AN ANALYSIS OF FINANCING INNOVATION AND COMMERCIALIZATION IN CANADA'S FUNCTIONAL FOOD AND NUTRACEUTICAL SECTOR

Deepananda Herath
Postdoctoral Research Associate
Department of Food, Agricultural and Resource Economics
University of Guelph
Guelph, N1G 2W1
Canada
Phone: 1 519 8244120 X 53428, Fax: 1 519 767 1510, Email: dherath@uogulph.ca

J. A. L. Cranfield
Associate Professor
Department of Food, Agricultural and Resource Economics
University of Guelph
Guelph, N1G 2W1
Canada
Phone: 1 519 8244120 X 5353708, Fax: 1 519 767 1510, Email: jcranfie@uogulph.ca

Spencer Henson
Professor
Department of Food, Agricultural and Resource Economics
University of Guelph
Guelph, N1G 2W1
Canada
Phone: 1 519 8244120 X 53134, Fax: 1 519 767 1510, Email: shenson@uogulph.ca

Dave Sparling
Associate Professor
Department of Food, Agricultural and Resource Economics
University of Guelph
Guelph, N1G 2W1
Canada
Phone: 1 519 8244120 X 52775, Fax: 1 519 767 1510, Email: dsparlin@uogulph.ca

Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Long Beach, California, July 23-26, 2006.

AN ANALYSIS OF FINANCING INNOVATION AND COMMERCIALIZATION IN CANADA'S FUNCTIONAL FOOD AND NUTRACEUTICAL SECTOR

ABSTRACT

Growing consumer interest in functional foods and nutraceuticals has been seen as a significant business opportunity for the agri-food sector. Many of the new firms in this sector are small and medium sized enterprises (SMEs). These SMEs often face difficulties in obtaining financing for their functional food and nutraceutical innovation and commercialization activities. We develop and implement two models to show what factors affect a firm's decision to seek external financing and the level of financing obtained. Firm size, being privately held and engaging in contractual arrangements, have negative impacts on the likelihood of a firm seeking external funding, while firms which are intensively involved in the functional food and nutraceutical sector, with greater prospects for business expansion and/or are involved in partnerships are more likely to seek external financing. Larger firms and those involved in functional food and nutraceutical research and development receive a greater amount of capital when they decided to raise capital. However, firms focused on functional foods and nutraceuticals, as opposed to more diversified firms, and those involved in product development and concept scale-up receive less capital. Our findings highlight the importance of public support in addressing the capital requirements of functional food and nutraceutical firms and underscore the considerable burden in this respect borne by smaller sized firms.

Keywords: Functional foods; Nutraceuticals, Economics, Finance, SMEs

AN ANALYSIS OF FINANCING INNOVATION AND COMMERCIALIZATION IN CANADA'S FUNCTIONAL FOOD AND NUTRACEUTICAL SECTOR

Recent consumer research in Canada suggests that consumers are increasingly aware of functional foods and nutraceuticals and value the potential health benefits associated with a range of functional ingredients (West et al. 2002; AAFC 2004; Health Canada 2005). Indeed, there is evidence that consumers have moved beyond awareness; a growing proportion of consumers have tried functional foods and nutraceuticals, with a significant minority using such products on a regular basis. These trends are not unique to Canada, with similar developments being observed in many industrialized country markets. Market research data for the period 2002 to 2004 (AC Nielson 2004) suggest that, among the seven food and beverage product categories with the greatest rates of growth in sales, six categories were health-promoting products. Not unsurprising, functional foods and nutraceuticals have been recognized as a significant business opportunity for the agri-food sector and, at the same time, a potentially effective means to promote health and well-being in the population and reduce health-related costs (Malla et al. 2005).

Recognizing the market potential for functional foods and nutraceuticals, a number of firms in Canada have begun to capitalize on the opportunities trends in consumer demand present. While data is somewhat limited, it is estimated that the Canadian nutrition sector grew eight percent over the period 2002 and 2003, with an estimated value of nearly US$5 billion in 2003 (Nutrition Business Journal 2004). The majority of firms in the Canadian functional food and nutraceutical sector are small and medium-sized enterprises (SMEs); a 2003 survey (on which the analysis reported below is based) of firms engaged in this sector found that around 50 percent of firms had less than 20 employees, while 85 percent had less than 100 employees. The key focus of this paper is the extent to which firms face difficulties in exploiting opportunities in the functional food and

nutraceutical sector predominantly due to problems accessing finance and, in turn, the extent to which this relates to the predominance of SMEs.

Kamien and Schwartz (1978, p. 252) observe: "among the leading characteristics commonly associated with industrial research and development, one of the most prominent is the virtual necessity for it to be financed internally from a firm's current profits and accumulated funds." This reliance on self-financing often arises as financiers and investors ration capital to minimize exposure to risk, or to seek out a higher risk-adjusted rate of return. Problems accessing capital are a predominant obstacle for SMEs seeking to finance their innovation activities through sources external to the firm. Indeed, the literature suggests a disparity between the rate of return required by entrepreneurs investing their own funds and that required by external investors (Hall 2005). A variety of reasons for the expectation of higher rates of return among external financiers are documented in the literature. Arrow (1962) notes the moral hazard problems associated with external financing of risky innovative activities, whereby a detailed account of such activities are not provided to the external financier due to the risk of leaking confidential proprietary information. Thus, the reluctance of innovative firms to reveal their ideas to financial markets (because of the non-rival nature of such information) reduces the quality of the signal the firm can deliver about a potential project (Bhattacharya and Ritter 1983). It is argued, therefore, that due to these informational asymmetries and moral hazard problems, innovative activities are difficult to finance in a freely-competitive market (Nelson 1959; Arrow 1962; Trester 1994; Gompers 2001).

An added ramification to the signalling problem associated with raising capital for innovative activities is the significant informational rent created by the highly regulated nature of the functional food and nutraceutical sector, especially in the case of novel foods. Scientific uncertainty regarding the efficacy of functional foods and nutraceuticals can aggravate informational frictions between the lender and the borrower. Further, there may be risks associated with the protracted process of

approval of novel foods, especially where this process is not well understand and developed, such as in Canada. Innovative activities of this kind are hard to monitor due to information asymmetries and there is a significant potential for the misalignment of interests between the innovating firm and providers of external financing.

In addition to the problems of information asymmetry and moral hazard associated with raising capital for research and development, there is frequently a lack of collateral, especially among SMEs, because of the dominant role of human capital (in the form of highly educated and skilled scientists) in the innovation process. Limited collateral may constrain the ability of innovative firms, and especially SMEs, to borrow, presenting perhaps a *prima facae* case for government to act as a source of financing. Addressing such difficulties, however, requires a better understanding of the factors that mitigate a firm's ability to undertake innovation, specifically in the current context of functional food and nutraceutical development and commercialization. An unknown in this regard is the capacity of firms in the functional food and nutraceutical sector to respond to the emerging demand for such products and the constraints that hinder their efforts.

Development and commercialization of functional foods and nutraceuticals share many of the characteristics of advanced food innovation, but also have certain unique attributes, in particular where these are the product of biotechnology. Thus, for example, specific functional foods and nutraceuticals may not have been produced and consumed in Canada previously and are subject to prior regulatory approval as novel products (Health Canada 2005). Further, the ability to make health-related claims on functional foods and nutraceuticals is strictly controlled and, within the limits of current regulations, is dependent on the availability of scientific evidence demonstrating appreciable health benefits. Broadly, these regulatory processes influence the nature of product development and commercialization, enhancing levels of capital intensiveness, including both physical resources and human capital, and having an effect on the level of risk associated with

innovation. Regulatory differences between Canada and other countries with respect to health claims and approval processes for functional foods and nutraceuticals can further exacerbate the problems experienced by innovative firms in raising external finance, such that capital rationing is the norm rather than the exception.

The current paper seeks to enhance understanding of the ability of firms in the functional food and nutraceutical sector in Canada to raise capital in pursuit of product development and commercialization. Specifically, it explores the characteristics of firms that seek external financing and those that are successful in this pursuit, highlighting those factors that tend to facilitate or impede access to capital and the amount of financing that is raised. Data are obtained from the Functional Food and Nutraceutical Survey (FFNS) undertaken by Statistics Canada in 2003. This survey provides relatively detailed information on the nature of firms engaged in the functional food and nutraceutical sector. Using these data, the analysis below presents the first in-depth assessment of the role of external financing in the functional food and nutraceutical sector, and indeed advanced food innovation more generally, not only in Canada but internationally.

Conceptual Framework

Many factors influence of a firm's propensity to seek capital as a means to finance their innovation and commercialization activities (Hall 2002, 2005). These multi-factorial influences create challenges when attempting to measure the role of a firm or sector-specific characteristic. Indeed, we have a rather imprecise understanding of the direction and magnitude of the impact a particular characteristic has on a firm's propensity to raise capital, both generally and in the specific context of the functional food and nutraceutical sector. In this context, there is scope to undertake empirical analysis in order to better understand the determinants of financing for innovation and

commercialization. Before doing so, however, we develop a conceptual framework to help shape our understanding of behaviour of firms seeking capital.

Much of the early conceptual work on firm-level capital seeking focused on deriving optimality rules to guide what factors shape the level of investment a firm requires. This work was often undertaken in the context of investment in capital stock in neoclassical growth models (see Aghion and Howitt 1997), or investment in research and development/innovation in decision or game theoretic settings (see, for example, Kamien and Schwartz 1982). We assume an innovating firm seeks external financing (i.e. capital) as an input to the production process. The production process generates ideas and knowledge (i.e. human capital, innovations, etc.) which leads to development of revenue-generating output (i.e. physical products, intellectual products or services). However, the success in developing a revenue-generating output is uncertain, *a priori*. In this sense, the firm could be viewed as determining the expected profit maximizing level of capital investment. Such an approach leads to an optimality condition for investment which equates the expected marginal value product of investment in research and development/innovation (i.e. the firm's derived demand for capital raised via financing) to the (marginal) cost of capital (i.e. the supply of capital).

We can represent this notion by assuming firms behave as though they seek to maximize expected profits by choosing a level of investment in innovation/commercialization activities and that these activities lead to revenue generating output. For clarity, we abstract away from dynamics and note that profits could be measured in period t as the discounted value of expected future profits.[i] We also assume that the firm only seeks outside investment, that is it does not utilize internal financing.[ii] Moreover, capital investment is assumed to be complementary with respect to other inputs and characteristics of the firm. This behavioural model can be expressed as:

$$\underset{k \geq 0}{Max} \quad \pi = E[Pf(k\psi(\mathbf{Q},\mathbf{z})) - rk - \mathbf{w}'\mathbf{z}] \tag{1}$$

where π is (expected) profit, $E[\ ]$ is the expectation operator, P is price of output (either a product or process), output is produced via a production function, $f(\ )$, which depends on the level of capital, and capital is interacted with the function $\psi(\mathbf{Q},\mathbf{z})$, where $\mathbf{Q}$ is a vector of firm specific exogenous factors and $\mathbf{z}$ is the vector of other factors of production, which are assumed fixed. The interaction of capital with $\psi(\mathbf{Q},\mathbf{z})$ reflects the notion that the unique combination of these other factors and inputs within each firm affects the marginal productivity of capital within each firm.[iii] The second to last element in (1) represents to cost of capital, where r is the rental rate and k is the level of capital, while the last element shows the value of other inputs (i.e. the inner product of the vector of input prices, $\mathbf{w}'$, and vector of other inputs, $\mathbf{z}$) to the production process.

For simplicity, we assume that only revenue is uncertain. In this case, the Lagrange function associated with (1) is:

$$\underset{k,\lambda}{Max} \quad L = E[Pf(k\psi(\mathbf{Q},\mathbf{z}))] - rk - \mathbf{w}'\mathbf{z} - \lambda k \tag{1'}$$

Equation (1') leads to the following Kuhn-Tucker conditions:

$$E(Pf_k\psi(\mathbf{Q},\mathbf{z})) - r - \lambda = 0. \tag{2a}$$

$$\lambda \geq 0,\ k \geq 0,\ \lambda k = 0. \tag{2b}$$

where f_k is the marginal physical product of capital. Assuming an interior solution (i.e. $\lambda = 0$), equation (2a) equates the expected marginal value product of capital in the production of an

innovation based product/process to the marginal cost of capital. Firms will demand capital up to the point where the expected marginal benefits equal the marginal cost of capital. Moreover, the expected marginal benefits reflect the firm's marginal productivity of capital and the firm's inherent capacity to develop and commercialize innovations, as reflected by the interaction of capital with the function $\psi(\mathbf{Q},\mathbf{z})$. Equation (2a) suggests that firms have a derived demand for capital investment: $k = g(r, P \mid \boldsymbol{\Theta}, \mathbf{Q}, \mathbf{z})$, where derived demand for capital is conditioned on the vector, $\boldsymbol{\Theta}$, which reflects parameters in $f(\,)$, $\psi(\,)$ and the expectation process, as well as $\mathbf{Q}$ and $\mathbf{z}$.

Derived demand for capital manifests itself via business plans and proposals presented to external financiers. Experience and observation of the marketplace tells us that such business plans and proposals are complex and reflect much more than the expected marginal value product. Indeed, characteristics of the firm, its capabilities, partnerships, experience and overall scope for success will all be articulated in these proposals. In this respect, the parameter vector $\boldsymbol{\Theta}$ also reflects these firm based characteristics. Moreover, such derived demands will have a choke price (or choke interest rate) at which the firm would choose not to seek external financing. Both panels in Figure 1 illustrate the notion of derived demand for capital with a choke price denoted by *c*. This figure assumes the production function is well behaved with respect to the level of capital.

Assuming firms are price takers in capital markets, then they will face a perfectly elastic supply of capital. The latter is illustrated in panel 1a of figure 1 with a horizontal line at the interest rate *r*. A firm with derived demand for capital denoted $g^{-1}(k, P \mid \boldsymbol{\Theta}, \mathbf{Q}, \mathbf{z})$ and facing interest rate (or capital cost) r, will have an optimal level of capital investment *k**. Note, however, that if $c - \lambda < r$, for a non-zero λ, then a corner solution will result. Panel 1a in figure 1 illustrates the impact of a non-zero Lagrange multiplier via the downward shift in the inverse derived demand by an amount equal to λ, with the result being an optimal level of capital investment equal to zero.

Recognize also that financiers fund projects based on a myriad of factors. Examples of factors influencing a financing decision include market size, technology used, perceived probability of success, time to market, cost to market, the management team, and other factors such as firm resources, size and other revenue streams. Because of the role these other factors play, financiers will often ration capital made available to firms based on an assessment of the likely success of the project/firm being funded. This assessment will often lead to a risk premium being added to the risk free interest rate. Such an outcome is illustrated in panel 1b in figure 1, where a risk premium, δ, has been added to the risk free rate to arrive at a risk adjusted interest rate, r'. In this case, the level of investment, denoted k**, is not optimal (from the firm's perspective), but it is not zero either. It is important to recognize that the adjustment factor, δ, reflects the financier's perception of the firm, and specifically, the financier's perception of the firm's marginal physical product of capital invested in innovation. Given the scope of demand for capital investment, and time financiers devote to scrutinizing firms and knowledge they possess, the adjustment likely reflects the characteristics of the firm more so than the characteristics of the financier. Also recognize that in an extreme case, the risk premium may be such that the firm would choose not to seek (accept) capital investment from the financier (i.e. a corner solution results).

Regardless of the case, the resulting level of investment will depend on a number of exogenous factors. Clearly, factors exogenous to the firm and the financier will play a role. However, given the many different sources of external financing, and the relatively large amounts of capital that are generally available, we assume that the supply of capital is perfectly elastic. Such a view is entirely consistent with the notion of a threshold level of return required by financiers, as well as the fact that many different sources of financing exist. As such, the factors driving access to, and obtaining of, investment funds (i.e. capital) reflect the characteristics of the firm seeking such funds.[iv] Assuming a perfectly elastic supply of capital allows us to formulate a reduced form model relating

the decision to seek investment (or the level of capital obtained) in terms of factors specific to the firm seeking funds. Moreover, given the arguments made about how δ reflects firm characteristics, then assuming the level of capital investment reflects characteristics of the firm seems reasonable. Firms with characteristics which prove useful in demonstrating scope for potential success will gain access to funds.

The literature is replete with studies examining the factors influencing research and development and innovation financing (see Hall 2002; 2005 for a recent discussion). However, much of the previous work in this area has focused on the role of financial and liquidity constraints. Yet, other factors are also surely important. In this regard we note that the literature is relatively silent in terms of explaining other factors which might influence which firms seek capital and, in turn, what influences how much capital is actually received. In the context of the conceptual model above, the first issue, whether a firm seeks capital, relates to whether $r > g^{-1}(k, P \mid \boldsymbol{\Theta}, \mathbf{Q}, \mathbf{z})$, while the second issue, how much does a firm receive, relates to solution of $r = g^{-1}(k, P \mid \boldsymbol{\Theta}, \mathbf{Q}, \mathbf{z})$. Our empirical model directly captures these two notions using a discrete event model and a two-step estimation procedure, respectively. We conjecture that a firm's chance of accessing capital, and the amount of capital received, is influenced by a variety of observable and measurable firm and sector-specific characteristics. These characteristics reflect: firm size and the intensity of involvement in the functional food and nutraceutical sector; prospects for business expansion; types of activities related to development/commercialization undertaken by the firm; firm ownership structure; distribution channels utilized by the firm; business practices of the firm; and the disease focus of functional foods and/or nutraceuticals produced by the firm.

Firm size has been found to be an important driver of the intensity of firm innovation (see for example Traore 2004; van Moorsel 2005). The rationale for including firm size here relates to the fact that larger firms may be better able to spread research and development costs over more

projects, in turn facing lower capital requirements per unit of innovative output and requiring less external financing. As well, larger firms may be better suited to self-financing, which again would lower the need for external sources of capital. Moreover, firm size (i.e. an increase in firm size) could affect the marginal product of capital, possibly affecting the attractiveness of investment to a financier. Smaller firms may require external financing as a means of remaining viable as their capital burn rate is typically proportionately greater than for larger firm, while smaller firm's may have no (or little) revenue from which to finance innovation. Regardless, scope exists for an inverse relationship between firm size and capital requirements through external sources. On the other hand, larger firms, with more resource requirements, could face more stringent financial or liquidity constraints and therefore require additional outside financing.

A firm's intensity of involvement in the functional food and nutraceutical sector and prospects for business expansion are included to reflect the positioning of the firm and their scope for future growth. The functional food and nutraceutical sector is growing at a fast rate (Nutrition Business Journal 2004). Large sectoral growth rates might give financiers cause to view firms in that sector more favorably when the firm seeks funds. Intensity is included to reflect that some firms in the sector devote themselves to developing and marketing of functional foods and nutraceuticals only, while others view such products as complementary to their existing suite of products in other areas. Given growth in the sector, a firm which devotes a large amount of its resources to functional foods and nutraceuticals may be more like to receive capital (and possibly more capital) as it will "ride the growth" of the functional food and nutraceutical sector. Prospects for business expansion reflect the same notion.

Van Moorsel et al. (2006) found positioning within the spectrum from product development to "goods on the market" is an important factor in shaping the innovative capacity of firms in the Canadian biotechnology sector. In this regard, the types of activities a firm undertakes related to

functional food and nutraceutical product development and commercialization are included to reflect the firms' relative position within the sector. For instance, some firms position themselves in the development stage of the market, while other focus on commercialization (i.e. marketing) of products. The capital requirements for functional food and nutraceutical product development are different from those needed for marketing such products. Moreover, the nature of the market place in the various stages of the functional foods and nutraceuticals market differ; various market levels in the functional food and nutraceutical sector are more competitive than others, while others are more regulated. Such differences may affect a firm's propensity to obtain capital and, as such, are included here.

Various factors related to the firm are also included. These include firm ownership structure, the distribution channels utilized by the firm and the firm's business practices. While largely driven by empirical consideration, many antecedents to this paper have found such factors to be important. Moreover, if policy is to be shaped in a way that better enables access to capital, understanding how these factors may (or may not) play a role could be useful. Lastly, to reflect the fact that various disease states may offer more economically beneficial outcomes, the disease focus of the functional foods and/or nutraceuticals produced by the firm are also included. The notion here is that a firm developing (or marketing) a product which addresses a widespread and/or severe disease states may have a greater chance of obtaining capital than a product which prevents a disease with less severe health outcomes.

Empirical Framework

The previous section outlined an approach to conceptualizing circumstances in which a firm would seek capital and the amount of capital they obtain if they seek capital. Our empirical analysis considers these issues with two separate models. In the first instance we develop a discrete event

model which relates the decision to seek capital to the factors discussed above. We then develop a two-step model to aid in the determination of factors which influence the amount of capital investment a capital seeking firm receives.

The former is accomplished by modeling the probability of the event that the firm seeks capital via a latent model. In particular, we define an index function $Y_i^* = g_i^{-1}(k, P \mid \boldsymbol{\Theta}, \mathbf{Q}, \mathbf{z}) - r_i$ and write $Y_i = 1$ if $Y_i^* \leq 0$ (in which case the firm seeks capital) and $Y_i = 0$ if $Y_i^* > 0$ (in which case the firm does not seek capital), where the index *i* denotes observations. Clearly, the latent variable, Y_i^*, relates directly to the Lagrange multiplier (to see this note that the latent variable equals the same term as the Lagrange multiplier in (2a), namely $g^{-1}(k, P \mid \boldsymbol{\Theta}, \mathbf{Q}, \mathbf{z}) - r$). We re-specify the index function as $Y_i^* = \mathbf{X_i}\boldsymbol{\beta} + \varepsilon_i$, where $\mathbf{X_i}$ is a vector of exogenous factors, $\boldsymbol{\beta}$ is a vector of unobserved parameters and ε_i is an error term reflecting, among other things, errors in optimization and unobservable factors influencing the decision to seek (or not seek) capital. It is assumed that the probability of a given firm making a choice to be a "seeker" or "non-seeker" is a function of these characteristics. Therefore, the probability of a given firm choosing to raise capital can be characterized using the following:

$$\Pr(Y_i = 0) = \Pr(\mathbf{X_i}\boldsymbol{\beta} + \varepsilon_i > 0) \tag{3}$$

$$\Pr(Y_i = 1) = \Pr(\mathbf{X_i}\boldsymbol{\beta} + \varepsilon_i \leq 0) \tag{4}$$

Since equations (3) and (4) capture all probabilities of the random variable ε_i, such probabilities can be characterized by a cumulative probability density function (Davidson and MacKinnon 1993). A cumulative normal density function is used to characterize ε_i, in which case the probability model

represented in (3) and (4) is a bivariate probit model. Once the parameters of the model are estimated, it is possible to compute probability of an individual firm not-seeking capital ($\Pr(Y_i=0)$) and seeking capital ($\Pr(Y_i=1)$), as well as the marginal effects (i.e. change in the probability of seeking or not-seeking financing) arising from changes in the explanatory variables.

While capital-seeking is an interesting issue influencing innovation and commercialization in the functional food and nutraceutical sector, the amount of capital received by firms is perhaps a more important issue. Thus, we also explore the factors influencing the amount of capital received by firms in the functional food and nutraceutical sector.[v] Note, however, that the decision to seek or not seek capital is not a random outcome within the sample; "capital seeker" and "capital non-seeker" status is unlikely to be a random outcome, with important systematic differences between these two groups. Firms who received zero capital may have a systematic association with certain firm characteristics if such zero capital outcomes are due to "non-seeker" status. Thus, the amount of capital received by "capital seekers" may not, in general, provide a reliable estimate of what "capital non-seekers" would have received had they decided to raise capital.

The capital-seeking decision-making process is thus sequential, where the dichotomous outcome (seeker or non-seeker) is followed by a continuous outcome (the amount of capital received). The Heckman two-step approach (Heckman, 1976) has been extensively used in estimating such dichotomous-continuous models. In this procedure, a probit model, reflecting the dichotomous decision, is estimated in the first stage and a regression equation with a continuous non-zero dependent variable is estimated in the second. Suppose the amount of capital raised (a dependent variable of continuous outcome) is *dollar*. We assume that the firm's derived demand for capital can be represented via the following:

$$dollar_i = \mathbf{X_i}\boldsymbol{\zeta} + \varepsilon_i \qquad (5)$$

However, this dependent variable is only observable for firms who choose to seek capital, with the decision to seek capital represented by the following relationship:

$$\Lambda_i^* = \mathbf{W_i}\boldsymbol{\gamma} + u_i \tag{6}$$

where Λ_i^* is a latent variable, $\mathbf{W_i}$ is a 1xm vector of explanatory variables, $\boldsymbol{\gamma}$ is a mx1 vector of unobservable parameters, and *dollar* will be observed only when $\Lambda_i^* > 0$. In light of this, expected amount of capital raised, given that a firm seeks to raise capital, is given by equation (7):

$$E(dollar_i | dollar_i \text{ observed}) = E[dollar_i \mid \Lambda_i^* > 0] \tag{7}$$

$$= E[dollar_i \mid u_i > -\mathbf{W}\boldsymbol{\gamma}_\mathbf{i}] \tag{8}$$

$$= \mathbf{X_i}\boldsymbol{\zeta} + E[\varepsilon_i \mid u_i > -\mathbf{W}\boldsymbol{\gamma}_\mathbf{i}] \tag{9}$$

Assuming u_i and ε_i have a bivariate normal distribution with zero means and correlation ϱ, then (9) can be written as:

$$E(dollar_i | dollar_i \text{ observed}) = \mathbf{X_i}\boldsymbol{\zeta} + \varrho\sigma_\varepsilon\lambda_i \tag{10}$$

where λ_i is the inverse Mills ratio from the probit estimate of the dichotomous outcome (see Greene 2003 for details).Inclusion of the Mills ratio controls for the sequential decision making process (i.e. controls for sample selection issues in our dichotomous-continuous outcome), and

permits the role that factors in $\mathbf{X}_i$ play in shaping the amount of capital received to be recovered. We use the maximum likelihood method with Heckman's two step estimation procedure to estimate γ for the dichotomous process and ζ for the continuous process.

Data and variables

Data for this analysis was obtained from a 2003 survey of the functional food and nutraceutical sector (FFNS survey) conducted by the Small Business and Special Survey Division of Statistics Canada on behalf of Agriculture and Agri-Food Canada. The sample frame was developed using firms who had indicated that they are engaged in activities related to functional foods and nutraceuticals activities in the Biotechnology Use and Development Survey (BUDS) undertaken in 2001. The sample frame included 576 firms, of which 146 indicated that they were still engaged in activities related to functional food and nutraceutical sector (Table 1). Of these 146 firms, 78 self-identified as having activities exclusively related to nutraceuticals, 27 firms self-identified as having activities exclusively related to functional foods, 26 firms indicated activities in both sectors, and 15 firms are engaged in other activities related to functional foods and nutraceuticals that are not related to the six activities listed in Table 1.

TABLE 1 HERE

Through preliminary analysis of the FFNS data, the seven groups of firm characteristics discussed in the conceptual framework were selected as explanatory variables for the *attpt* (attempt to raise capital) and *dollar* (amount of capital raised) models. Descriptive statistics for each group of explanatory variables are reported in Table 2. We assert that these characteristics distinguish firms in a manner that empirically-useful inferences can be derived through the analysis. As will be seen,

firm size plays an important role in this analysis and so we also split out the means of the data according to firm size (defined as the number of employees).

TABLE 2 HERE

In the analysis, firm size (*size*) and intensity of involvement in the functional food and nutraceutical sector intensity (*ffnint*) is derived based on the total number of employees and the number of employees who are engaged in activities specifically related to functional foods and nutraceuticals. Firm size is based on the total number of employees in 2002, including permanent and seasonal/casual/contract employees. Average firm size is 492 employees (with a standard deviation of 2,850) with substantial variation within the sample. One might expect firm size to be inversely related to the chance of seeking capital, the notion being that larger firms have access to capital reserves via internal financing. However, one might also expect that smaller, capital seeking firms obtain less capital as their size diminishes the need for capital compared to larger firms. The ratio of employees engaged in activities directly related to functional foods and nutraceuticals to total employees is used as a measure of intensity of involvement in the functional food and nutraceutical sector (*ffnint*). The sample average of measured intensity is 64.3 percent, but varies across firm size, with smaller firms being more intensely focused on functional foods and nutraceuticals. Intensity is expected to be positively related to both the probability that a firm seeks capital and the amount of capital obtained. The premise here is that firms which are intensely engaged in functional food and nutraceutical development are more likely to have a high choke price (reflecting large development costs), thus raising the chance of an interior solution and the optimal amount of capital a firm obtains.

The prospect for a firm to expand its business is measured in terms of the number of new hirings (*inboom*) and the number of unfilled vacancies (*unfill*) in 2002 with respect to activities directly related to functional foods and nutraceuticals. These variables are included as both the number of new hirings and unfilled positions will reflect the anticipated human capital needs of the firms. Our contention is that such anticipated capacity is a measure of the potential for business expansion (and, following Spence (1977) and Dixit (1980) may carry with it strategic implications related to human capital capacity which make the firm more appealing to potential investors). Both variables are expected to have a positive influence on the probability of a firm seeking capital and the amount of capital obtained. Firms with greater growth potential are more likely to be viewed positively by financiers. As well, firms with a larger number of recent new hires and unfilled positions are likely to be undertaking more development relative to firms without new hires and unfilled positions. This could be reflected in an upwards shift in the derived demand for capital, thus raising the chance that the firm will seek capital and the amount of capital received by the firm. Note that inboom increases in firm size, while unfill falls in firm size.

The firm's activities related to the development and/or commercialization of functional foods and nutraceuticals is characterized using six dummy variables related to participation in research and development (*rd*), product development/scale up (*prdev*), ingredient manufacture (*igmfg*), manufacture of consumer-ready products (*crdyp*), wholesaling (*whole*), and retailing (*retail*). Around 65 percent of the firms are involved in product development and scaling-up, but only around 26 percent in retailing. Our expectation is that firms involved in activities related to the early stage of the development to on-the-market continuum (e.g. research and development, product development/scale-up) are more likely to seek capital and have higher capital needs compared to firms involved in the distribution and marketing of functional foods and nutraceuticals.

The ownership structure of firms was represented with five dummy variables. Around 86 percent of the firms are Canadian owned (*cnd*) and about 72 percent are private corporations (*pvt*). Relatively few (about 11 percent) are multinationals (*multina*) or public corporations (*pubco*), while around nine percent are unincorporated partnership (*ptshp*). We do not have strong sign expectations for Canadian ownership, but would expect multinationals and public corporations to have less need for capital. The notion here is that such firms have access to other forms of capital, either through a parent company or via IPO/stock offerings, thus suggesting a negative effect in both empirical models. Privately owned firms and partnerships, which often have limited amounts of capital, are more likely to have greater need for capital, which suggests a positive effect of these variables, both on the probability of seeking financing and the amount received.

The three main distribution channels used by the firms are direct sales to customers (*direct*), sales through retailers/wholesalers (*rtwh*) and exporting (*export*). Approximately, 54 percent of the firms were engage in exporting, while 44 percent sold direct to consumers through the internet or mail order. The expected effect of these variables are uncertain and largely an empirical issue.

In the analysis, a distinction is made between five business practices, namely whether the firm is in a partnership (*partner*), whether the firm has contracted out functional food and nutraceutical-related activities (*contrac*), whether intellectual property rights (IPRs) have been granted to other firms (*grtipr*), whether intellectual property rights have been acquired from other firms (*aqipr*), and the number of existing and pending patents belonging to the firm (*patents*). Approximately 37 percent of firms had engaged in a partnership, while 40 percent had contracted-out functional food and nutraceutical-related activities. Significantly more firms had acquired intellectual property rights from other firms (17%) than had granted such rights to other firms (5%). Broadly speaking these variables reflect networking and information sharing of the firm with other firms/agencies. One might expect that firms engaged in activities which involve little/no

expenditure or scope for raising revenue (i.e. partnerships and granting of IPRs) will have less demand for capital, either because expertise/knowledge is garnered via the partnership or because granting of IPRs is a source of revenue which can be used to finance innovation activities. On the other hand, involvement in partnerships and granting of IPRs could reflect a great deal of innovation activity by the firm, thus suggesting a positive effect of these variables. Involvement in activities which involved the expenditure of capital (i.e. acquiring IPRs, contracting out activities and development of patents) would raise capital demands, thus suggesting a positive effect of these variables. However, firms which undertake these activities, especially acquiring IPRs and contracting, may do so because they lack the expertise and capacity needed to successfully execute these activities. In this sense, purchasing IPRs and contracting out functional food and nutraceutical activities could be a least cost solution for many firms, and reflect less need for capital. In this instance, the variables *aqipr* and *contrac* are expected to have a negative effect. Finally, seven dummy variables are used to characterize the diseases on which the functional foods and/or nutraceuticals of the firms focus. The dummy variables have a value of one if the firm has product lines for more than one disease type (*multipro*), and if a firm has product lines for heart and vascular disease (*heart*), diabetes (*diabet*), cancer (*cancer*), gut health (*gut*), immune system conditions (*immune*) and bone health (*bone*). Across the sample, 72 percent of firms have products that focus on more than one disease type. The disease state for which the largest proportion (54%) of firms had products was heart and vascular disease. Sign expectations for *multipro* are mix; firms with multiple product lines may face greater need for capital as existing resources become too thinly spread across product lines. On the other hand, knowledge and innovation spillovers and economies of scope may actually reduce the need for capital of firms with multiple product lines. The role of the disease state variables is uncertain and largely an empirical issue.

Of the 146 firms responding to the FFNS survey, 45 firms (31%) had attempted to raise capital. The majority of these firms reported product innovation and commercialization as the principle reason for attempting to raise capital from external sources (Figure 2). Firms had sought financing through a variety of sources (Figure 3), mostly through commercial banks, Canadian venture capital and government. The majority of firms raising capital had done so through commercial banks and were Canadian owned (86%) and private corporations (about 72%). The average size of firms that had attempted to raise capital was 39 employees, while average size of firms not seeking external financing was 445 employees. Moreover, the intensity of involvement in the functional food and nutraceutical sector among firms seeking capital was 80 percent, compared to 58 percent for firms not seeking external financing. This suggests that smaller firms with a greater focus on the functional food and nutraceutical sector had a greater propensity to seek external financing for their innovation and commercialization activities (as illustrated in Table 2). Such a result is not unsurprising given the small scale of many of the start-up firms engaged in functional food and nutraceutical innovation and commercialization. However, larger firms sought more capital compared to smaller firms (at least in total).

Results of the Regression Analysis

Probit Analysis of Seeking Capital

The results of the probit regression on the dichotomous outcome of seeking finance (*attpt*) are reported in Table 3. Overall, the regression model explains the dichotomous outcome of seeking capital reasonably well (the psuedo-R^2 is 0.44, which is relative high for cross-sectional data). The Chi Square value for the goodness of fit test is significant with a p-value of 0.003. As expected, an inverse relationship exists between *size* and the probability that a firm will seek capital. In particular, the coefficient on this variable is negative and significant at the five percent significance level. The

marginal probability for the size variable indicates that a one percent increase in firm size reduces the likelihood of a firm seeking capital by 0.0023 percent.[vi] Presumably, larger firms are more likely to have internal budgetary resources to enable self-financing and would not have to access external capital sources, suggesting at the outset that issues and problems associated with external finance are more an issue for SMEs.

TABLE 3 HERE

The estimated coefficient on *ffnint* is positive and significant at the one percent level. Firms with a greater share of their business related to functional food and nutraceutical activities (*ffnint*) have a higher likelihood of seeking capital. In particular, a one percent increase in the intensity of participation in the functional food and nutraceutical sector (*ffnint*) would increase the likelihood of a seeking external finance by 0.76 percent. As expected, variables representing the firm's prospects for expanding their business related to functional foods and nutraceuticals (i.e. *inboom* and *unfill*) have statistically significant and positive coefficient estimates. Firms with a higher number of new hirings or with unfilled positions in the FFN sector are more likely to search for capital. Moreover, the impact of potential for business expansion is not trivial in shaping the probability of seeking financing. For instance, a one percent increase in the number of new hirings with responsibilities directly related to functional foods and nutraceuticals would increase the probability of seeking capital by 1.6 percent. Indeed, many of the firms in this sector are new or very young firms, small in size and typically face internal financing constraints. This highlights the crucial role played by the availability of external financing for the expansion of business activities in the functional food and nutraceutical sector.

Interestingly, the various functions performed by the firms related to functional food and nutraceuticals had no significant impact on the propensity to seek capital. As indicated above, one might expect firms engaged in research and development to have a greater likelihood of searching for capital; while the coefficient for the dummy corresponding to involvement in research and development (*rd*) is positive, it is not significant.

Firm ownership appears to play little role in shaping the likelihood that a firm will seek capital. In fact, only the coefficient for the dummy variable *pvt* is significant (at the five percent level), and has a negative sign, in contrast to expectations. Switching from any other ownership arrangement to being a private corporation would decrease the likelihood of seeking capital by 3.1 percent. Private ownership brings with it less need for external financing; privately owned firms in the sample appear to have sufficient levels of internal capital. Canadian-owned firms have a greater propensity to searching for capital, yet the coefficient is not significant at the five percent level.

There are no systematic associations between distribution channels used by firms in the functional food and nutraceutical sector and the propensity to seek capital. Although, the coefficients for *direct* and *export* were negative, they were not significant at the five percent level. However, among the business practices of firms in the functional food and nutraceutical sector, being in a partnership is positively associated, and significant, with the likelihood of seeking capital. Moreover, the likelihood of seeking capital would increase by about three percent if a firm is in a partnership relative to a firm which is not. In this respect it is possible that the very purpose of forming a partnership is to secure access to external financing. However, only about 14 percent of the firms in the FFNS reported that the purpose of their partnership was for accessing capital, while only eight percent of the firms who attempted to raise capital reported that the purpose of the partnership to which they belonged was to access capital. Indeed, the major rationale for establishing a partnership was to conduct scientific research and development (36%), access

markets/distribution channels (28%) or production/manufacture (27%). These results suggest that firms seek capital to access needed services that they are reluctant to undertake in-house, perhaps because of the lack of internal capabilities or economies of scope. Or it may be that firms involved in partnerships are actively involved in development and require both financing and external knowledge to complete. Moreover, it is important to note that the services being sought through partnerships could be viewed as an indirect means of accessing capital (either physical or human). The sign on the coefficient for the *contrac* variable is negative and significant at the five percent level. As discussed above, firms which can afford to contract out functional food and nutraceutical related activities do not suffer from a lack of capital and, therefore, do not seek capital. Nevertheless, firms with insufficient financial resources (and need external capital) are more likely to secure outside expertise through partnerships while those with more internal resources (and need less/no external capital) are more likely to hire necessary external capabilities.

Finally, there is no systematic association between the likelihood of seeking capital and the focus by firms on more than one disease state, nor the specific diseases on which the functional food and nutraceutical firm's focus. None of the disease-state dummy variables had significant coefficients at the five percent level. In retrospect, this is perhaps contrary to *a priori* expectations. For example, firms engaged in functional food and nutraceutical activities related to multiple diseases might be considered in greater need of external finance because of the scope of separable activities associated with products directed at different disease states.

Heckman's two stage approach for seeking capital and amount of capital raised

The Heckman two step method, as outlined above, is used to explore the influence of variables on the amount of capital raised by the firms in the Canadian functional food and nutraceutical sector. The two-step method is generally sensitive to specifying a correct model (Stata 8). Indeed, there

were collinearity problems when attempting to estimate the model which included all of the *a priori* variables, as specified in Table 2. An added complication was that, out of 146 firms, only 26 firms reported non-zero values for the amount of capital raised. Thus, through the estimation process, the least number of collinear variables were dropped and the model re-estimated. In this process we strived to keep variables representing all of the seven variable groupings. Nevertheless, the results must be interpreted with care.

In the Heckman two-step approach, the first stage is the probit estimation of the dichotomous outcome of the "seek"/"non-seek" decision. This process is characterized by Equation 6, with regressors ($\mathbf{W}_i$) taken from variables which are significant in the "seek" decision in Table 3, namely *size*, *ffnint*, *unfill*, *inboom*, *pvt*, *partner*, *contrac*. Non-collinear variables explaining the dollar amount raised, ($\mathbf{X}_i$) as characterized by Equation 5 are *rd*, *prdev*, *export*, *size*, *ffnint*, *partner*, *contrac*, *grtipr*, *aqipr*, *patents* and *multipro*. The results are reported in Table 4.

TABLE 4 HERE

The error terms of the two processes (u_i and ε_i of Equations 6 and 7) are perfectly correlated (ϱ=-1) indicating that using OLS regression for the dollar amount received by these firms would result in be inconsistent estimates. The Wald test of the null hypothesis that all coefficients are jointly equal to zero is rejected with Chi Square value of 40.76 and p-value of 0.0003. The selection component of the Heckman procedure does not provide any additional information since all of these variables were taken from the previous probit model. With the exception of *ffnint* and *unfill*, the estimated coefficients concord with the results of the probit regression reported in Table 3. For the two variables with different coefficient signs (i.e. *ffnint* and *unfill*), the coefficient estimates are not statistically significant at the ten percent level.

In the dollar amount raised model (i.e. the continuous portion of the dichotomous-continuous decisions), coefficients on the variables *rd* and *size* are positive and significant at the ten and five percent, respectively. When a firm is involved in research and development activities it needs more capital and is more likely to search with greater intensity for external funding, with the end result being a higher level of obtained capital. Larger firms are more likely to raise greater amounts of capital since they have a larger equity base to act as collateral and may be considered lower risk, and may have greater capital requirements. A one percent increase in firm size would increase the amount of capital raised by about C$11,000, if a firm decided to seek capital, while firms engaged in research and development raised C$1.7 million more than firms not engaged in research and development. The coefficients for the variables *prdev* and *ffnint* are negative and significant at the five and one percent level, respectively. The inverse relationship between level of capital obtained and *prdev* likely reflects the risks inherent in developing a new product and scaling-up production to a commercial level. Financiers may be leery of funding unproven concepts, which would result in greater capital rationing to the firms engaged in product developing/scaling-up, hence the inverse relationship.

The negative and significant coefficient for the firm's intensity of involvement in the functional food and nutraceutical sector suggests that, *ceterius paribus*, involvement in this sector decreases the amount of capital firms can raise. This may reflect the novel nature of many of the products in this sector and the infancy of markets in this sector, making potential financers wary of making large investments in forms therein engaged. Indeed, we might expect quite significant asymmetric information and moral hazard problems, especially where firms are reluctant to release information on innovative products at the developmental stage.

However, results related to *ffnint* do present a vexing dilemma for firms; firms with a high level of functional food and nutraceutical intensity are more likely to seek external financing, but

obtain less capital than a firm which has a lower level of functional food and nutraceutical intensity. This again may reflect capital rationing by financiers based on an uncertain future. In particular, the functional food and nutraceutical sector is in its infancy. While growth rates thus far have been strong, the future remains less certain. As functional foods and nutraceuticals move through the product life cycle, growth rates will slow and returns will likely diminish. As well, uncertainty with respect to the regulatory environment in Canada and abroad (i.e. in Canada's export markets) may give financiers cause to discount anticipated rates of return to firms heavily engaged in this sector. Both of these factors may lead to capital rationing with respect to functional food and nutraceutical intensity firms, and hence the observed results.

The variables *multipro*, *patents*, *grtipr* and *export* have positive coefficients, while *partner*, *contrac*, and *aqipr* have negative coefficients, although none are significant at the five percent level. Thus, these components of the model do not appear to provide any useful information to our analysis. Such result underscores the importance of the few significant variables in capturing firm's demand for capital in Canada's functional food and nutraceutical sector.

Summary and Conclusion

Growth in consumer interest in functional foods and nutraceuticals has been seen as a significant business opportunity for the agri-food sector in Canada. As a result, the functional food and nutraceutical sector is expanding rapidly, although many of the new firms in the sector are SMEs and face typical difficulties obtaining financing for their innovation and commercialization activities. The aim of this paper is to understand better the factors which affect a firm's decision to seek external financing and the level of financing obtained as a result.

The first aim is explored using a discrete choice analysis of the decision to seek external funding. Results from this analysis indicate that smaller firms, firms organized as privately held

corporations and those which contract out functional food and nutraceutical activities are less likely to seek external funding. However, firms which are more intensely involved in the functional food and nutraceutical sector, who have great prospects for business expansion and have been involved in a partnership are more likely to seek external financing.

The second aim is addressed by developing a sample-selection model where the choice to seek external financing is included in the first stage and the amount of funding to be obtained is included in the second stage. Larger firms are less likely to raise capital through external sources, but received greater amounts of capital when they decided to raise capital. Firms with a greater share of functional food and nutraceutical activities in their business are more likely to search for capital, but receive less capital than less intensive firms. Often, such functional food and nutraceutical intensive firms are small start-up ventures. Our finding with respect to intensity not only highlights the importance of some public support for capital requirements for such firms, but also the additional burden on smaller functional food and nutraceutical intensive firms. Smaller firms encounter more difficulties accessing capital. The role of the firm in the functional food and nutraceutical development and commercialization process plays a role in the amount of funding obtained. Firms engaged in pure research and development received more capital, while firms in the product development and scaling-up process received less capital compared to firms engaged in other activities. This suggests that financiers may ration capital on a differential basis according to the firm's role. Alternatively, research and development based firms may have higher capital requirements and therefore seek, and obtain, access to larger amounts of capital, while product development and scale-up based firms have lower capital requirements and therefore seek less money.

The conceptual literature suggests that information asymmetry, the non-rival nature of knowledge, liquidity constraints and lack of collateral are reasons why there is under-investment in

research and development and innovation (see for example Hall 2002; 2005). Moreover, these factors often underlie calls for government programs which enable firms to access capital for research and development and innovation. If such under-investment has occurred, then a natural question to ask is how do the results reported here aid in the development or shaping of policies and programs which might enable greater access to capital. We maintain that two key points stand out. First, such policies ought to be targeted to smaller firms. These firms are more likely to seek external financing, potentially demonstrating a greater unsatisfied need, but receive less capital than larger firms. Second, consideration ought to be given to directing access to capital to firms which are more specialized in the functional food and nutraceutical sector (i.e. the functional food and nutraceutical intensive firms). The latter firms are more likely to seek capital (again demonstrating a potential need), but receive less capital than firms which are more diversified. Given the scope for regulatory impediments to future growth opportunities in the functional food and nutraceutical sector, firms which specialize may be viewed by financiers as more risky precisely because of regulatory uncertainty at home and abroad. Despite the growth and scope for opportunity in this sector, the anticipated returns to firms which specialize in functional foods and/or nutraceuticals may be discounted due to the regulatory environment, the result being under-investment (or no investment). Since this under-investment stems from deficiencies in the regulatory environment, one could argue that not only do these deficiencies need to be addressed, but capital access programs could also be designed to facilitate socially optimal investment during the transition to a new regulatory environment.

References

Aghion, P. and P. Howitt. 1997. *Endogenous Growth Theory*. MIT Press, Cambridge Mass.

Agriculture and Agri-Food Canada (AAFC). 2004. *Demand for Food Products Supporting Health and Wellness*. Agriculture and Agri-Food Canada, Ottawa.

AC Nielson, 2004. *What's Hot Around the Globe: Insights on growth in food and beverages, 2004*. Executive News Reports from ACNielsen Global Services.

Aghion, P. and P. Howitt. 1997. *Endogenous Growth Theory*. Cambridge, Mass.: The MIT Press.

Arrow, K. J. 1962. "Economic Welfare and the Allocation of Resources for Invention" in R. Nelson ed., *The Rate and Direction of Inventive Activity*, Princeton, NJ, Princeton University Press

Bhattacharya, S and J. R. Ritter. 1983. "Innovation and Communication: Signalling with Partial Disclosure." *Review of Economic Studies*, 50:243-277.

Dixit, A. 1980. "The Role of Investment in Entry-Deterrence." *Economic Journal* 90(357):95-106.

Gompers, P. and J. Lerner. 2001. "The Venture Capital Revolution." *Journal of Economic Perspectives.* 15(2): 145–168

Hall, B.H. 2002. "The Financing of Research and Development". *Economics Department, University of California, Berkeley,* Working Paper E02-311.

Hall, B. H. 2005. "The Financing of Innovation" in Shane, S. (ed.). *Handbook of Technology and Innovation Management*, Oxford: Blackwell Publishers, Ltd.

Health Canada. 2003. "*The Growing Burden of Heart Diseases and Stroke in Canada.*" http://www.cvdinfobase.ca/cvdbook/CVD_En03.pdf

Health Canada, 2005. *Baseline Natural Health Products Survey Among Consumers*, Final Report. Conducted by Ipsos Reid.

Health Canada, 1997. *Economic Burden of Illness in Canada, 1993*. Ottawa, Ontario: Health Canada,

Population and Public Health Branch.

Health Canada "*What are Novel Foods?*" downloaded Dec. 17, 2005 from http://www.hc-sc.gc.ca/fn-_an/gmf-agm/index_e.html

Kamien, M and N. L. Schwartz. 1978. "Self Financing of an R & D Project." *American Economic Review* 68:252-261.

Kamien, M and N. L. Schwartz. 1982. *Market Structure and Innovation*. Cambridge: Cambridge University Press.

Malla, S., J. Hobbs and O. Perger. 2005. "Novel Functional Foods: Transfat Free Nexera Canola and Health Care Costs." 97th EAAE Seminar *The Economics and Policy of Diet and Health.*

Murphy, J., H. Furtan and A. Schmitz. 1993. "The gains from agricultural research under distorted trade" *Journal of Public Economics*, 51:161-172.

Nelson, R. R.. 1959. "The simple economics of basic scientific research," *Journal of Political Economy*, 67: 297-306.

Nutrition Business Journal. 2004. Global Nutrition Industry, 9 (1-12)

Traore, N., 2004. "Canadian Biotech Firms' Creative Capacity: On the Role of Absorptive Capacity, Relational Capital, Learning and Firm Characteristics." *International Journal of Biotechnology* 6(1): 1-19.

Trester, J.J. 1994. "Venture Capital Contracting Under Asymmetric Information." *The Wharton Financial Institutions Center.* accessed Jan. 8 2006http://fic.wharton.upenn.edu/fic/papers/94/9406.pdf.

STATA 8. 2003 *STATA Base Reference Manual Release 8*. Vol. 2. A Stata Press Publication, STATA CORPORATION, College Station, Texas.

Spence, A.M. 1977. "Entry, Capacity, Investment and Oligopolistic Pricing." *Bell Journal of Economics* 8(2):534-544.

van Moorsel, D, 2005. *Structure and Characteristics of the Canadian Biotechnology Industry*. Unpublished

M.Sc. Thesis, Department of Agricultural Economics and Business, University of Guelph, ON.

van Moorsel, D, J.A. L. Cranfield and David Sparling. 2006. "Factors Affecting Biotechnology Innovation in Canada: Analysis of the 2001 Biotechnology Use and Development Survey." *International Journal of Biotechnology* (In press).

West, G.E., Gendron, C., Larue, B. and Lambert, R. 2002. "Consumers' Valuation of Functional Properties of Foods: Results from a Canada-Wide Survey." *Canadian Journal of Agricultural Economics*, 50, 541-558.

Table 1. Number of firms across activities in the Canadian functional foods and nutraceuticals sector

Sector	Number of firms
Nutraceutical activities only	**78**
Nutraceuticals that are extracted or purified from plants (for example beta-glucan from oats, antioxidants from blueberries, isoflavanoids from soy, sterols from wood pulp, essential fatty acids from primrose oil, soluble fiber from fenugreek, etc.)	64
Nutraceuticals that are ground, dried, powdered, and pressed from plant materials (for example Echinacea, fenugreek, valerian, black cohosh, and gingseng, etc.)	71
Nutraceuticals that are produced extracted or purified from animals and microorganisms (for example Elk velvet, essential fatty acids, enzymes, carotenoids, etc.)	39
Nutraceuticals that are produced, extracted or purified from marine sources (for example. Glucosamine, chitosan, products from algae, seaweed, kelp, fish oils, etc)	53
Functional food activities only	**27**
Foods that have added active ingredients other than vitamins or minerals and have been scientifically demonstrated to provide health benefits beyond their basic nutritional functions (for example Muffins with beta-glucan, drinks with herb blends, foods with added soluble fibre, etc.)	63
Foods specially enhanced to contain more of a functional component, through plant breeding techniques, genetic modification, processing, or special live stock feeding techniques, that have been scientifically demonstrated to provide health benefits beyond their basic nutritional functions (for example tomato with enhanced lycopene level, canola high in carotenoids, strawberries containing increase levels of ellagic acid, omega-3 eggs, etc.)	20
Firm in both functional food and nutraceutical activities	**26**
Other Activities (not related to above 6 but other FFN related activities)	**15**
Total Number of Firms	**146**

Table 2. Description of explanatory variables

			Whole sample (n=146)		Small firms[a] (n=96)	Medium firms[a] (n=24)	Large firms[a] (n=26)
Name	**Description**	**Type**	**Mean**	**Std Dev.**	**Mean**	**Mean**	**Mean**
	Dependent variables						
attpt=1	If firm attempted to raise capital in 2002 otherwise zero	dummy	0.315	0.466	0.347	0.292	0.208
dollar	Amount of capital received by a firm requesting capital (in dollars)	scale	1247462	2610639	343172	468000	4801500
	Independent variables						
	Firm Size and Involvement in Functional Foods and Nutraceutical Sector						
size	Number of all employees of the firm (in 2002)	integer	491.628	2850.137	12.521	78.348	2626.231
ffnint	Number of employee in FFN activities/Total Employees	ratio	0.640	0.407	0.769	0.504	0.280
	Prospects for Business Expansion						
inboom	Number of new hirings in 2002 for FFN activities	integer	1.946	5.032	1.000	2.217	5.363
unfill=1	If firm has currently unfilled positions for FFN activities	dummy	0.229	0.422	0.260	0.174	0.160
	Activities						
rd=1	If firm participate in R & D activities otherwise zero	dummy	0.534	0.501	0.510	0.667	0.500
prdev=1	If firm participate in product development/scale up otherwise zero	dummy	0.651	0.478	0.573	0.958	0.654
igmfg=1	If firm manufacture ingredients otherwise zero	dummy	0.274	0.448	0.292	0.292	0.192
crdyp=1	If firm manufacture consumer ready products otherwise zero	dummy	0.562	0.498	0.521	0.583	0.692
whole=1	If firm is a wholesaler of products otherwise zero	dummy	0.479	0.501	0.562	0.375	0.269
retail =1	If firm is a retailer of products otherwise zero	dummy	0.260	0.440	0.271	0.334	0.154
	Business Ownership						
multina=1	If firm is a multinational otherwise zero	dummy	0.116	0.322	0.084	0.084	0.270
pvt=1	If firm is a private corporation otherwise zero	dummy	0.719	0.451	0.781	0.750	0.466
pubco=1	If firm is a public corporation otherwise zero	dummy	0.110	0.313	0.083	0.042	0.270
ptshp=1	If firm is a unincorporated partnership otherwise zero	dummy	0.089	0.286	0.114	0.083	0.000
cnd=1	If firm ownership is Canadian (excluded foreign) otherwise zero	dummy	0.856	0.352	0.917	0.834	0.654
	Distribution Channels						
direct=1	If firm sells to customers directly	dummy	0.438	0.498	0.510	0.334	0.270
rtwh=1	If firm sells through retailers/wholesalers	dummy	0.692	0.463	0.708	0.625	0.692
export=1	If firm is an exporter (excluded non-exporting)	dummy	0.541	0.500	0.573	0.625	0.346
	Business Practices						
partner=1	If firm has been in a partnership	dummy	0.375	0.486	0.330	0.375	0.538
contrac=1	If firm has contracted out functional foods and nutraceutical activities	dummy	0.396	0.491	0.4176	0.434	0.280
grtipr=1	If firm has granted intellectual property rights to other firms	dummy	0.049	0.217	0.053	0.043	0.040

aqipr=1	If firm has acquired intellectual property rights from other firms	dummy	0.169	0.376	0.189	0.095	0.160
patents	Number of existing and pending patents	integer	1.315	6.494	1.740	0.792	0.231
	Disease Focus of Products						
multipro=1	If firm has products lines for more than one disease status	dummy	0.719	0.451	0.677	0.834	0.770
heart=1	If firm has products lines for vascular and heart health	dummy	0.541	0.500	0.500	0.625	0.615
diabet=1	If firm has product lines for diabetes	dummy	0.363	0.483	0.375	0.417	0.269
cancer=1	If firm has product lines for cancer	dummy	0.329	0.471	0.344	0.250	0.346
gut=1	If firm has product lines for gut health	dummy	0.390	0.490	0.323	0.541	0.500
immun=1	If firm has product lines for immune system	dummy	0.466	0.501	0.458	0.625	0.346
bone=1	If firm has product lines for bone health	dummy	0.349	0.478	0.292	0.417	0.500

a. Small firms have less than 50 employees, medium firms have between 50 and 149 employees, larger firms have 150 employees or more.

Table 3. Regression results for probit analysis of 'seeking capital' decision

Name	Description	Coefficent	P-value	marginal probability %
Cons	Regression Constant	-2.005439	0.115	
	Firm Size and Involvement in Functional Foods and Nutraceutical Sector			
size	Number of all employees of the firm (in 2002)	-0.0061166	**0.012****	-0.00229
ffnint	Number of employee in FFN activities/Total Employees	2.03415	**0.006*****	0.76197
	Prospects for Business Expansion			
inboom	Number of employees hired in 2002 for FFN activities	1.221267	**0.015****	1.61426
unfill=1	If firm has currently unfilled positions for FFN activities	0.1224831	**0.029****	0.04588
	Activities			
rd=1	If firm participate in R & D activities otherwise zero	0.5288859	0.271	
prdev=1	If firm participate in product development/scale up otherwise zero	-0.1799914	0.75	
igmfg=1	If firm manufacture ingredients otherwise zero	-0.7358607	0.184	
crdyp=1	If firm manufacture consumer ready products otherwise zero	0.2109186	0.643	
whole=1	If firm is a wholesaler of products otherwise zero	0.0355694	0.946	
retail =1	If firm is a retailer of products otherwise zero	0.6609096	0.276	
	Business Ownership			
multina=1	If firm is a multinational otherwise zero	-1.912661	0.105	
pvt=1	If firm is a private corporation otherwise zero	-1.678879	**0.049****	-3.1028
pubco=1	If firm is a public corporation otherwise zero	-0.5358424	0.624	
ptshp=1	If firm is a unincorporated partnership otherwise zero	-1.192045	0.208	
cnd=1	If firm ownership is Canadian (excluded foreign) otherwise zero	1.297047	0.205	
	Distribution Channels			
direct=1	If firm sells to customers directly	-0.2153158	0.676	
rtwh=1	If firm sells through retailers/wholesalers	0.4506189	0.388	
export=1	If firm is an exporter (excluded non-exporting)	-0.7356804	0.156	
	Business Practices			
partner=1	If firm has been in a partnership	1.92333	**0.001*****	3.19894
contrac=1	If firm has contracted out FFN activities	-1.139688	**0.039****	-0.46018
grtipr=1	If firm has granted intellectual property rights to other firms	0.7066242	0.486	
aqipr=1	If firm has acquired intellectual property rights from other firms	-0.0985204	0.857	
patents	Number of existing and pending patents	0.0405107	0.202	
	Disease Focus of Products			
multipro=1	If firm has products lines for more than one disease status	-0.1637227	0.737	
heart=1	If firm has products lines for vascular and heart health	-0.096356	0.855	
diabet=1	If firm has product lines for diabetes	0.0108554	0.987	
cancer=1	If firm has product lines for cancer	-0.6116602	0.23	
gut=1	If firm has product lines for gut health	0.0348286	0.958	
immun=1	If firm has product lines for immune system	0.5512856	0.373	
bone=1	If firm has product lines for bone health	-0.6875929	0.233	

Number of observations = 107
Log likelihood = -37.70755
Pseudo R^2 = 0.4425
Log Likelihood Ratio Test chi square 2(30) = 59.86
*** Significant at the one percent level
** Significant at the five percent level

Table 4. Regression results for Heckman two-step method

Variable	Coefficient	p-value
Select		
constant	-1.13986	0.015**
size	-0.0029	0.08*
ffnint	0.546596	0.277
unfill	0.273239	0.426
inboom	0.100671	0.004***
pvt	-0.83798	0.025**
partner	0.728806	0.05**
contrac	-0.11523	0.739
Dollar		
constant	7846453	0.003***
Rd	1650107	0.086*
prdev	-2653396	0.028**
export	997359.4	0.295
Size	10971.21	0.017**
ffnint	-4562925	0.003***
partner	-1568823	0.139
contrac	-1142717	0.256
grtipr	1076597	0.409
Aqipr	-563971	0.733
patents	7498.192	0.841
multipro	1375927	0.196

Number of observations 118
Wald test chi square (2, 15)= 40.76 (p=0.0003)
*** Significant at the one percent level
** Significant at the five percent level
* Significant at the ten percent level

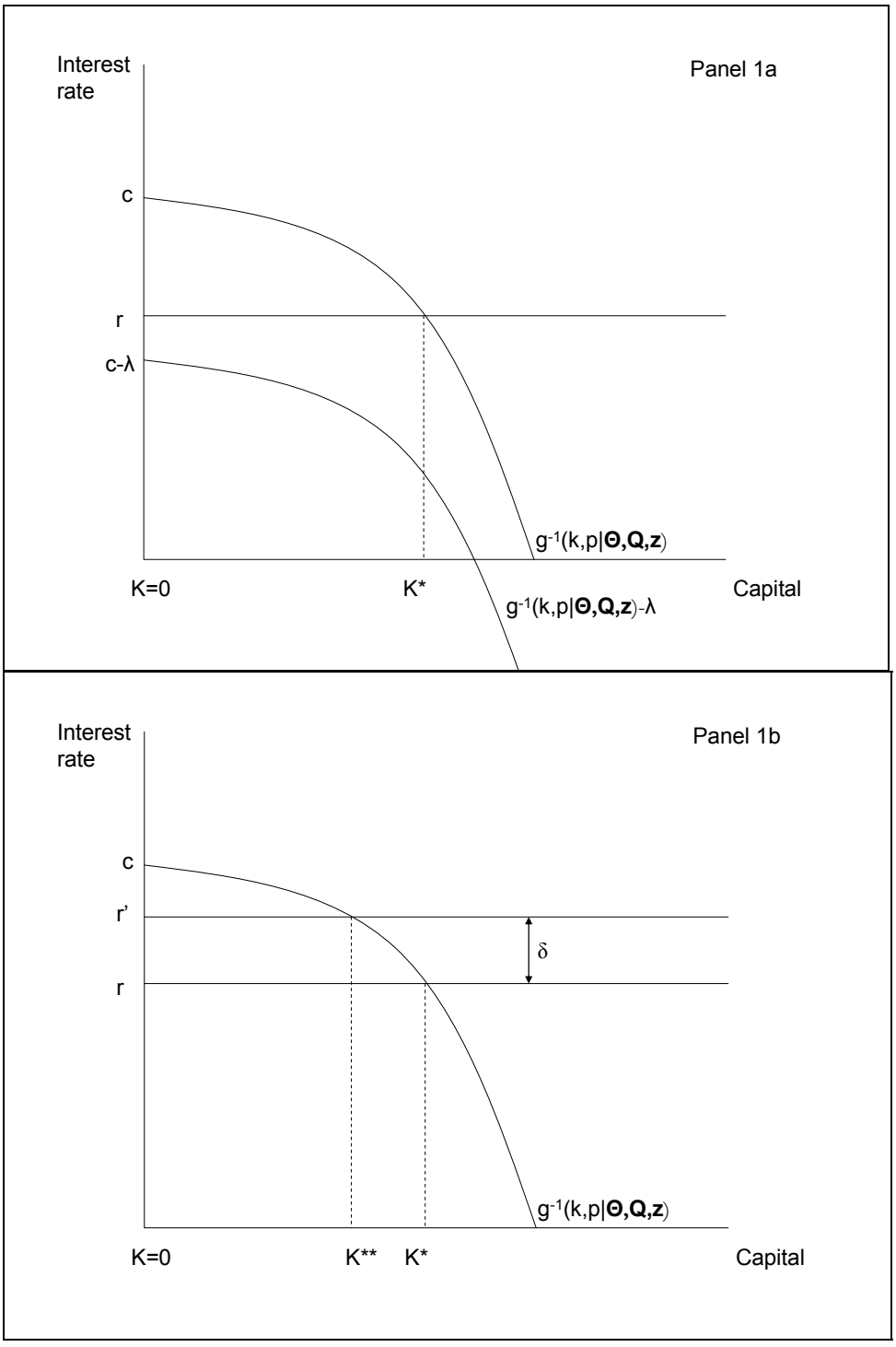

Figure 1. Derived demand and supply of capital

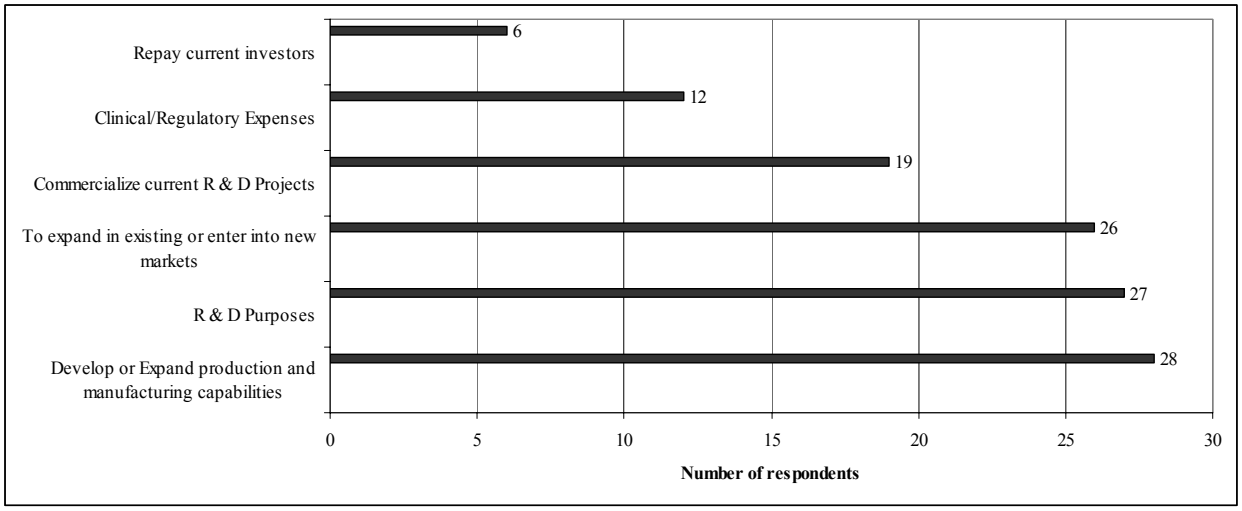

Figure 1. Reasons for attempting to raise capital among Canadian firms in functional foods and nutraceuticals sector

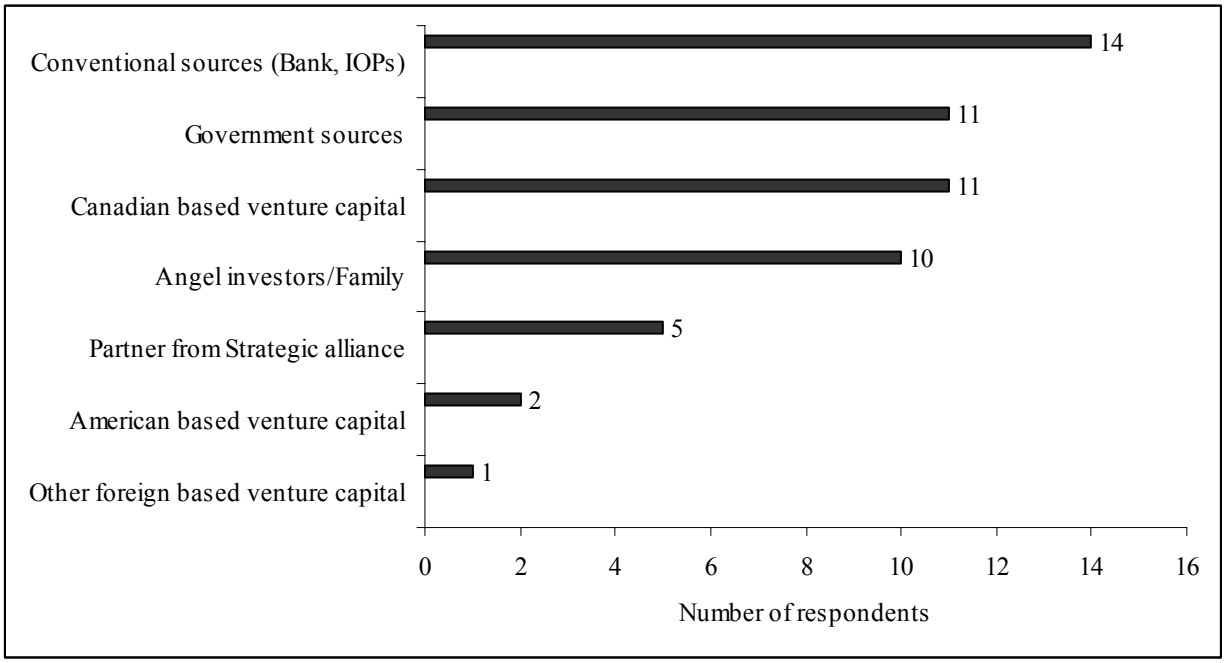

Figure 2. Sources of capital for firms in the Canadian functional foods and nutraceuticals sector

End Notes

[i] Murphy et al. (1993) invoked a similar assumption when assessing the gains from agricultural research with distorted trade.

[ii] This assumption could be relaxed, but would require additional structure which differentiates between internal and external financing and adds a mechanism by which internal financing is achieved via capital structure. As such detail is not required for our simple analytical model, we have chosen not to incorporate internal/external financing decisions.

[iii] This approach reflects the notion that the marginal productivity of capital can be enhanced via factors specific to the firm. In some respects, such a view has roots in contemporary growth theory based models (especially endogenous growth theory), wherein the ideas, people and technology within the firm drive its innovations and output (see Aghion and Howitt 1997, for example).

[iv] We recognize that the nature of the financier may also play a role. For instance, different financiers may have different thresholds. However, it could be argued that such differences will be eroded via competition in the capital market, such that individual thresholds converge on a common threshold (perhaps with slight adjustment for risk).

[v] Here we model the amount of capital a firm is successful in raising, given that they were a capital seeker. This amount, however, may have been less than the quantity of capital the firm was attempting to raise, which we do not address here.

[vi] For sake of brevity, we only report marginal effects for the statistically significant variables.