Academic consulting may involve providing expert advice, resolving technical problems or testing and validating new concepts. We differentiated academic consulting generating additional personal income from consulting services provided without being paid, referred to as informal consulting. Furthermore, we subdivided informal consulting as consulting services provided to government organizations from consulting services provided to companies. Consulting services are usually provided by individual academics in response to the different types of resources they have access to. We hypothesized that different types of consulting would be explained by the recourse to different types of resources. The conceptual framework and hypotheses developed in this paper were related to four categories of resources that were likely to influence engagement in different forms of academic consulting: 1) financial resources; 2) knowledge resources; 3) organizational resources; and 4) relational assets.

The descriptive results show that 58.1% of academics in natural sciences and engineering *never* or *rarely* provided expertise or technical support, without being paid, to solve technical problems for private firms, whereas 14.5% of them provided *often* or *very often* such unpaid consulting service activities. Likewise, with regard to unpaid consultation for government agencies or organizations, 68.2% of the respondents indicated that they *never* or *rarely* provided expertise or technical support, without being paid, to solve technical problems for government agencies or organizations, whereas 11.9% of them indicated doing so *often* or *very often*. As for paid consultation, 62.2% of the academics generated 0% of their personal income from consulting activities. The average percentage of a researcher's personal income generated from consulting activities was 2.29%, with a standard deviation of 6.80%. These descriptive results suggest that academics in natural sciences and engineering provide informal advice in an untraded manner (Faulkner and Senker, 1994) almost as frequently as in formal consulting assignments where they are remunerated. In more practical terms, it also suggests that academics are as frequently motivated by a marginal increase in their personal income as by the desire to gain insights into the challenges faced by industry or government agencies or to gain access to data and research materials (Perkmann and Walsh, 2008). The high level of engagement of academics in informal consulting where they provide expert advice and services to firms and government organizations free of charge suggests that the marginal cost of providing unpaid consulting services is low because the expertise required to provide these consulting services is likely based on expertise acquired through other activities. Moreover, the data show that on average, academics do not earn a substantial consultancy income and therefore, that the provision of consulting services does not come at the expense of academic activities, for a large majority.

Overall, full professors in engineering of large-sized research universities who rely on private funding for the success of their research projects and on larger research units (or laboratories), who invest more time in the technical validation of knowledge and in the protection of their discoveries and inventions, while having stronger ties with companies or government agencies, are more engaged than their colleagues in consulting activities.

We initially expected that the results of the econometric models would show that different factors explain paid and unpaid consulting engagement. The results of the statistical analysis exhibit two patterns: a first pattern regarding engagement in paid and unpaid provision of expert advice provided to companies is positively associated with private funding, size of research units (or laboratories), large-sized research universities, technical validation of knowledge, protection of knowledge (protection of IP), and strong ties with people in private firms. By comparison, a second pattern regarding engagement in consulting services provided to government organizations is positively associated with size of research units, but not with private funding, more teaching than for academics providing consulting services to private firms, large-sized research universities like for academics engaged in consulting services to private firms, a larger number of publications which is a factor not related to consulting for academics providing consulting services to private firms, technical validation of knowledge like it is the case for academics engaged in the provision of consulting services to private firms, but not with protected knowledge like it is the case for these academics who provide consulting services to private firms, and with strong ties with people in government organizations rather than with people in private firms like it is the case for academics who provide consulting services to private firms. Overall, by comparison to the market of consulting services to private firms, the market of consulting activities with government agencies is positively associated with academics who have more publications, are more engaged in teaching, and do not protect as much their inventions and discoveries.

These results suggest that certain types of knowledge resources matter more on the market of academic consulting. The fact that the technical validation of knowledge is positively associated with paid and unpaid consulting services and with consulting with private firms and government organizations suggests that the demand for consulting services is not related to discoveries and inventions, but to validated discoveries and inventions. It suggests that academics who develop their inventions and discoveries beyond a basic research stage to validate them are more likely to generate the interest of receptor companies and receptor government organizations.

The positive association between research university size and research unit size with consulting suggests that the academics in larger research institutions and in larger laboratories are more likely to develop and possess the expertise required to successfully provide consulting services.

The absence of statistically significant relations between the provision of consulting services by individual academics and the services provided by university technology transfer offices suggests that the provision of consulting services can be successfully provided individually, without the support of their technology transfer offices.

Unpaid consulting with government organizations is positively associated with the number of publications, while the number of publications is not significantly related with consulting services provided to private firms. These results imply that the provision of consulting services has no negative impact on publication performance and that in some cases, it may even be associated with a positive impact on publications.

The fact that the strength of ties with firms and government organizations is associated with engagement in consulting suggests that academics who want to engage in consulting activities should forge strong ties with people in these organizations.

What are the practical implications of these results for the management of universities and the formulation of knowledge and technology transfer policy? First, the fact that academic consulting appears to be a discretionary individual behaviour rather than a collective activity suggests that universities have limited control on these activities. This institutional limit is reinforced by the fact that many universities allow their faculty members to spend up to 20% of their time on outside activities. That being said, the absence of negative relations between publication performance and consulting suggests that universities might benefit far more by promoting the consulting activities of their faculty members. Hence, the provision of consulting services might generate ideas for new research projects that contribute to the advancement of science and to the production of knowledge that contribute to solve practical problems. Furthermore, both paid and unpaid consulting activities represent knowledge transfer activities that universities should attempt to better document, not in order to control academics, but in order to provide more evidence on how academics transfer knowledge to companies and government organizations that contributes to resolve practical problems in providing expert advice and services, helping companies and government organizations to innovate. Finally, knowledge and technology transfer policy should pay more attention to the contribution of academics engaged in consulting because they likely contribute significantly to help firms and government agencies solve practical problems that improve their productive and innovative capabilities.

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Table 1
Descriptive Statistics

Dependent variable: Unpaid consultation					
Description:	Scale of measurement				
How frequently have you provided, over the past 5 years, expertise or technical support, without being paid, to help solve technical problems for…?	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Very often (5)
	In % of researchers				
• private firms	38.4	19.7	27.4	9.5	5.0
• government agencies or organizations	49.4	18.4	20.3	7.9	4.0

Dependent variable: Paid consultation			
Description: *Approximately what percentage of your personal income was generated from consulting activities in 2006?*			
	0 % of personal income *generated from consulting activities*	Mean	Standard deviation
	62.2 % of researchers	2.29	6.80

Independent Variables	Type of variables	Minimum	Maximum	Mean	Standard deviation
Continuous variables:					
• Research unit size (full time research personnel)	Continuous: number	0	100	3.58	5.35
• Teaching activities (%)	Continuous: number	0	100	30.10	14.59
• Publication assets (articles)	Continuous: number	0	400	17.96	24.21

Categorical variables:		
• Internal funding	23.7%—consider the funding from their universities *very important* or *extremely important* to the success of their research projects over the past 5 years	
• Private funding	22.2%—consider the funding from private firms *very important* or *extremely important* to the success of their research projects over the past 5 years	
• Services provided by university TTO	30.2%—have used the services of their universities' technology transfer offices or organizations that provide transfer services over the past 5 years	
• Validated knowledge	21.2%—declared that they engaged *sometimes*, *often* or *very often* in the demonstration of the technical feasibility of their technology, product or process at each stage from theory through manufacturability and delivery to customers over the past 5 years	
• Protected knowledge	41.5%—declared that they engaged at least in one of the five following forms of intellectual property protection over the past 5 years: *Patent applications; Copyrights; Trademarks; Designs; Non-disclosure or confidentiality agreements*	
• Strength of ties with representatives of private firms	• Strong Ties: • Weak Ties:	32.2% 67.8%
• Strength of ties with representatives of government agencies or organizations	• Strong Ties: • Weak Ties:	31.7% 68.3%
• Research size of university of affiliation	• Small-sized research university: • Medium-sized research university: • large-sized research university:	10.8% 19.9% 69.3%
• Seniority	• Grantee researcher : • Assistant professor : • Associate professor: • Emeritus : • Full professor :	2.9% 22.4% 24.5% 6.2% 44.0%
• Research fields	• Chemistry: • Computer sciences: • Earth sciences: • Life sciences: • Mathematics & statistics: • Physics & space sciences : • Engineering :	8.8% 11.5% 10.3% 24.7% 11.5% 8.4% 24.8%

Table 2
Estimated ordered Logit models of factors affecting the involvement of researchers in unpaid consulting service activities to private firms and government agencies

	PANEL A	PANEL B
Dependent variables :	Unpaid consulting service activities to private firms [CONS_FIRM]	Involvement in unpaid consulting service activities to government agencies [CONS_GVT]
Independent variables	Coefficients (β)	Coefficients (β)
Financial assets		
Internal funding *[INTFUND]*	-.045	-.131
Private funding *[PRIFUND]*	.684 ***	.147
Organizational assets		
Research unit size *[SQUNIT]* [a]	.070 *	.113 **
Teaching activities *[SQTEACH]* [a]	.005	.058 ***
Small-sized research university *[SMALL]* [b]	-.261 **	-.467 ***
Medium-sized research university *[MEDIUM]* [b]	-.033	.151
Services provided by university TTO *[TTO]*	-.015	.039
Attributes of knowledge assets		
Publication assets *[SQPUB]* [a]	.015	.091 ***
Validated knowledge *[POP]*	.799 ***	.767 ***
Protected knowledge *[PIP]*	.357 ***	.170
Relational assets		
Strength of ties with representatives of private firms (Close & Somewhat close=1) *[TIESF]*	1.272 ***	---
Strength of ties with representatives of government departments/agencies (Close & Somewhat close=1) *[TIESG]*	---	1.674 ***
Control variables		
Seniority		
Grantee *[GRANTEE]* [c]	.351	.541 **
Assistant *[ASSISTANT]* [c]	-.333 ***	.028
Associate *[ASSOCIATE]* [c]	-.233 **	.040
Emeritus *[EMERITUS]* [c]	.247	.497 **
Research fields		
Chemistry *[CHEM]* [d]	-.562 ***	-.986 ***
Computer sciences *[COMPU]* [d]	-.604 ***	-.730 ***
Earth sciences *[EARTH]*	.384 **	.385 **
Life sciences *[LIFE]*	-.224 **	-.016 *
Mathematics & statistics *[MASTA]* [d]	-.337 ***	-.591 **
Physics & space sciences *[PHYSPA]* [d]	-.519 ***	-.622 ***
Ancillary parameters		
Threshold 1	1.497 ***	2.726 ***
Threshold 2	3.336 ***	4.277 ***
Measures of fit		
Sample Size	1712	1796
Likelihood Ratio Chi-square (*df* = 21)	522.46	473.99
Nagelkerke R^2 (Pseudo R^2)	.309	.285
Percentage of correct predictions	62.56%	69.49%

*; ** and *** indicate that variable is significant at 10%, 5% and 1%, respectively.
[a] SQ indicates the square root transformation of the variable whose name it precedes.
[b] The reference category is Large-sized research university.
[c] The reference category is Full Professor.
[d] The reference category is Engineering.

Table 3
Estimated count data models of factors affecting the involvement of researchers in paid consulting service activities to private firms and government agencies

	PANEL C	PANEL D
Dependent variables : *Percentage of personal income generated from consulting activities*	Negative Binomial	Zero Altered Negative Binomial
Independent variables	Coefficients (β)	Coefficients (β)
Constant	1.949	1.434
Financial assets		
Internal funding *[INTFUND]*	-.282 **	-.125 **
Private funding *[PRIFUND]*	.316 **	.291 ***
Organizational assets		
Research unit size *[SQUNIT]* [a]	.117 **	.072 **
Teaching activities *[SQTEACH]* [a]	-.298 ***	-.179 ***
Small-sized research university *[SMALL]* [b]	-.499 **	-.188 ***
Medium-sized research university *[MEDIUM]* [b]	-.212	-.140 **
Services provided by university TTO *[TTO]*	-.183	-.062
Attributes of knowledge assets		
Publication assets *[SQPUB]* [a]	-.025	-.005
Validated knowledge *[POP]*	.313 ***	.266 ***
Protected knowledge *[PIP]*	.443 ***	.334 ***
Relational assets		
Strength of ties with representatives of private firms (Close & Somewhat close=1) *[TIESF]*	.872 ***	.661 ***
Strength of ties with representatives of government departments/agencies (Close & Somewhat close=1) *[TIESG]*	.401 ***	.318 ***
Control variables		
Seniority		
Grantee *[GRANTEE]* [c]	-.991 **	-.718 ***
Assistant *[ASSISTANT]* [c]	-.457 ***	-.303 ***
Associate *[ASSOCIATE]* [c]	-.315 **	-.205 ***
Emeritus *[EMERITUS]* [c]	-.398	-.214
Research fields		
Chemistry *[CHEM]* [d]	-.719 ***	-.423 ***
Computer sciences *[COMPU]* [d]	-.429 **	-.411 ***
Earth sciences *[EARTH]*	-.368 **	-.257 **
Life sciences *[LIFE]*	-.858 ***	-.632 ***
Mathematics & statistics *[MASTA]* [d]	-.657 ***	-.552 ***
Physics & space sciences *[PHYSPA]* [d]	-.978 ***	-.651 ***
Sample Size	2150	2150
Alpha dispersion parameter (*p-value*)	7.58 (*0.000*)	---
Vuong statistic (*p-value*)	---	9.12 (*0.000*)
Likelihood Ratio Chi-square (*df* = 22)	10467.16***	8544.92***

*; ** and *** indicate that variable is significant at 10%, 5% and 1%, respectively.
[a] SQ indicates the square root transformation of the variable whose name it precedes.
[b] The reference category is Large-sized research university.
[c] The reference category is Full Professor.
[d] The reference category is Engineering.

Appendix 1
Definitions of Dependent and Independent Variables

Dependent variables	Measure	Method (Range)
Unpaid consulting services to private firms [CONS_FIRM]	• Measured using a 5-point scale of frequency ranging from 1 (*Never*) to 5 (*Very often*) regarding the provision of consulting services to private firms associated with the research field of the respondent. Consulting activities refer to commercial activities that exclude university-industry research collaboration projects.	Ordinal (the scale ranges between 1 and 5)
Unpaid consulting services to government agencies or organizations [CONS_GVT]	• Measured using a 5-point scale of frequency ranging from 1 (*Never*) to 5 (*Very often*) regarding the provision of consulting services to government agencies or organizations associated with the research field of the respondent. Consulting activities refer to commercial activities that exclude university-industry research collaboration projects.	

Independent variables	Measure	Method (Range)
Continuous variables		
Research unit size [SQUNIT]	• Measured as the number of equivalent full time research personnel (excluding administrative support) supported by the researcher's research grants and contracts. This variable was matched with the normal distribution using a square root transformation.	Ratio
Teaching activities [SQTEACH]	• Measured as the percentage of time spent by the researcher on teaching activities. This variable was matched with the normal distribution using a square root transformation.	Ratio
Publication assets [SQPUB]	• Measured as the total number of articles published in scholarly journals during the last 5 years. This variable was matched with the normal distribution using a square root transformation.	Ratio
Categorical Variables		
Internal funding [INTFUND]	Dichotomous variable: - coded '1' if the researcher considered that funding from his/her university was *Very important* or *Extremely important* to the success of his/her research projects over the past 5 years, and 0 otherwise.	
Private funding [PRIFUND]	Dichotomous variable: - coded '1' if the researcher considered that funding from private firms was *Very important* or *Extremely important* to the success of his/her research projects over the past 5 years, and 0 otherwise.	
Strength of ties with representatives of private firms [TIESF]	Dichotomous variable: - coded '1' if the researcher described her/his working relationship with managers/professionals in private firms in the past 5 years as *Very close*, practically like being in the same work group, or *Somewhat close,* practically like discussing and solving issues together, and 0 otherwise (*Somewhat Distant,* like with people that you do not know well, or *Distant,* like a working group with which you can only have a quick exchange of information, or *Very distant*, practically like with people that you do not know at all).	
Strength of ties with representatives of private firms [TIESG]	Dichotomous variable: - coded '1' if the researcher described her/his working relationship with managers/professionals in government departments/agencies in the past 5 years as *Very close*, practically like being in the same work group, or *Somewhat close,* practically like discussing and solving issues together, and 0 otherwise (*Somewhat Distant,* like with people that you do not know well, or *Distant,* like a working group with which you can only have a quick exchange of information, or *Very distant,* practically like with people that you do not know at all).	
Validated knowledge [POP]	Dichotomous variable: - coded '1' if the researcher answered *Sometimes*, *Often* or *Very often* to the following question, and 0 otherwise: How frequently have you personally, or your university on your behalf, engaged in the following activity regarding technologies, products or processes that resulted from your research over the past 5 years: *Demonstrated the technical feasibility of my technology, product or process at each stage from theory through manufacturability and delivery to customers* (1 = Never; 2 = Rarely; 3 = Sometimes; 4 = Often; and 5 = Very often).	

Appendix 1 (Continued)
Definitions of Dependent and Independent Variables

Services provided by university TTO [TTO]	Dichotomous variable: - coded '1' if the researcher answered *Yes* to the following question, and 0 otherwise: *Have you used the services of your university's technology transfer office or an organization that provides technology transfer services over the past 5 years?*
Protected knowledge [PIP]	Dichotomous variable: - coded '1' if, over the past 5 years, the researcher or her/his university on her/his behalf was engaged at least in one of the following five forms of intellectual property protection, and 0 if the researcher or her/his university on her/his behalf was never engaged in such forms of intellectual property protection: 1. Patent application(s); 2. Copyright(s); 3. Trademark(s); 4. Design(s); 5. Non-disclosure or confidentiality agreement(s).
Seniority	The level of seniority in the academic ranks was measured as follows: grantee researcher (GRANTEE) is a binary variable coded 1 if the researcher is not tenured and if his salary is supported by research grants, and coded 0 otherwise; assistant professor (ASSIST) is a binary variable coded 1 if the researcher is an assistant professor, and coded 0 otherwise; associate professor (ASSOC) is a binary variable coded 1 if the researcher is an associate professor, and coded 0 otherwise; (EMERITUS) is a binary variable coded 1 if the researcher is an emeritus professor, and coded 0 otherwise; finally, full professor (FULL) is a binary variable coded 1 if the researcher is a full professor, and coded 0 otherwise. This last category of researchers was used as the reference category in the econometric models.
Research university size	Research university size was measured with three binary variables: SMALL is a binary variable coded 1 if the researcher is affiliated with a large-sized research university, and coded 0 otherwise; MEDIUM is a binary variable coded 1 if the researcher is affiliated with a medium-sized research university, and coded 0 otherwise; finally, LARGE is a binary variable coded 1 if the researcher is affiliated with a large-sized research university, and coded 0 otherwise. This last category of researchers was used as the reference category in the econometric models. This categorization of universities in large, medium and small sizes was developed by the staff of the Natural Sciences and Engineering Research Council of Canada (NSERC), based on the levels of the total funding received by the various universities from national and provincial research councils.
Research fields	Research fields were measured with a series of dichotomous variables defined as follows: CHEM is a binary variable coded 1 if the respondent was a researcher in chemistry, and 0 otherwise; COMPU is a binary variable coded 1 if the respondent was a researcher in computer sciences, and 0 otherwise; EARTH is a binary variable coded 1 if the respondent was a researcher in earth sciences, and 0 otherwise; LIFE is a binary variable coded 1 if the respondent was a researcher in life sciences, and 0 otherwise; MASTA is a binary variable coded 1 if the respondent was a researcher in mathematics and statistics, and 0 otherwise; PHYSPA is a binary variable coded 1 if the respondent was a researcher in physics and space sciences, and 0 otherwise; finally, ENGIN is a binary variable coded 1 if the respondent was a researcher in engineering, and 0 otherwise. This last category of researchers was used as the reference category in the econometric models. These mutually exclusive categories are based on the NSERC'S database and they refer to the names of the peer review committees selected by the researchers when they submit applications for research grants.