Financial Constraints, Innovation, and Productivity

By

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A Thesis

Presented to

The University of Guelph

In partial fulfillment of requirements

For the degree of

Master of Science

in

Food, Agricultural and Resource Economics

Guelph, Ontario, Canada

ABSTRACT

FINANCIAL CONSTRAINTS, INNOVATION, AND PRODUCTIVITY

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University of Guelph, 2019

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This thesis examines the relationships between financial constraints, innovation, and labour productivity among firms in eastern Europe and central Asia. To analyse the impact of financial constraint on firm-level innovation, this thesis follows the theoretical framework laid out by Gorodnichenko and Schnitzer (2013). Furthermore, using a multivariate probit model, financial constraints were found to decrease the likelihood of a firm introducing product, process, and production license innovations. The results also suggest that product, process, organizational, and production license innovation are complementary to each other (*i.e.*, firms tend to introduce them together). The existence of complementarity among innovations may make it more difficult for financially constrained firms to successfully innovate. Findings also suggest that organizational and product innovations are at least positively correlated with firm labour productivity.

Dedication

I dedicate this thesis to the Pulsar crew. It has been a privilege flying with you all. You've genuinely had a huge impact on my life, and I will treasure the memories of our adventures. Here is to many more. If you ever stop by my sector of the galaxy, let me know. The first round of Sylvassi brew is on me. Best of luck in all your endeavors. May your biscuits be forever fluffy.

Acknowledgments

First, I would like to thank the Ontario Agri-Food Innovation Alliance for funding this thesis. Most importantly, I would like to thank my parents and family for their continued support in my life. To my advisor, Dr. Getu Hailu, thank you for your patience and all the hard work that you put into me. I still don't know how you put up with me. You taught me many important skills, and I am glad to have had you as my advisor. Thank you to all the faculty and staff in the FARE department for your tireless commitment to the students. Also, to all my fellow students and RA's in the FARE department, you guys are amazing. I don't know what I did to deserve a group of friends like you. You supported me through my highs and lows, and I am so grateful for it. A special shout out goes to my cohort. You have all helped me grow as a person. Lastly, Troy, Jackie, and Watson played a key role in the completion of this thesis.

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Chapter 1 : Introduction

1.1. Motivation

Innovation and productivity are at the centre of policy discussion in Canada and elsewhere. Productivity is widely regarded as the main driver of economic growth. Productivity is commonly used as an index for the standard of living. Increased labour productivity is associated with higher wages and firm profits which, in turn, provide the capacity for better public services such as health care, public infrastructure, and environmental initiatives (Therrien and Hanel, 2010). Firm-level innovation is a key factor that influences productivity. Firm-level innovation, defined loosely as the introduction of a new good/service or the introduction of new means of production, plays an important role in productivity growth. The relationship between innovation and productivity is documented by a depth of empirical evidence (e.g., Loof and Heshmatti (2006) and Hall (2011)).

A primary characteristic of innovation is, however, the need for funding to finance substantial up-front investment costs as the returns to innovation are often realized in the future. Innovation involves activities such as conducting R&D, obtaining new production equipment, certifying new products to meet industry standards, and marketing these products. In the early stage of R&D, the success of the innovative activities can be uncertain making it difficult to obtain funding. If a firm is financially constrained, the ability to innovate may be limited. In the context of innovation, a financial constraint refers to a situation where a firm would innovate if it possessed the necessary finance internally, but the firm is unable to innovate because the added cost of obtaining finance externally is too high (Torre et al, 2017). This thesis assesses the relationship between financial constraints and innovation.

Finance is particularly important for the growth of small and medium enterprises (SME) that need capital to achieve economies of scale and enter new markets (Acs and Audretsch, 1988). Previous cross-country studies have found that development in a country's financial sector can have both positive and negative impacts on the competitiveness and productivity of a sector (e.g., Klapper et al., 2006; Cecchetti and Kharroubi, 2012). Kuntchev et al. (2013) conduct a meta-analysis of studies using firm-level innovation surveys and note that a common finding is that the impact of financial constraints is more pronounced for SME's.

Despite the importance of financing in innovation, there is limited research on the links between finance and innovation. Furthermore, it is not clear if this link depends on the type of innovation, e.g., process, product, organizational, and marketing innovations. This is important because the innovative process is inherently complex, and there may be heterogeneity in terms of which factors influence different types of innovation. Studies such as Brewin et al. (2009), Adner and Levinthal (2001), Fritsch and Meschede (2001), and Gorodnichenko and Schnitzer (2013) use firm-level data to examine the determinants of product innovation and process innovations but omit organizational and marketing innovation. This is an important gap in the literature because factors such as financial constraint may influence organizational and marketing innovations differently in comparison to product and process innovations. In addition, complementary relationships may exist between different innovation types such that organizational and marketing innovations could ameliorate the effect that product and process innovations have on productivity.

Studies that differentiate between product and process innovation while controlling for the effect of financial constraints (e.g., Gorodnichenko and Schnitzer 2013) use univariate probit models. A univariate probit model assumes that the likelihood of implementing different types of innovation are independent of one another. Independence between innovations can be violated if two or more innovations are complements. The violation of the independence assumption may introduce omitted variable bias on the parameter of interest (Greene, 2003; Brewin et al., 2009). This bias can arise out of correlation between the unobserved variation of different types of innovation. As an example, suppose product and process innovations have a complementary nature and that process innovations are influenced by financial constraints while product innovations are not. Even though product innovation does not depend on financial constraint, a univariate estimation of the product innovation equation may indicate a statistically significant relationship between financial constraint and product innovation. This observation may occur because product innovation is correlated with process innovation which, in turn, is affected by financial constraint. Thus, the estimation of the impact of financial constraint on a specific type of innovation can be biased through the omission of the complementarity effect between innovation types.

This thesis examines the relationship between firm financial constraints, innovation, and productivity using two years of firm-level data from Eastern Europe and Central Asia. I control for the complementary relationships between types of innovation using a multivariate probit approach. Using interaction terms in a linear probability model, I also investigate how the complementarity of innovations may be related to innovative outcomes such as labour productivity. The results indicate that financial constraints have a negative effect on a firm's likelihood to innovate. Furthermore, I find evidence suggesting that product, process, organizational, and marketing innovations are complementary. A potential explanation for this observed complementarity is that simultaneous adoption of innovations may have a greater impact on innovative outcomes, such as profits, than introducing a single type of innovation.

This thesis makes three primary contributions to the literature in innovation economics. First, it adds to the literature that examines the determinants of innovations (including product, process, marketing, and organizational). Second, it adds to the literature that examines the adoption of complementary innovations. Firms often tend to adopt innovations that are complements. If innovations are complements, increasing the level of any of them increases the marginal profitability of the other (Milgrom and Roberts 1995). If the decisions to adopt innovations – e.g., product innovation and process innovation – are correlated, then models that allow for joint estimation of these decisions on a firm-specific basis may be appropriate. Third, the thesis contributes to the literature that examines the effect of financial constraints on innovations. In the context of studying firms' innovation decisions, our work is related to Gorodnichenko and Schnitzer (2013) who estimate the effect of financial constraints on innovation decisions. Gorodnichenko and Schnitzer (2013) do not model innovation decisions simultaneously. They focus on estimating a single equation for each innovation decision. By contrast, we jointly estimate innovation decisions to account for the complementarity between innovations.

1.2. Research Questions

- Do financial constraints influence the likelihood of firm innovation?
- Is there complementarity between types of innovation?
- Does innovation influence labour productivity?

1.3. Thesis Outline

The rest of this thesis is organized as follows. Chapter 2 provides a review of the theory that relates finance to innovation and productivity. Chapter 2 also reviews the theory related to innovation measures and discusses the advantages and drawbacks of various measures. Chapter 3 provides a conceptual framework to assess how financial constraint can influence a firm's decision to innovate. Chapter 4 describes the data. Chapter 5 provides empirical framework to address the research questions. Additionally, chapter 5 explains potential endogeneity issues and provides an identification strategy. Chapter 6 presents the results and robustness checks. Finally, chapter 7 provides a summary, conclusion, and potential policy implications.

Chapter 2 : Literature Review

2.1. Definition of Innovation

In the 3rd edition of *The Oslo Manual,* the Organisation for Economic Co-operation and Development (OECD) defines innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (OECD 2005, p. 46). In economic theory, the word 'innovation' generally represents a component of technological change (Stoneman, 1995). In the Schumpeterian tradition, technological change refers to the entire process of improving products, production techniques, material inputs, and management in an economic system (Stoneman, 1995, p. 2). Technological change is then separated into three stages: (1) the generation of new ideas, (2) the development of ideas into marketable products and processes, and (3) the diffusion of such products and processes across potential markets (Stoneman 1995, p. 2). While there is no standard definition for the role that innovation plays in technological change, the OECD defines innovation to represent the adoption or implementation of new technology, which is an important element in the diffusion stage of technological change (Karshenas and Stoneman, 1995; OECD, 2005). This study will follow the OECD's definition of innovation partly because it is consistent with the definition used in the 2014 SFGSME. Moreover, noteworthy papers on innovation such as Griffith et al. (2006), Lööf and Heshmati (2006), Brewin et al. (2009) and Hall et al. (2009) have used definitions that are consistent with the OECD's.

2.2. Productivity and Innovation

Innovation is generally accepted by economists as a primary driver of consumer welfare and firm productivity (Garcia and Calantone, 2002). In recognition of the benefits of innovation, many nations are engaged in the race for a global innovation advantage (Atkinson and Ezel, 2012). Solow (1956) identified technological progress a primary determinant of economic growth in the Solow Growth Model. In this model, technological progress was considered an exogenous factor for the firm. However, seminal papers by Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992) introduced endogenous growth theory in which technological progress is still considered the basis of productivity growth, but technological progress can be affected by economic choices of firms. Endogenous growth theory suggests that firm innovation can influence productivity by impacting technological progress (Romer 1990, Grossman and Helpman 1991, and Aghion and Howitt 1992). Klette and Kortum (2004) advanced endogenous growth theory by establishing a link between innovative measures, such as R&D and patenting, with firm output growth, entry, exit, and size distributions. Klette and Kortum also used firm-level data and found a positive relationship between R&D and productivity. Using 2005 firm-level Canadian data, Therrien and Hanel (2010) also find that firm size, R&D intensity, and investment in equipment are positively related to the likelihood of introducing both process and product innovation.

Several other empirical studies use firm-level data and find a positive relationship between labour productivity and innovation. For example, Griffith et al. (2006) analyze data from France, Germany, Spain, and the UK and find that firms with higher R&D expenditures were more likely to innovate and were more productive from 1998-2000. Lööf and Heshmati (2006) use Swedish data and find a positive relationship between innovation generated sales, employee growth and productivity across multiple industries. Hall et al. (2009) focus on Italian SME's and find that both process and product innovations had a positive impact on a firm's productivity. Another finding from Therrien and Hanel (2010) is that innovation-related expenditures are significant predictors of the number of patent holdings and innovation related sales. Innovation related sales were also a significant determinant of labour productivity. Another Canadian study by Carew and Florkowski (2010) examined firm-level data from 1994-2005. Carew and Florkowski found positive relationships between multiple innovation related variables (physical capital, human capital, and business R&D expenditures) and firm labour productivity.

It is also noteworthy that there is limited literature that examines the relationship between innovation and productivity using data that is less than ten years old. During this time, changes in economies may have influenced innovation levels along with the types of innovations pursued. For example, in the food manufacturing sector, it is possible that the 2008 recession coupled with the consolidation of food retailers might have led to squeezed margins for the food manufacturing industry. In such a scenario, investments in innovation are susceptible to cutbacks, which can have lasting effects on productivity growth (Law and Singh, 2014). A report by Archibugi et al. (2013) noted that innovation-related expenditure in the UK dropped by 8% in 2008 compared to 2006 levels. Furthermore, a working paper by Levine and Warusawitharana (2014) indicates that innovation cuts from the 2008 recession are contributing to sustained low productivity growth in Europe. However, there is limited literature examining whether innovation levels along with the relationship between innovation and productivity have changed during the past ten years in Canada.

2.3. Innovation and Firm Size

In the innovation literature, firm size is frequently a variable of interest. Cohen (1995) summarises the Schumpeterian hypothesis that large firms innovate proportionally more than small firms. Justifications for this claim include greater availability of capital funds for large firms, economies of scale in R&D, relatively low average costs, and high returns to innovation due to greater volumes of existing output (Cohen 1995, 184). Counter-arguments to the Schumpeterian hypothesis have also been offered. It is commonly argued that as firms grow, R&D efficiency is undermined through the loss of managerial control or excessive bureaucracy (Scherer and Ross 1990). A second argument posits that as firms grow, the incentive to innovate for individual employees weakens as large corporations foster a more conservative business environment (Scherer and Ross 1990). Yet, as argued by Lee et al. (2010), SME's can have a relative advantage over large firms because a flexible production process allows SME's to be more innovative.

The empirical literature examines the relationship between firm size and innovation typically concludes that innovation scales up with firm size. However, specific market environments can favour large and small firms. Early studies such as Horowitz (1962) and Hamberg (1964) find evidence of innovation scaling up proportionally more than firm size. However, these studies did not control for industry fixed effects, which can bias estimates for the effect of firm size (Nelson et al., 1967). Most subsequent studies controlling for industry-specific effects could not establish a more than proportional advantage for large firms (Cohen, 1995). Referencing the work of Baldwin and Scott (1987) and Scherer and Ross (1990), Cohen (1995) claims that the consensus is that most industries display innovation rising proportionally with firm size. A body of more recent studies using firm-level data has suggested that, in certain market environments, large firms conduct proportionally more R&D, invest more in physical capital, and conduct more process innovations (e.g., Acs and Audretsch, 1988; Tourigny and Le, 2004; Cozzarin, 2004). However, certain market environments have also been shown to favour SME innovation. For example, in a study on European manufacturers, Vaona and Pianta (2008) found that, in sectors with high concentration ratios, SME's demonstrated higher innovation rates than large firms. Learning what market environments encourage innovation for SME's vs. large firms is an area which has not been extensively explored in a Canadian context and may be useful for designing economic policy.

2.4. Finance, Firm Growth, and Innovation

The idea of industry-specific factors influencing innovation has roots in classic papers such as Schumpeter (1943) who stresses the significant impact that market structure can have on R&D and innovation. Availability of finance as a market characteristic has received attention from previous works. Cash flow, as a measure of internal finance, has been suggested to drive innovation and R&D by many empirical studies (Antonelli, 1989; Hao and Jaffe, 1990; and Kraft, 1989). There is an ongoing debate as to whether cash flow encourages R&D or whether it reflects the profitability of past R&D. Using simple lag structures, Hao and Jaffe (1990) and Himmelberg and Petersen (1994) provide evidence that causality runs from cash flow to R&D. Many cross-country studies find that financial barriers restrict firm growth (Beck and Demirguc-Kunt, 2006; Klapper et al., 2006; Levine et al. 2000; Tourigny and Le, 2004). They also frequently find that the effect on productivity is more pronounced on SMEs. Beck et al. (2006) claim that one possible explanation for SME's susceptibility to financial barriers is larger firms' ability to generate more internal finance along with the less risky nature of financing a large firm. Furthermore, easier access to external finance is linked with a more competitive business environment, and a competitive business environment is positively linked with innovation and productivity growth (Klapper et al. 2006). Beck et al. (2006) reviews relevant literature and concludes that easier access to finance and well-developed financial markets generally have a positive impact on SME growth and productivity.

However, in the past ten years, there has been a growing literature indicating the existence of a threshold of financial development beyond which there are negative impacts on economic activity. For example, Cecchetti and Kharroubi (2012) use cross-country macro data and find that private sector credit extended by banks is negatively correlated with indicators of economic growth after credit levels reach 90% of GDP. They also find that faster growth in the financial sector is associated with slower economic growth (i.e., GDP growth). They argue that this result is caused by the financial sector not significantly contributing to real economic growth while competing with the rest of the economy for scarce resources. Using data from 87 developed and developing countries, Law and Singh (2014) obtain similar results to support an inverted U-shaped relationship between financial development and economic growth. The authors considered three measures of financial development (private sector credit, liquid liabilities, and domestic credit), and in each case, they found thresholds beyond which financial development hurt economic growth.

In addition to the scarce resources theory, Arcand et al. (2015) expand on some of the theories concerning why large financial systems can harm economic growth. One explanation starts by suggesting that, as economies become richer, financial services provided by banks become less important. If the marginal GDP growth from bank credit decreases with the level of economic development while the actual amount of bank credit does not decrease proportional to other sources of finance, then GDP growth would be expected to decrease due to using inefficient financial channels, i.e., channels which result in less GDP growth in comparison to other channels with higher marginal GDP growth. Little work has been done using firm-level data to examine the efficiency of different financial channels for specific markets. An alternative theory from Arcand et al. (2015) relates to risk-taking and volatility. Based on the empirical results from Easterly et al. (2001), economic output volatility starts to increase where private sector credit reaches roughly 100% of the GDP. Accordingly, this volatility is linked to exacerbations of economic downturns.

Given the link between innovation and productivity, understanding the relationship between finance and innovation may be useful for understanding what drives productivity. There is limited research examining if and how different channels of finance might be related to innovation. Kortum and Lerner (2000) find that increases in venture capital activity in the U.S. are associated with higher patenting rates. In this study, multiple indicators of innovative outcomes suggested that venture capital-funded innovations outperformed innovations using other sources of funding. The authors did note that selectivity bias could not be ruled out of these results. Bernstein (2015) finds that being a publicly listed firm increases the productivity benefits from innovation and shifts work toward more conventional and internal projects. Lerner et al. (2011) reach similar conclusions when examining the innovation rates of firms bought by private equity corporations. Moreover, Lerner (2012) finds that conglomerate firms frequently trade at a discount in comparison to non-conglomerate firms and that managers of conglomerates often reduce R&D budgets to meet short-term profit targets. Their results suggested that, while deep capital markets may be a valuable resource for a publicly traded company, they may also inhibit certain innovations. In a Canadian context, we could not find academic research using firm-level data to examine the relationship between finance sources and productivity or innovation.

2.5. Measuring Firm-Level Innovation

Before discussing measures of innovation, it is first useful to investigate the complex nature of the innovation. Recall that for that innovation refers to the adoption or implementation of a new good, production process, organizational structure or marketing strategy. However, before innovation can be implemented by a firm, the underlying knowledge about the innovation must first be invented and the firm must acquire this knowledge. To acquire such knowledge, firms often devote resources to R&D for the purposes of directly improving the level of technology available to the firm and positively impacting the firm's ability to innovate using foreign-bought technology (Cohen and Levinthal 1998). Evidence of this exists in the fact that firms in major industrialised countries consistently spend more on internal R&D than on acquiring technologies developed from other countries (OECD, 2005). This suggests that internal R&D and the purchase of foreign technology are not perfect substitutes for obtaining technological knowledge with which to innovate.

Furthermore, as noted by Stoneman (1995), there are different kinds of technological knowledge. For instance, research knowledge can be thought of as pertaining to scientific laws and theoretical models, whereas development knowledge pertains to the application of research knowledge to specific projects and is often the product of activities such as designing, building and testing prototypes, and pilot plants. The costs associated with acquiring development knowledge helps to explain why the dissemination of new technologies is not straightforward. Even if a certain technology is relatively well-studied, imitation costs can prevent firms from adopting new technology. Thus, in addition to invention, the accumulation of tacit knowledge is also important to the process of imitation.

We can now highlight some of the major roles of cumulative knowledge, and how it complecates the innovative process. The need for cumulative knowledge in imitation helps explain why R&D complements the absorption of foreign technologies in the process of innovation. Internal R&D augments a firm's competencies to learn about external technological developments and how they can be applied to their own firm. Furthermore, since cumulative knowledge affects the invention of new technological knowledge, it is reasonable that there is a feedback loop from innovation to invention. As more firms acquire technological knowledge in the process of innovation, they are better equipped to make their own new contributions to technological knowledge.

Lastly, it should be noted that due to the inherent complexity of knowledge creation and dissemination, technologies are diverse. Some technologies, such as pharmaceuticals, are marked by low imitation costs relative to the cost of invention, while others such as chemical manufacturing generally face high imitation costs (Mansfield et al., 1981). Even with technologies with similar imitation costs, there can be wide variation into the source of imitation costs (i.e., knowledge accumulation versus the cost of material inputs). The implication of the wide variation of technologies is that the accuracy of certain technology indicators can vary depending on the nature of the technology.

In an ideal scenario, innovation would be captured by a measure which describes the type (e.g., new product vs. new production process) of innovation, the complete costs of the innovation, and the long and short-term effects on productivity. However, the complexity of innovation and technological progress makes obtaining an ideal measure very difficult in practice. One of the main problems associated with measuring innovation is capturing the knowledge accumulation that led to innovation. This issue is further complecated by the fact that knowledge accumulation differs across technologies. Thus, in a hypothetical case where two innovations achieve the same outcome but use different technologies, the knowledge cumulation needed for each innovation could be drastically different. In addition, the uncertainty of the success of innovation implies that there are direct and indirect costs that are often not fully known to the firm before undertaking the innovation. Lastly, unobservable spillovers of innovation that have long term effects on productivity can also make it difficult to measure the full benefits of innovation. We now will briefly go over different measures for innovation that have received attention in the literature

2.4.1. R&D

A sizeable empirical literature exists on the topic of measuring innovation with the consensus being that the appropriateness of a measure for innovation depends on specific market circumstances. R&D expenditures have been extensively used as a proxy for innovation because R&D is a common precursor for firm innovation (Cohen, 1995). The use of R&D as a proxy is supported by many papers linking R&D activity and the likelihood that a firm will innovate (Cohen, 1995). However, in a review of innovation studies, Patel and Pavitt (1995) point out that R&D accounts for a small proportion of innovative activities in certain manufacturing sectors and are poor predictors of innovative outcomes in these cases. Alternatively, patents have been extensively used as an indicator of innovation since they are a common by-product of innovation (Griliches et al., 1987). While patents are a useful innovation proxy for certain sectors (e.g., pharmaceuticals), Levin et al. (1987) note that they are an unreliable indicator of innovative efforts in sectors with high imitation costs such as the automobile industry. Patel and Pavitt (1995) also acknowledge the growing usage of direct measures of innovative output from the identification of significant innovations and their sources along with large-scale surveys. The authors note that ranking the significance or magnitude of innovations is a substantial challenge associated with using innovation survey data. Crépon et al. (1998) and Lööf and Heshmati (2006) are also noteworthy works for showing that measures of innovative output (e.g., innovative sales) are often better at predicting innovation's effect on productivity effect than measures of innovative input (e.g., R&D).

2.4.2. Patents

In an economic context, patents are often thought of as an intermediate output of innovation. Using patents as a proxy for innovation has some advantages. First, in comparison to measures which represent inputs to the innovative process, such as R&D, patents are more likely to associated with an actual innovation, i.e., the output of the innovation process. This is because patents are used to protect the intellectual property of inventions and, thus, can serve as an approximate record of new inventions which are a key intermediate component in the innovative process. Patent data is often readily available in comparison to other more direct measures of innovative output such as survey data. Furthermore, the economic value of a patent can be estimated using measures such as the citation count on the patent.

However, there are many criticisms for using patents as a proxy for innovation. For example, the propensity to patent an innovation varies greatly between industries and technologies (Acs and Audretsch, 1989). Some proposed causes for this observed variation include the varying imitation costs and the competitive conditions of a market (Acs and Audretsch, 1989). Another criticism is that, while patents are common precursors to invention, they may not be associated with the successful implementation of an invention. The economic value of different patents can vary greatly and common control variables (such patent citations) have notable limitations (Schankerman and Pakes, 1985). Furthermore, if a researcher is concerned with the adoption of innovation, patents may be a poor measure to use since patents restrict the ability of other firms to adopt an innovation.

2.4.3. Direct Measurements and Surveys

Another approach to measuring innovation is the use of innovation surveys in combination with certain business data. The main advantage of using surveys is that it allows researchers to obtain measures on the output of the innovation process in comparison to relying on patents and R&D activity which represent inputs. Measuring innovative output offers relative stability in comparisons to inputs as evolving technologies and markets can change the role that a certain input plays in the innovation process.

Surveys can also be useful for classifying different kinds of innovation, e.g., new good or service versus a process innovation. One of the challenges of innovation related research is dealing with the heterogeneity between innovations. Innovations vary not just in their impact on productivity but also in terms of the factors that influence an innovation (Akcigit and Kerr, 2018). For example, while R&D spending may be a large determinant of whether a pharmaceutical company successfully introduces a new drug, it may play a lesser role in determining whether a food processing firm changes its management structure. To help explain some of this heterogeneity, innovations are often categorised into various groups in innovation surveys.

A primary drawback of using innovation surveys is that they can lack information about the significance or value of innovation. To illustrate this problem, consider a car manufacturer that introduces a new colour for an existing model of vehicle while also introducing a new line of cars with a more fuel-efficient engine. The colour innovation is generally considered to have less value as an innovation, but both changes will count as one innovation. As such, it will be difficult to distinguish between high and low-value innovations. Survey data can also face problems of measurement error and/or lack of precise data from the respondents. Given that measures of innovation inputs and output have differing advantages and shortfalls, it is common to use multiple measures for robustness purposes.

2.6. Innovation Complementarity

If innovations are grouped into classifications, then a natural question is whether these types of innovation are complements or substitutes for one another. In a theoretical setting, research has suggested that a complementary relationship may exist between product and process innovations. Athey and Schmutzler (1995) investigated how investment in research that promotes more research in the future can impact innovation decisions for product and process innovations. The introduction of a new product was modelled with an upwards shift of the demand curve while a process innovation was modelled with a decrease in the marginal cost of production. With this framework, Athey and Schmutzler (1995) showed that firms had more to gain if they introduced both of these types of innovation simultaneously. Results from a model developed by Kim and Mauborgne (2004) also indicate that firms simultaneously seek to reduce costs while improving product variety. Additionally, Mantovani (2006) finds that firms with greater market power have more incentive to invest in product and process innovation simultaneously.

In most cases, the rationale behind the complementary relationship between product and process innovation is that the implementation a product innovation increases the potential net benefit for a process innovation and vice versa. As noted by Brewin et al. (2009), complementarity may also arise out of innovation synergies, i.e., product innovation may also decrease the cost of process innovation. Furthermore, Brewin et al. (2009) argue that if a firm develops an innovation inhouse (versus adopting a technology developed externally), it may increase the firm's stock of knowledge. This improved stock of knowledge may then make it easier for a firm to implement other types of innovation. Lastly, another potential cause for innovation complementarity is that certain innovations span multiple categories of innovation (Stoneman, 1995).

Empirical evidence also indicates the existence of a complementary relationship between product and process innovations. Rouvinen (2002) find evidence of complementarity between product and process innovation using the estimated correlation between the two types of innovation from a bivariate probit model. Reichstein and Salter (2006) come to a similar conclusion with post-estimation of the correlation between two univariate logit models. Brewin et al. (2009) used a multivariate probit model and found that the complementarity of product and process innovation was significantly stronger when the innovation was developed in-house. Miravete and Pernias (2004) use a structural model to also find evidence of complementarity and conclude that complementarity is largely caused by the unexplained variation in the model. An important note is that all these studies find that the evidence for complementarity exists in the unexplained variation.

There is also empirical evidence linking non-technical innovations, such as marketing and organizational innovation, with product and process innovation. Schmidt and Rammer (2007) use bivariate probit models with German industry data to reach this conclusion. A complementary relationship between organizational and a product/process innovation is suggested in the results from Sapprasert (2010) and Faria and Lima (2009). Polder et al. (2010) also found evidence of complementarity between product, process, and organizational innovation. They also found that when introduced together these innovations had a greater impact on productivity.

One theory to explain the observed relationship between organizational innovation and product and process innovations is made by Brynjolfsson and Milgrom (2013). Suppose a firm is considering adopting a new production system and there are many complementarities in the existing production system. Then, if there are conflicts between old practices and the new system, there may be serious difficulties in transitioning to the new system. This is because, if there are many complementarities in the old system, then changing one practice with an innovation may actually reduce the overall performance of the system (Brynjolfsson and Milgrom, 2013). Organizational innovations can be important for reducing the conflicts between old and new production systems, thus, allowing easier adoption of new products and production systems (Brynjolfsson and Milgrom, 2013).

In disaccord to this argument, Gilli et al. (2014) use Wald tests to find no evidence of complementarity between product, process, and organizational innovation in terms of it's impact on "environmental productivity", *i.e.*, carbon emissions per unit of input. Hall et al. (2009) also do not find evidence of complementarity between innovations in their productivity equations. Furthermore, Jovanovic and Stolyarov (2000) use a theoretical model to show that if there are significant fixed costs of two complementary innovations, financial constraints will incentivize the firm to introduce the innovations sequentially (*i.e.*, one at a time) rather than simultaneously. Battisti et al. (2015) find empirical evidence to support Jovanovic and Stolyarov (2000) by analysing firm adoption two specific innovations: (1) computer aided design/manufacture equipment and (2) inter-organizational design teams with customers and suppliers. Although these two innovations are believed to be complementary, the researchers find evidence that they are commonly adopted sequentially among Italian manufacturing firms (Battisti et al., 2015).

2.7. Measuring Financial Constraint

A financial constraint is a broad concept; however, financial constraints are typically measured according to (i) a firm's access to external credit and (ii) the cost of external credit assuming the firm has access to it (Gorodnichenko and Schnitzer, 2013). Firm access to external credit is typically associated with developing countries and would likely not be a major issue for economies with well developed financial markets such as Canada. Thus, the Canadian analysis will focus on the cost of external finance.

One method through which financial constraint can be measured is survey data. Surveys on financial constraint typically involve respondents reporting a perceived level of constraint. Such measures have been used previously by papers such as Gorodnichenko and Schnitzer (2013) and Busom et al. (2014). A perceived financial constraint can have the advantage of directly measuring the constraint aspect of financial constraints; however, this method can introduce measurement error from respondents along with the heterogeneity of the respondent's perception of financial constraint. Two other common measures of financial constraints are cash flow and a variety of leveraging measures. Cash flow essentially captures a firm's ability to finance internally and has been found to play an important role in determining firms' innovation spending in various countries (Brown et al., 2009, 2012; Brown and Petersen, 2011). High leverage measures in a firm have been negatively associated with productivity growth and some innovation measures (Nucci et al. 2005; Nunes et al. 2007; Coricelli et al. 2012). While these observations could be the result of a firm taking on too much debt that it will not be able to repay, higher leverage measures could also be a sign that low equity and asset levels are increasing the cost of being able to secure external finance.

Another dimension of the cost of external finance which has received limited attention from the literature is the source of finance. Assuming that firms are profit maximisers, the source of finance used by a firm should be its lowest cost option including all direct and indirect costs (Fazzari et al., 1988). The fact that firms use a variety of sources of finance suggests that the cheapest source of finance can differ across firms. Then it is also plausible that different firms may differ in terms of the cheapest source of finance available as suggested by Cleary (2006). Expanding on this, it is also possible that certain sources of finance are particularly suited for firms wishing to innovate, i.e., such sources are relatively cheap. However, if a firm wishing to innovate had difficulty in accessing finance for reasons such as transaction costs of applying for finance, then this could be a financial constraint.

Chapter 3 : Conceptual Framework

The conceptual framework presented below provides the foundation to assess how financing sources relate to firm innovation and productivity. The framework highlights key relationships between the cost of external financing and the likelihood of innovation. The theoretical framework also provides the basis for developing an empirical analysis in chapter 5.

The chapter begins by assuming profit maximising firm in a perfectly competitive financial market and then allows for financial frictions that restrict a firm's ability to obtain external finance. Next, the chapter adapts a microeconomic model from Gorodnichenko and Schnitzer (2013) of how financial restrictions can influence a firm's innovation decisions. A partial equilibrium analysis of this model formalizes the impact of the direct and indirect costs of external finance on the likelihood of innovation. The chapter will conclude with a brief explanation of how the cost of external finance can differ across financial sources and across firms; this will help formulate testable hypotheses for the empirical analysis.

3.1. Problem of Access to Finance

To begin, in a perfectly competitive market that has negligible transaction costs, perfect information, and no taxes, financial capital would flow seamlessly from lenders to borrowers with profitable investment projects. In this situation, the decision to borrow or lend would be determined solely by the rate of return on investment projects along with the agents' time and risk preferences. As discussed in Modigliani and Miller (1958; 1963), a perfectly competitive financial market should also imply that the average cost of finance for debt and equity sources are equal. In this scenario, all profitable projects would receive external funding, *i.e.*, all projects with a rate of return meeting the market risk-adjusted cost of capital would be funded.

However, financial frictions that restrict this seamless flow of capital from lenders to borrowers by driving a wedge between the internal rate of return on an investment project and the rate of return that lenders require. For example, Modigliani and Miller use a theoretical model to show that in a perfectly competitive market "the average cost of capital to any firm is completely independent of its capital structure" (Modigliani and Miller, 1958, p. 268). They then introduce a corporate income tax into the model to show that the overall cost of capital increases with the introduction of the tax (Modigliani and Miller 1958; 1963). Furthermore, they show that this increase in the cost of finance would contribute to a decrease in a firm's incentive to invest. Taxes and other financial frictions can restrict firms' access to external finance and result in otherwise profitable projects not being financed. The next two paragraphs explore how other financial frictions, namely, transaction costs and principal-agent problems can also lead to an increase in a financial constraint.

First, transaction costs broadly refer to any implicit or explicit costs that are incurred as a result of the buying or selling process. In a financial context, lending transactions often requires activities such as matching investors with borrowers, researching investment/funding opportunities, and maintaining extensive records. In some circumstances, financial investment institutions can help lower the transaction costs for investors and borrowers. Many transaction costs, e.g., researching investment opportunities, are somewhat fixed in nature allowing large financial intermediaries to take advantage of economies of scale (Torre et al., 2017). The size of financial intermediary corporations may also speak to the magnitude of the transaction costs associated with the financial investment that firms and investors would otherwise face. In 2018, the combined net income of the two investment banks J.P. Morgan and Goldman Sachs totalled over $40 billion USD. Although financial intermediaries may reduce their impact, transaction costs introduce a gap between the rate of return that lenders receive versus the interest rates that borrowers pay. Thus, compared to the case of no transaction costs, firms face higher costs of obtaining external finance for innovative projects.

The second category of financial friction is principal-agent problems between the borrower (principal) and the lender (agent). Principal-agent problems can arise at different times in the lending transaction. Before the project had been financed, information asymmetries about the quality of the project introduce uncertainty to the transaction. Uncertainty is distinguished from risk in that risk implies a known probability that the investment will be successful, and that the borrower will repay. Under uncertainty, these probabilities are not known. In turn, low-risk investment projects can be difficult to distinguish from high-risk projects, and “good” projects may have difficulty securing funding as they compete for a finite supply of finance. Furthermore, after the project is financed the lender might take some action which could affect the probability of success of the project or lie about the success of the project in order to not pay back the full amount. To address these issues, the lender must allocate resources towards the monitoring and enforcement (e.g., legal action) of the lending contract. To pay for these added costs, lenders must increase their lending rates which exacerbates the transaction cost problem. In summary, the introduction of transaction costs and principal-agent problems leads to higher costs of obtaining external finance.

3.2. Model Setup

To help clarify how financial sources impact a firm's decision to innovate, this section presents a model of firm behaviour developed by Gorodnichenko and Schnitzer (2013) that focuses on the interaction between financial constraints and innovation. A few simplifying assumptions are made to highlight the key economic factors at work. The assumptions will be noted throughout the description of the model.

To start, suppose a profit-maximising manager of a firm has an opportunity to innovate at a fixed cost of F_I before beginning production. The innovation can be financed in one of two ways: 1) using only internal funds from the firm's previous cash flows and/or the owner's wealth, 2) using some amount of external finance. It is assumed that external funding is more expensive than internal funding and a unit of external finance costs the firm $\gamma > 1$ while the opportunity cost of internal finance is normalized to 1. Here, note that γ represents the costs of obtaining external credit and the indirect costs that are associated with external finance not being available. The model proposes two stages: an innovation stage and a production stage (see figure 3.1). In the first stage, the manager decides whether to spend money on an innovation. In the second stage, the manager attempts to finance production, which is influenced by the innovation decision in the first stage.

In stage 1, the manager has an option to implement the innovation but must rely on internal funds at this point. Specifying that innovation must first be financed using internal funds is consistent with empirical evidence (e.g., Hall and Lerner (2010); Ughetto (2008)). Intuitively, innovation is especially prone to asymmetric information between the borrower and the lender making it hard to collateralize. Thus, obtaining external finance in this stage would be costly at best. The exception to this may be very large firms. This is because firm size may act as a signal on the likelihood of success for an innovation (e.g., financing an innovation for Amazon generally is perceived less risky than financing an identical project for a smaller company).

In stage 2, the firm begins production, which can be financed from either internal or external sources. If possible, the firm would prefer to use internal finance since the firm will pay a premium of $\gamma - 1$ for external finance. Let the *a priori* probability that enough internal funding is available be q. The likelihood that the firm will need to use external financing for production is thus $1 - q$. Intuitively, q explains how likely a firm is to have to use a more expensive sources of finance and potentially experience a financial constraint.

Two categories of events can influence the likelihood of the firm needing external finance in stage 2, i.e., the demand for external finance. First, the manager can spend internal finance on innovation in stage 1. This would leave less funds available for production in stage 2. If innovation is conducted in stage 1, the likelihood of having enough internal funds for production is lowered by $\delta_I > 0$. Thus, innovation increases the probability that a firm will need to use external finance. The second event that can impact the likelihood of needing external finance is an exogenous liquidity shock. A liquidity shock is any unexpected shock to a firm's cash flow, for example, a natural disaster damages production equipment and the firm has to pay for repairs. Let a liquidity shock lower the probability of being able to finance production internally by $\delta_L > 0$. It is assumed that the liquidity shock occurs and is observed prior to the manager's innovation decision. Therefore, it will impact the decision to innovate. As an example, if the manager decides to innovate in stage 1 and the firm experiences a liquidity shock, then the probability of being able to finance production internally is given by $q - \delta_I - \delta_L$ while the probability of needing external finance is $(1 - q + \delta_I + \delta_L)$. Both innovation and liquidity shocks increase the probability that the firm will have to use a more expensive source of finance and potentially experience a financial constraint.

Now consider firm profits. In stage 1, the manager decides whether to innovate. Let π_i denote the firm's profit given that the manager decided not to innovate and π_i^I denote profit when the manager has implemented an innovation. The subscript i is an indicator for the use of external finance. That is, if production does not use any external finance then $i = 0$, and if the firm does use external finance then $i = \gamma$. Note that π_i^I does not include the cost of the innovation. This leads to the first assumption.

ASSUMPTION 1: *Ceteris paribus*, the profits under innovation are greater than the profits under no innovation, excluding the fixed costs of innovation. Mathematically, this is represented by the following expression.

$$\pi_i^I > \pi_i$$

A second assumption deals with profits under internal and external finance.

ASSUMPTION 2: Relative to financing production solely with internal funds, profits decrease if a firm must use any external finance to fund production. This is assumed to be true regardless of whether the firm innovates. Mathematically, this can be expressed by the following.

$$\pi_0 > \pi_\gamma \qquad \text{and} \qquad \pi_0^I > \pi_\gamma^I$$

Another important assumption of this model is that, given the firm is using external finance, the increases in profit resulting from innovation $(\pi_\gamma^I - \pi_\gamma)$ is decreasing in the premium on external finance. That is, the extra profit from innovation decreases in the cost of external finance.

ASSUMPTION 3: The increase in profit from innovation is decreasing in the premium (γ) on innovation. In mathematical terms, this says the following.

$$\frac{d(\pi_\gamma^I - \pi_\gamma)}{d\gamma} < 0$$

Although it is not immediately obvious, the Mathematical Appendix is devoted to showing that this assumption holds for a Dixit and Stiglitz monopolistic competition model (Dixit and Stiglitz, 1977). The Mathematical Appendix also shows that this result holds for innovations that reduce costs of production and innovations that increase demand.

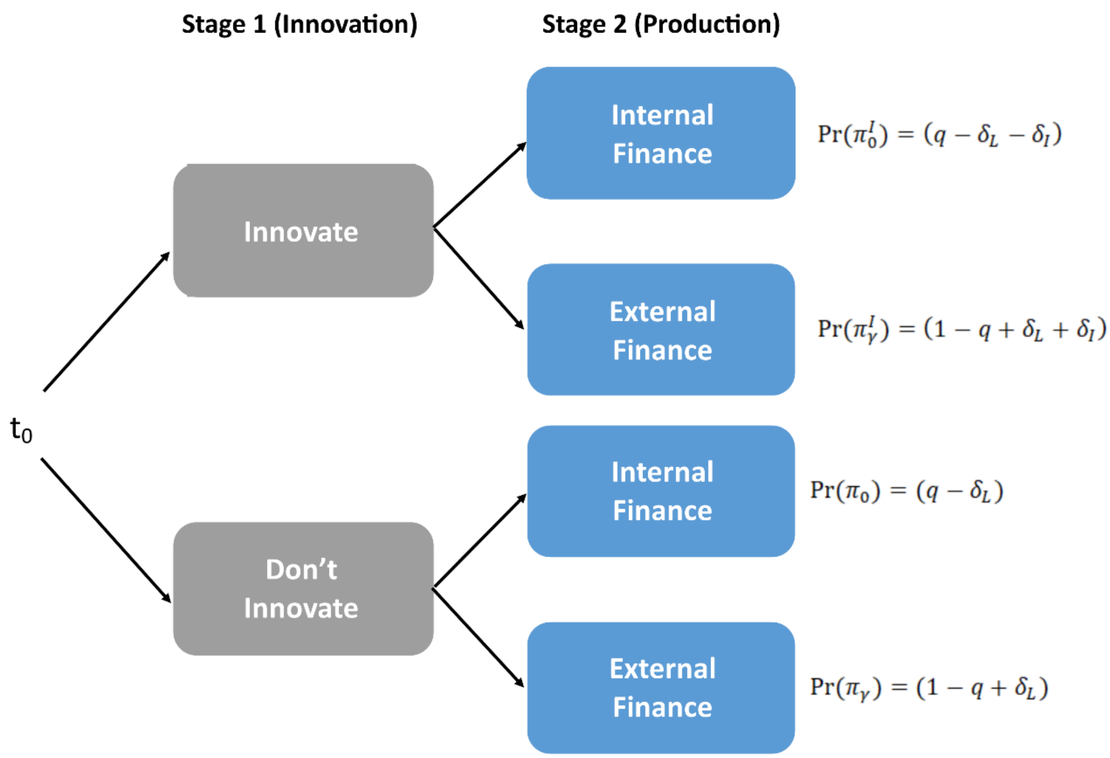

Figure 3-1: Graphical representation of a two-stage conceptual model
Source: Author

Turning to the manager's decision to innovate, the expected profit, if the firm does not innovate, can be written as:

$$E(\pi) = (q - \delta_L)\pi_0 + (1 - q + \delta_L)\pi_\gamma \quad (3.1)$$

Similarly, the expected profit if the firm does innovate is:

$$E(\pi|I) = (q - \delta_L - \delta_I)\pi_0^I + (1 - q + \delta_L + \delta_I)\pi_\gamma^I - F_I \quad (3.2)$$

where the fixed cost of the innovation is denoted by F_I. Following Gorodnichenko and Schnitzer (2013) the manager is assumed to be a risk neutral profit maximiser. The incentive to innovate in stage 1 can then be expressed as:

$$\Delta_\pi^I \equiv E(\pi|I) - E(\pi) \tag{3.3}$$

$$= (q - \delta_L)(\pi_0^I - \pi_0) + (1 - q + \delta_L)(\pi_\gamma^I - \pi_\gamma) - \delta_I(\pi_0^I - \pi_\gamma^I) - F_I$$

and the manager will decide to innovate if and only if $\Delta_\pi^I > 0$. The term Δ_π^I is the key decision variable for the firm and will be further investigated in the next section.

3.3. Partial Equilibrium Analysis

To examine the impact of the exogenous liquidity shocks on the expected change in profit from innovation, consider the first derivative of Δ_π^I with respect to a liquidity shock's impact on the probability of needing external finance δ_L:

$$\frac{d\Delta_\pi^I}{d\delta_L} = -(\pi_0^I - \pi_0) + (\pi_\gamma^I - \pi_\gamma) < 0 \tag{3.4}$$

where the inequality in equation (3.4) follows from assumptions 1 and 2. Thus, larger liquidity shocks decrease the likelihood of innovation. This makes intuitive sense because larger liquidity shocks increase the likelihood that the firm will need to use external finance which would increase the effective cost of innovation. To examine the effect of the added cost of external finance on innovation, consider the derivative of Δ_π^I with respect to the added cost of external finance γ:

$$\frac{d\Delta_\pi^I}{d\gamma} = (1 - q + \delta_L)\frac{d(\pi_\gamma^I - \pi_\gamma)}{d\gamma} + \delta_L \frac{d\pi_\gamma}{d\gamma} < 0 \tag{3.5}$$

Since π_γ represents profit given that the firm is using external finance and γ represents the cost of external finance, it can be expected that $\frac{d\pi_\gamma}{d\gamma} < 0$. By this conclusion along with assumption 3, the inequality in equation (3.5) holds. The interpretation of equation (3.5) is that more expensive external finance decreases the likelihood that the firm will innovate.

It is also interesting to consider the following second-order effect:

$$\frac{d\Delta_\pi^I}{d\delta_L d\gamma} = \frac{d(\pi_\gamma^I - \pi_\gamma)}{d\gamma} < 0 \tag{3.6}$$

where the inequality in equation (3.6) follows from assumption 3. Thus, there is a negative interaction between liquidity shocks and the cost of external finance, i.e., the more expensive the external finance is, the more susceptible is the innovation decision to liquidity shocks.

To summarize, three main results are drawn from this analysis. First, since the impact of innovation on the likelihood of needing external finance (δ_I) is assumed to be positive, the model predicts that innovation will make a firm more likely to need external finance. Secondly, higher premiums on external finance are expected to decrease the likelihood that a firm will innovate. Lastly, the model predicts that higher premiums on external finance exacerbate the negative effect of liquidity shocks on a firm's decision to innovate.

3.4. Complementarity of Innovation

Complementarity is an important concept to consider because it can alter the payoffs and costs of introducing innovations (Milgrom and Roberts, 1995). Milgrom and Roberts (1995) define two activities to be complements if "doing (more of) any one of them increases the returns to doing (more of) the others" (Milgrom and Roberts, 1995, p. 181). To define complementarity mathematically, I follow the framework laid out in Brynjolfsson and Milgrom (2013). I start with considering a profit maximising firm that can adopt two possible innovations: innovation 1 and innovation 2. The firm is discerning whether to adopt one of or both of the innovations. Also, assume that it is possible for the firm to adopt the innovations together and separately. Following the notation from the previous section, let $\Delta_{\pi,1}^I$ and $\Delta_{\pi,2}^I$ be the change in net profit if the firm adopts innovation 1 and innovation 2 separately while $\Delta^I_{\pi,B}$ is the change in net profit if the firm adopts both innovations together. Two innovations are then said to be complementary if the following is true regardless of the firm's other choices (Brynjolfsson and Milgrom 2013).

$$\Delta^I_{\pi,B} \geq \Delta^I_{\pi,1} + \Delta^I_{\pi,2} \tag{3.7}$$

A consequence of equation (3.7) is that, *ceteris paribus*, if innovation 1 has already been introduced then the existence of complementarity increases net profit from also adopting innovation 2. Consequently, this increases the likelihood that the firm will adopt innovation 2.

With this definition for complementarity between two innovations, the definition can be extended to consider three or more innovations. A set of three or more innovations are complementary if *every* possible pair of innovations within the set is complementary. In practice, this means that to evaluate the complementarity of a set of innovations, one can check all the possible pairwise complementarity relationships within the set (Brynjolfsson and Milgrom 2013).

3.5. Factors affecting Cost of External Finance

This section explores the cost of external finance (denoted by γ in the above model) and how it can be influenced by certain financial factors. Transaction costs associated with external finance can increase the rate of return required by external lenders to fund a project. In a demand and supply framework, the introduction of transaction costs can be modelled as a leftward shift in the supply curve for finance (See Figure 3.2). In this framework, investors collectively represent supply, and the firm's seeking finance comprise demand. The shift in supply from transaction costs will effectively increase the price that firms face, although the magnitude of the increase will depend on the elasticities of supply and demand (compare $P_2 - P_1$ in panel A with panel B in Figure 3.2). In the extreme case of a perfectly elastic demand, this increase in price for finance effectively increases γ in the theoretical model. From equation (3.5), an increase in γ should decrease the incentive for a firm to innovate.

Furthermore, the introduction of the principal-agent problems from a frictionless market can exacerbate transaction costs if the principal-agent problems are resolved with monitoring and enforcement efforts. The principal-agent problems can also lead to a decrease in the number of investors willing to lend money especially at higher interest rates due to the uncertainty of returns, i.e., credit rationing. A credit rationing situation arising from the principal-agent problems can increase γ since this parameter includes the indirect costs associated with firms not being able to secure external finance. We can assume that if a firm would have secured external finance with no credit rationing, then the indirect cost of not obtaining external finance is greater than the direct cost of external finance.

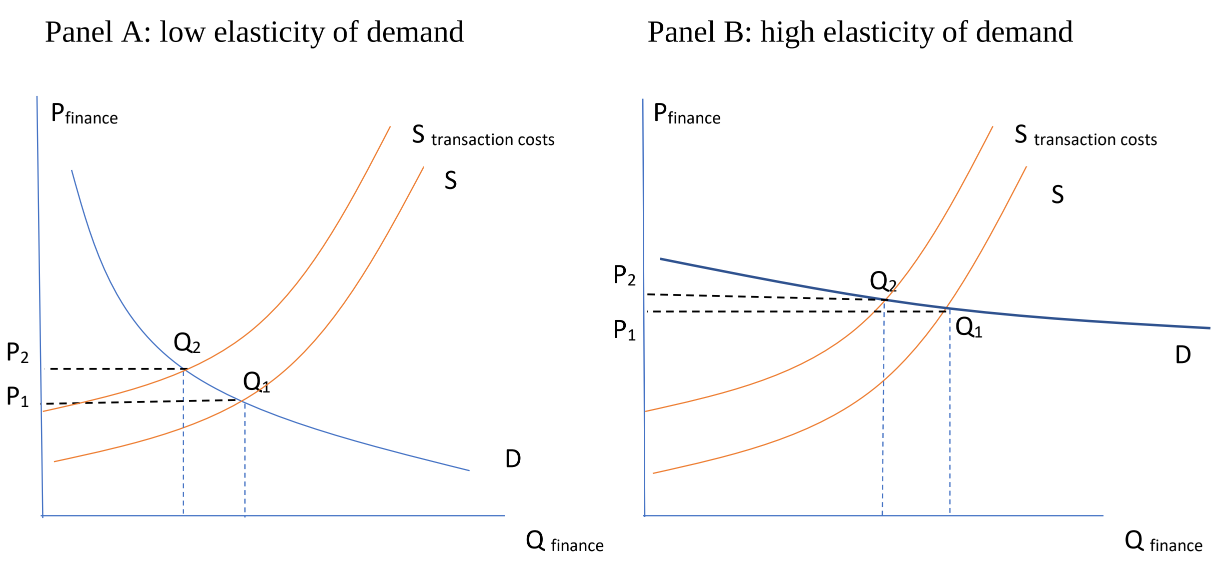

Figure 3-2: Impact of transaction cost on a financial market

Thus, with credit rationing, more firms that would otherwise have purchased external finance (especially those with projects with high indirect costs) cannot obtain finance and face the higher indirect costs of not obtaining finance, which increases γ. From equation (3.5), therefore, the net effect of transaction costs and principal-agent problems will be to decrease the likelihood of innovation.

Given the complex reality of financial programs, it is likely that the true cost of obtaining external finance (γ) may vary from firm to firm. It is also possible that there is variation in γ across different sources of finance. For example, the effect of principal agent problems may be more severe in the case of equity finance versus debt finance. Assuming that firms are profit maximisers, it follows that if a firm uses a particular source of external finance, then that source was the lowest cost option. Differences in sources of external finance may be an interesting topic for future research; however, this analysis will follow the argument of Modigliani and Miller (1958; 1963) and assume that the average cost of external finance does not differ based on the specific source of external.

Government action can also impact the cost of external finance. There is reasonable motivation for government intervention in financial markets to encourage innovation because innovation is vital for long-term productivity growth and innovation is often associated with positive spillover effects that are not always internalized by firms. For example, while studying the Streptococcus bacteria used to make yogurt food scientists accidentally discovered important functions of CRISPR sequences in bacteria which revolutionized gene editing sciences and could have many social benefits. Ignoring macroeconomic effects of monetary policy, the government can encourage innovation by offering finance, administered via subsidies or tax incentives, to innovation projects at lending rates below market rates. The government can also attempt to lower the transaction costs faced by borrowers and lenders through activities such as public research and financial regulation. In connection to financial regulation, the government can also help alleviate the impact of the principal-agent problems on lending rates through enforcement of financial regulations to discourage activities such as fraud. Theoretically, all these policies can have the effect of decreasing the cost of external financing γ as defined in the above model.

Chapter 4 : Data

The purpose of this chapter is to describe the data used in this study as well as the main variables that are used in the empirical framework.

4.1. Data Description

The data for this study comes from the 2002 and 2005 versions of the Business Environment and Enterprise Performance Survey (BEEPS), a joint initiative of the European Bank for Reconstruction and Development (EBRD) and the World Bank Group.[1] These are large surveys of 14,000 firms in 2002 and 10,000 firms in 2005 in 27 transition countries in eastern Europe and central Asia (see Table 4-1). The following is a table of observations by country.

[1] This data can currently be accessed through the ERBD website: https://ebrd-beeps.com/ and is also published as supporting material for Gorodnichenko and Schnitzer (2013): https://doi.org/10.1111/jeea.12033

Table 4-1: Observations by country

Country	Freqency	Percent
Former Yugoslavia	807	3.29
Macedonia	536	2.18
Albania	513	2.09
Croatia	599	2.44
Turkey	1,585	6.46
Bosnia	582	2.37
Slovenia	559	2.28
Poland	2,372	9.67
Ukraine	1,504	6.13
Belarus	854	3.48
Hungary	1,411	5.75
Czech Republic	918	3.74
Slovakia	581	2.37
Romania	1,391	5.67
Bulgaria	761	3.1
Moldova	842	3.43
Latvia	532	2.17
Lithuania	554	2.26
Estonia	539	2.2
Georgia	516	2.1
Armenia	824	3.36
Kazakhstan	1,360	5.54
Azerbaijan	802	3.27
Uzbekistan	832	3.39
Russia	1,665	6.79
Tajikistan	558	2.27
Kyrgyzstan	537	2.19
Total	24,534	100

There are 756 firms that were surveyed in both the 2002 and 2005 versions of the survey. This subsample of firms represents a panel dataset. However, because this subsample is relatively small, the data will be pooled and treated as cross sectional data (with a control variable for year). The surveys relied on the same sampling frames and used identical questionnaires in all countries. To ensure that the samples are representative of the relevant population of firms, the surveys used stratified random sampling. In each country, the sectoral composition of the sampling frame was determined by each sector's relative contribution to

GDP. Firms that operate in sectors subject to government price regulation and prudential supervision, such as banking, electric power, rail transport, and water and wastewater, were excluded from the sample. The sample includes very small firms with as few as two employees and large firms with up to 10,000 employees. Moreover, the data include firms in rural areas as well as large cities. Hence, this data set enables an analysis of diverse firms in many countries. In addition to basic information about firm characteristics such as age, employment size and composition, and degree of competition, BEEPS collects information on self-reported measures of access to finance. BEEPS also asks firms to report various types of innovation activity.

4.2. Variable Descriptions

The following is description of the explanatory variables from the BEEPS data that will be used in the empirical framework.

Financial constraint (FC) is the main variable of interest and is intended to capture financial constraint that is faced by firms. The BEEPS survey contains a question asking how much of an obstacle is access to external finance to the firm's growth. The responses to this question were *no obstacle, minor obstacle, moderate obstacle,* and *major obstacle*. This is the variable that is used to measure financial constraint in this analysis.

Number of employees (L) measures the number of employees in the firm and is intended to control for firm size. In the empirical analysis, $Log(L)$ is used to reduce specification error and so that coefficients can be interpreted as elasticities. The square of logged labour is also included to control for a potential nonlinear relationship between firm size and innovation

Education level of workers (EDU) refers to the share of employees with a university education.

Temporary labour (*Temporary Labour*) describes the share of temporary workers in the firm.

Skilled labour ($SKILL$) denotes the share of skilled workers. The definition of "skilled" labour was left to the discretion of the respondent. The variables (EDU), (*Temporary Labour*), and ($SKILL$) are used to account for human capital differences within firms.

Age is the log of years since the firm began operation and is included to account for the possibility that entrepreneurs may start a new firm with the intent to introduce a specific innovation.

Competes in international markets (CNM) is a dummy variable that indicates whether a firm competes in international markets

$Markup$ is the respondent's response to a question asking for the average markup on sold products. $Markup$ and (CNM) are used to control for the competitive pressures that a firm faces within it's the specific market.

Share of sales to multi-national enterprises ($SMNE$) refers to the share of sales to multinational enterprises and ($Import$) refers to the share of imported inputs. These variables are used to control for integration with foreign markets as more external exposure may help firms to adopt new technologies from these markets.

Location (Loc) is a set of dummies to control for the size of the population where the firm is operating. Firms located in more densely populated areas may be exposed to innovative business clusters and, thus, more likely to innovate.

Capacity utilization (CU) refers to the share of a firm's output to its maximum possible output. This is to control for the possibility that firms that are producing at near maximum capacity may have fewer firm resources to devote to innovation.

Lastly, to complement capacity utilization, optimal labour (*Optimal*) is a variable describing the percentage of the current workforce of the firm that the manager deems to be the optimal number of workers for their business. This variable is derived from the question: what would be your optimal level of employment as a percent of your existing workforce (e.g., 90% implies you would reduce your workforce by 10%, 110% means you want to expand by 10%)?

To investigate different types of innovation, five different measures for innovation are considered. All of the innovation variables are binary, *i.e.*, equal to one if the firm reported a certain category of innovation and zero otherwise. The following is a description of the types of innovation considered in this study.

Product innovation (*New Good*) is a dummy variable that describes whether a firm has begun selling a new good or service within the past three years. This variable was derived from the question: did your firm successfully develop a major new product line/service in the past three years?

Process innovation (*New Tech*) is a dummy variable that describes whether a firm has introduced a new or significantly improved production technology. This variable was derived from the question: did your firm introduce a new production technology in the past three years?

Organizational Innovation (*New Org*) is a dummy variable that measures whether a firm has made positive investment into a new organizational or management strategy. This variable was derived from the question: did your firm undergo any major reallocations of responsibility and resources between departments in the past three years?

Production license innovation (*New License*) is a dummy variable that refers to a firm obtaining a new licensing agreement for a product or production technology from an external source. Essentially, this variable represents an external process innovation. This variable was derived from the question: did your firm obtain a new production licensing agreement in the past three years?

Marketing innovation (*Ad* Invest) is a dummy variable that denotes positive investment into a new marketing or advertising campaign and will be used as a proxy for marketing innovation. This variable was derived from the question: did your firm invest in new marketing and/or advertising in the past three years?

A tabulation of the main financial constraint variables, innovation variables, and explanatory variables are provided in Table 4.2, Table 4.3, and Table 4.4.

Table 4-2: Summary of innovation variables

	2002		2005		Pooled	
Innovation Type	Frequency (%)	Obs.	Frequency (%)	Obs.	Frequency (%)	Obs.
New Good/Service	36.24	6,623	38.11	9,655	37.35	16,287
New production Technology	28.38	6,629	32.34	9,519	30.71	16,148
Organization Innovation	28.46	6,588	15.14	9,589	20.57	16,177
New Production License	17.95	6,628	12.91	9,655	14.96	16,283
Marketing Innovation	94.21	3,975	60.31	5,430	74.64	9,405

Table 4-1 presents a summary of the innovation variables from the 2002, 2005, and pooled (i.e., both 2002 and 2005) BEEPS data set. The sample presented in this table is restricted to privately owned domestic firms. The "Obs." columns denote the number of firms that answered a given innovation question. The "Frequency" columns are calculated by taking the number of firms that introduced a product, in-house process, organizational, external process, and marketing innovation and dividing that number by the "Obs." column.

Table 4-3: Summary of financial constraint variables

	2002		2005		Pooled	
Degree of obstacle to firm growth	Frequency (%)	Response Number	Frequency (%)	Response Number	Frequency (%)	Response Number
No Obstacle	34.84	2,199	36.33	3,343	35.72	5,542
Minor Obstacle	19.74	1,246	20.96	1,929	20.47	3,175
Moderate Obstacle	24.00	1,515	24.04	2,212	24.02	3,727
Major Obstacle	21.42	1,352	18.67	1,718	19.79	3,070

Table 4-2 presents a summary of the main financial constraint variables from the 2002, 2005, and pooled (i.e., both 2002 and 2005) BEEPS data set. The sample presented in this table is restricted to privately owned domestic firms. The survey asked firms to rate the degree to which access to finance is an obstacle to the growth of their business. Firms could respond with the four options displayed, ranging from "No Obstacle" to "Major Obstacle". The "Response Number" columns denote the number of firms that selected the degree of financial constraint. The "Frequency" columns are calculated by dividing the response number by the total number of responses in a selected sample.

Table 4-4: Summary statistics of explanatory variables

	2002			2005			Pooled		
Explanatory Variables	Mean	Standard Deviation	N	Mean	Standard Deviation	N	Mean	Standard Deviation	N
SMNE (%)	0.08	0.23	5414	0.06	0.18	8262	0.07	0.20	13676
Imports (%)	0.27	0.36	5275	0.26	0.36	8286	0.27	0.36	13561
Labour	118.62	750.11	13801	114.84	1264.77	8502	117.18	978.73	22303
Skilled L (%)	0.48	0.31	13801	0.49	0.31	8499	0.49	0.31	22300
EDU (%)	0.28	0.29	13799	0.26	0.29	8498	0.27	0.29	22297
Markup (%)	0.19	0.10	13573	0.23	0.14	8488	0.20	0.11	22061
Age	15.35	18.68	5590	15.72	17.34	8494	15.57	17.88	14084
Optimal L	1.05	0.30	5415	1.09	0.30	8383	1.07	0.30	13798
Temporary L (%)	0.08	0.16	5512	0.08	0.16	8384	0.08	0.16	13896
CU (%)	0.79	0.15	13792	0.80	0.21	8498	0.80	0.17	22290
CNM	0.40	0.49	13802	0.48	0.50	8502	0.43	0.50	22304
State Owned (%)	0.66	0.47	13802	0.10	0.30	8502	0.45	0.50	22304

Note that the “counts” differ between the variables within a given year. This is because some survey respondents occasionally answered some questions but not others. This sample includes government-owned firms. Foreign-owned firms were excluded from this subsample.

Because some firms chose to skip some questions, some of the observations contain missing values for certain variables. Furthermore, it is noteworthy that the percentage of firms that are currently or previously owned by the government (*State Owned*) is much lower in the 2005 survey relative to the 2002 survey. After removing all observations with missing values, observations identified as outliers (method for identifying outliers is described in section 6.1.), and corresponding to state-owned firms, the subsample that will be used to estimate the empirical model is obtained. It should be noted here that the main regression model of this thesis was also run on the full sample that includes currently or previously owned by the government (see Table 8-5 Appendix B). Summary statistics for this cleaned data are presented Table 4-4.

Table 4-5: Summary statistics of cleaned data

	2002			2005			Pooled		
Explanatory Variables	Mean	Standard Deviation	N	Mean	Standard Deviation	N	Mean	Standard Deviation	N
SMNE (%)	0.08	0.22	3525	0.05	0.17	6374	0.06	0.19	9899
Imports (%)	0.28	0.37	3525	0.27	0.37	6374	0.27	0.37	9899
Labour	89.27	903.50	3525	66.17	285.42	6374	74.39	585.84	9899
Skilled L (%)	0.47	0.31	3525	0.50	0.32	6374	0.49	0.31	9899
EDU (%)	0.29	0.30	3525	0.25	0.28	6374	0.27	0.29	9899
Markup (%)	0.19	0.14	3525	0.22	0.13	6374	0.21	0.13	9899
Age	11.95	13.96	3525	13.68	14.21	6374	13.07	14.14	9899
Optimal L	1.06	0.29	3525	1.10	0.31	6374	0.64	0.48	9899
Temporary L (%)	0.08	0.16	3525	0.08	0.16	6374	1.09	0.30	9899
CU (%)	0.79	0.21	3525	0.80	0.21	6374	0.08	0.16	9899
CNM	0.99	0.08	3525	0.48	0.50	6374	0.80	0.21	9899

This table presents the summary statistics for the final subsample which is used to estimate the main empirical model in section 6.3. This subsample is obtained by omitting observation with a missing value in any of the explanatory or dependent variable and by omitting any observation that is flagged as an outlier according to the method described in section 6.1.

Chapter 5 : Empirical Model

This chapter describes two main empirical models. The first model investigates the impact of firm financial constraints on the likelihood of firm innovation. This section provides estimation strategies along with an instrumental variable strategy to address potential endogeneity bias. The second model examines the relationship between productivity, innovation, and financial constraints.

5.1. Innovation and Financial Constraint

5.1.1. Multivariate Probit Innovation Model

This section describes the multivariate probit model that estimates the relationship between financial constraint and innovation. A multivariate probit model estimates multiple probit models simlultaneoulsy while allowing for correlation between the errors of the multiple probits. As will be further explained, allowing for correlation between the errors can help to avoid simultaneity bias.

If the correlations between the different types of innovation decisions are ignored, then the decision to implement a specific type of innovation can be estimated with a series of single equation probit models. If the innovation decisisons are correlated with one another and the explanatory variables cannot account for this correlation, estimating a single equation probit model can produce simultaneity bias in the parameter estimates. This simultaneity bias can result in underestimating or overestimating the impacts of various factors on each type of innovation (Cappellari and Jenkins, 2003). The multivariate probit model simultaneously estimates the effects of financial constraint and other control variables on each type of innovation while accounting for interaction among the unobserved innovation decisions (Cappellari and Jenkins, 2003). This joint estimation of the innovation equations allows for a more realistic scenario in which managers simultaneously decide whether to introduce a group of innovations that can act as complements or substitutes to each other.

To examine the link between financial constraints and innovation, this thesis will present a joint estimation of a firm's decision to implement the five types of innovation by using a multivariate probit (MVP) model. It is assumed that firms choose the innovation bundle that maximises the present value of their expected profits. The model defines the following innovation criterion Δ_{π}^{I}:

$$\Delta_{\pi im}^{I} = E(\pi|I)_{im} - E(\pi)_{im} \tag{5.1}$$

where Δ_{π}^{I} is the unobservable present value of the expected net benefit from innovation for the i^{th} firm. The subscript *m* is included to distinguish between the five types of innovation: product, process, organizational, production license and marketing innovation. $E(\pi)_{im}$ denotes the expected present value of current and future profits without innovation, and $E(\pi|I)_{im}$ denotes the expected present value of current and future profits if innovation *m* is introduced. Assume that firms develop or introduce innovations when $\Delta_{\pi im}^{*} > 0$.

Keeping in mind that $E(\pi|I)_{im}$ and $E(\pi)_{im}$ account for all costs and benefits (including opportunity costs), we observe the firm's innovation decision as:

$$I_{im} = \begin{cases} 1 & if\ \Delta_{\pi im}^{*} > 0 \\ 0 & otherwise \end{cases} \tag{5.2}$$

where I_{im} is a binary observable outcome such that $I_{im} = 1$ indicates that firm *i* has introduced the m^{th} innovation, and $I_{im} = 0$ indicates that the firm did not introduce the innovation.

The following equation can be estimated:

$$I_{im} = \Phi(\alpha'_m z_{im} + \beta_m{}' X_{im} + \varepsilon_{im}) \tag{5.3}$$

Where $\Phi(.)$ is the normal cumulative distribution function, z_{im} represents the independent variable of interest, i.e., financial constraint variable, and X_{im} represents the vector of control variables (e.g., number of employees, share of educated workers, and industry fixed effects). β and α are unknown parameters, and ε_{im} are error terms that are distributed as multivariate normal, each with a mean of zero, and variance-covariance matrix V, where V has values of 1 on the leading diagonal and correlations $\rho_{jk} = \rho_{kj}$ as the off-diagonal elements (Cappellari and Jenkins, 2003):

$$V = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} & \rho_{15} \\ \rho_{21} & 1 & \rho_{23} & \rho_{24} & \rho_{25} \\ \rho_{31} & \rho_{32} & 1 & \rho_{34} & \rho_{35} \\ \rho_{41} & \rho_{42} & \rho_{43} & 1 & \rho_{45} \\ \rho_{51} & \rho_{52} & \rho_{53} & \rho_{54} & 1 \end{bmatrix} \tag{5.4}$$

The parameters of the multivariate probit model are estimated via simulated maximum likelihood as described in Cappellari and Jenkins (2003).

5.1.2. Identification Strategy

As noted by Gorodnichenko and Schnitzer (2013), which will be referred to as GS from this point forward, estimating equation (5.3) by OLS or a simple probit may lead to upwards endogeneity bias on the parameter of interest α_m. The source of this bias is duality between innovation and financial constraint. This bias is in addition to the potential simultaneity that can arise from not using univariate probit over a multivariate probit model. While one of the results from the theoretical model in chapter 3 was that financial constraint should negatively impact innovation, the model also predicted that firms that decide to innovate have less financial capital available for the production stage. Thus, innovating firms are more likely to be feel financially constrained. Some empirical work has investigated the relationship between financial constraints and innovation. For example, Canepa and Stoneman (2008) report that firms from high-tech industries and small UK firms were the most likely to report a project being abandoned or delayed because of financial constraints. Using French survey data, Hajivassiliou and Savignac (2008) also find that innovation and financial constraints are positively correlated in the full sample but that the correlation becomes negative when the sample is restricted to firms they classify as likely innovators. Thus, there is expected underestimation of the parameter of interest and the source of this bias is that, in spending money to innovate, firms will be more likely to experience financial constraint.

To correct for endogeneity bias, GS propose using exogenous shocks to cash flow of a firm (interpreted as δ_L in the conceptual framework) as instrumental variables. In theory, liquidity shocks should influence internal funds as well as a firm's attractiveness to external investors but only influence innovation decisions indirectly through financial constraint, thus, satisfying the exclusion principal for instrumental variables. Three variables in the BEEPS data set are particularly suited to measuring exogenous cash shocks. The first is a dummy variable describing if a firm has overdue payments to suppliers (*Overdue*). Overdue payments can result in contractual fines and breakdown in the relationship between the firm and its suppliers. As such, financing innovation with overdue supply payments should represent an expensive method to finance innovation. As such, firms would not be expected to have overdue payments unless they were facing liquidity issues. In addition, when asked what their response to an unexpected shock to cash flow would be, approximately half of all firms in the sample reported that they would delay payments to their suppliers.

The BEEPS survey also contains variables describing the share of payments that are settled by debt swap or barter (i.e., the exchange of goods for other goods) (*debt/barter)* with customers and with suppliers. Since debt swaps and barters are relatively illiquid means of exchange, their presence could also signal that a firm is experiencing liquidity issues. Using debt swap or barter was another common reaction of firms to a hypothetical loss in cash flow. Overall, the three options of debt-swap, barter, and overdue payments accounted for over 75% of firms' response to an unexpected liquidity shock. Thus, the *Overdue* and *debt/barter* should be good proxies for liquidity shocks. As such, these two variables should be correlated with financial constraints while not being related to innovation to satisfy the exclusion restriction for an instrumental variable.

The third proxy for liquidity shocks that will be used as an instrumental variable is the losses that a firm experienced that were caused by unexpected events (*lost_sales)*. This variable is constructed by combining three questions from the BEEPS survey. The first question is "what percent of sales was lost due to delivery delays from material input suppliers?" The second question is "what percent of total sales was lost due to (i) Power outages or surges from the public grid; (ii) Insufficient water supply; (iii) Unavailable mainline telephone service?" The third question is "what percentage of the value of products your establishment shipped over the last 12 months was lost while in transit due to breakage, spoilage or theft?" From the perspective of the firm, these incidents should be unanticipated and likely to cause a liquidity shock. As such, (*lost_sales*) should be a strong predictor of financial constraints. Furthermore, there seems to be little reason to suspect that these unexpected losses would be predictors of innovation.

As with GS, I also find that these three instrumental variables are strong predictors of the endogenous variable. The F-statistic in the first stage regression is above 10 for most of the innovation equations which is a common benchmark for evaluating instrumental variables (See Table B.1). The exception for the first stage for marketing innovation model in which the F-statistic is 9.32. However, there are many missing values in the marketing innovation equation which could explain why the first-stage F-statistic is slightly below 10 (Table B.1). More tests on the appropriateness of the instrumental variables will be discussed in chapter 6.

Unlike GS, I implement the instrumental variables into a multivariate probit model, using two-stage least squares and a control function approach as described in Wooldridge (2015) (also see Heckman and Robb, 1985; 1986; Wooldridge, 1997; Heckman and Vytlacil, 1998; Rivers and Vuong 1988; 2004; Heckman and Navarro, 2004). The purpose of the control functions, in this context, is to implement the instrumental variables that were used in the univariate case, namely, overdue payments (*Overdue*), the share of transactions settled with debt swap or barter (*lost sales)*, and lost sales from unexpected events (*lost sales*). Control functions have the added benefit of providing a means of testing for exogeneity in each equation of the multivariate probit model (Wooldridge, 2015). An exogeneity test is useful as it provides information on the appropriateness of the instrumental variables. While control functions are a broad econometric technique, this analysis specifically follows the Rivers and Vuong (1988) approach which begins with a simplified probit model:

$$y = \Phi(\beta x + \alpha x' + u) \quad (5.5)$$

where x is a set of exogenous explanatory variables (not correlated with the error term), x' is a set of endogenous explanatory variables, and y are the dependent variables. It is then necessary to make a homoscedastic normality assumption about the instrumental variables:

$$x' = \pi z + v, v|z \sim N(0, \tau^2) \quad (5.6)$$

where z represents a vector of exogenous instruments (Rivers and Vuong, 1988). A key assumption of this approach is that the error terms, u and v, are independent of z (Rivers and Vuong, 1988). This is a common condition for control function approaches. With these conditions, the Rivers and Vuong two-step approach is to (i) regress x' on z to obtain the estimated residuals, $\hat{v}$ (ii) run probit model of y on x, x', and $\hat{v}$. Thus, with the CF approach, $\hat{v}$ is added to the original list of explanatory variables to control for potential endogeneity. Furthermore, a t test on $\hat{v}$ is valid to test whether x' is exogenous, i.e., $H_0: corr(v, u) = 0$ (Wooldridge 2015). The rejection of the t test on the $\hat{v}$ coefficient would suggest the existence of endogeneity bias and would support the validity of the instrumental variables (z) that were used to generate $\hat{v}$. This test on $\hat{v}$ is the primary reason for using control functions. It should also be noted that the control function estimates will be compared with the two-stage least squares estimates as a robustness check (see Table B.4).

5.2. Productivity Model

To examine the link between productivity, innovation, and sources of finance, the following regression model will be used:

$$\ln(q_i) = \alpha' z_i + \theta' I_{im} + \beta' X_i + \epsilon_i \qquad (5.5)$$

where q_i is the labour productivity of firm *i* measured as the ratio of total revenue to the number of employees, z_i represents sources of financing variables, and X_i represents a vector of control variables (e.g., number of employees). The same set of control variables as used in the innovation model are used in the productivity model. Furthermore, $\beta, \theta,$ and α denote variable coefficients to be estimated while ϵ_i represents an error term. I_{im} in the productivity model represents a vector of innovation dummy variables. These dummies describe whether a firm introduced specific type of innovation. Once again, the subscript *m* is an indicator for different types of innovation. The purpose of including innovation as an explanatory variable is to investigate the link between innovation and productivity, i.e., the efficiency of the innovation.

Least squares estimators are used to examine the link between financing, innovation and productivity. Financial constraints may impact labour productivity indirectly through innovation. It is also possible that financial constraints impact labour productivity through channels that are not innovation. For example, a firm facing financial constraints may be less able to replace worn out equipment, and this worn equipment could be lowering the productivity of the workers. In such a scenario, if having worn equipment is not correlated with one of the other explanatory variables, then the coefficient estimate of α would be negative.

Additionally, to account for the potential complementary relationships between different kinds of innovation, the innovation variables I_i can be implemented into the model as a series of pairwise interactions with one another. That is, for two kinds of innovation the model will include a dummy variable for each kind as well as an interaction variable that consists of the product of the two innovation dummies. Using this method will yield estimates of the effect of introducing the two kinds of innovation separately and introducing the two innovations together. To investigate different complementary relationships between innovation types, multiple models can be estimated with different pairs of innovation.

5.3. Outlier identification

Prior to estimation, Cook's distance is used to identify outlier observations (Cook, 1977). Cook's distance targets observations that by themselves can influence regression results. This method involves omitting an observation and estimating the model with the one missing data point. This process is then repeated for each observation. These coefficient estimates on the variable of interest (financial constraint) are then saved, and observations that correspond to estimates that are more than four standard deviations away from the mean of the coefficient estimates are flagged as an outlier. This method of outlier identification is conducted for each dependent variable, *i.e.*, the measure of innovation. The number of outliers identified using the Cook's distance method ranges from 36 to 140 depending on the type of innovation used. The sample is also restricted to non-government owned firms and non-foreign owned firms.

Chapter 6 : Results and Robustness Checks

6.1. Econometric Specification

To first replicate the results from GS, the analysis begins by estimating the following probit models for each innovation type:

$$
\begin{aligned}
I_{isct} = \Phi \{ & \beta_0 + \alpha_0 Fin.Constraint_{isct} + \beta_1 logL_{isct} + \beta_2 (logL_{isct})^2 + \beta_3 Edu_{isc,t-3} \\
& + \beta_4 Skill_{isc,t-3} + \beta_5 Log(Age_{isct}) + \beta_6 CNM_{isct} + \beta_7 Markup_{isct} + \beta_8 SMNE_{isct} \\
& + \beta_9 Import_{isct} + \beta_{10} CU_{isc,t-3} + \beta_{10} Temporary_{isct} + \beta_{11} Optimal_{isct} \\
& + \beta_{12} Loc_{isct} + \beta_{13} \tau_s + \beta_{14} \delta_c + \beta_{15} \theta_t + error \} \qquad (6.1)
\end{aligned}
$$

where I_{isct} is a binary variable equal to one if a firm reported a certain innovative activity and zero otherwise. $Fin.Constraint$ is the measure of financial of financial constraint, L is the number of employees, $Skill$ is the share of skilled workers, and Age is the age of the firm. CNM is an indicator for competing in international markets, $Markup$ is the average markup on the firm's products, $SMNE$ is the share of sales to multination firms, and $Import$ is the share of inputs that are imported. CU is capacity utilization, $Temporary$ describes the share of temporary workers, Loc describes whether the firm's physical location is in an urban or rural area, and $Optimal$ is the proportion of the current number of employees that the manager thinks is optimal. The subscripts *i, s, c, t* are indicators firm, industry, country, and time, respectively. Variables with the subscript $t-3$ refer to retrospect questions about firm characteristics in the three years prior. These are not lagged variables but indicate that the survey questions corresponding to these variables began with "In the past three years…" The parameters τ_s, δ_c, and θ_t represent industry, country, and year fixed effects, respectively. For the variable I_{isct}, GS uses only two measures of innovation (new good/service and new production technology) along with a dummy for R&D expenditures. This study considers five measures of innovations: *i.e.*, product, process, organization, marketing, and new production license.

The main parameter of interest in this model is the coefficient of the financial constraint variable α_0. Based on the equation 3.5 from the theoretical model which states that $\frac{d\Delta_\pi^I}{d\gamma} < 0$, the expected causal relationship between financial constraint and the likelihood of innovation is negative, *i.e*, $\alpha_0 < 0$. However, as discussed in the identification strategy, the estimates of α_0 may be upwards biased since innovation can increase the chances of a firm experiencing financial constraint (through δ_I in the theoretical model). If the effect of this bias is large enough, then, the observed estimates of the financial constraint coefficients can be positive or zero, i.e., $\alpha_0 \geq 0$. Because of the uncertainty surrounding the expected sign of the estimates of α_0, this analysis will test the null hypothesis that $\alpha_0 = 0$ against the alternative hypothesis that $\alpha_0 \neq 0$.

6.2. Univariate Probit Results

Table 6-1 shows the estimation of equation (6.1) with no instruments and all five of the innovation measures. All estimation results in this thesis use robust clustered standard errors. The clusters are defined by year and country. This is done because there may be similarities between firms in the same country and observed in the same year. Note from Table 6-1 that the estimates of α_0 in most of the equations are positive, albeit not significant, except for *production license*. These results are consistent with the concern that endogeneity bias may influence the estimates of α_0. It is also worth noting that the results from GS were successfully replicated for models (1) and (2). Models (3), (4) and (5) provide new estimation results.

Other interesting results from Table 6-1 include the estimated coefficients for *Ln (Labour)*. The estimate of the coefficient of *Ln (Labour)* is positive and significant at the 99% level for all five innovation models. This result provides evidence of economies of scale in innovation.

Furthermore, the coefficient estimates for *(Ln Labour)*^{2} are all negative and significant which could suggest that the likelihood of innovation increases at a decreasing rate with firm size. It is also noteworthy that the education of labour tends to be positively correlated to most innovation types, while the share of skilled labour is not significant for models (1)-(3) and is even negatively correlated with innovation as is the case with models (4) and (5). These results should be interpreted with caution.

Table 6-1: Single equation probit models – baseline model

	(1)	(2)	(3)	(4)	(5)
Explanatory Variables	Product Innovation	Process Innovation	Organization Innovation	Production License	Marketing Innovation
Fin. Constrain	0.018	-0.008	0.023	0.048***	0.030
	(0.013)	(0.015)	(0.017)	(0.016)	(0.022)
Exports to MNE	0.191**	0.170*	0.310***	0.329***	0.136
	(0.078)	(0.088)	(0.112)	(0.102)	(0.173)
Imports	0.245***	0.265***	0.123**	0.258***	0.438***
	(0.042)	(0.038)	(0.051)	(0.049)	(0.060)
Ln (L)	0.299***	0.346***	0.259***	0.273***	0.738***
	(0.042)	(0.045)	(0.044)	(0.051)	(0.068)
$(\text{Ln L})^2$	-0.025***	-0.025***	-0.017***	-0.011*	-0.045***
	(0.006)	(0.005)	(0.006)	(0.006)	(0.010)
Skilled L	0.036	0.006	-0.097	-0.181**	-0.253***
	(0.044)	(0.064)	(0.067)	(0.078)	(0.082)
Educated L	0.190***	0.189***	0.325***	0.295***	0.323***
	(0.065)	(0.057)	(0.069)	(0.073)	(0.101)
Markup	0.264**	0.525***	-0.031	0.238**	0.699***
	(0.118)	(0.101)	(0.140)	(0.119)	(0.218)
Age	-0.083***	-0.069***	-0.091***	0.022	-0.022
	(0.023)	(0.025)	(0.023)	(0.031)	(0.052)
Year (2005)	0.148***	0.244***	0.265***	0.157***	0.156**
	(0.164)	(0.190)	(0.183)	(0.229)	(0.322)
Optimal L	0.099**	0.186***	-0.088*	-0.447***	-1.776***
	(0.046)	(0.040)	(0.047)	(0.042)	(0.290)
Temporary L	0.196***	0.102**	0.092	0.245***	0.132**
	(0.045)	(0.049)	(0.064)	(0.052)	(0.061)
CU	0.045	-0.103	0.245**	-0.107	-0.048
	(0.106)	(0.109)	(0.108)	(0.096)	(0.164)
CNM	-0.206***	-0.249***	-0.255***	-0.685***	-0.447***
	(0.033)	(0.048)	(0.048)	(0.052)	(0.079)
Observations	10,291	10,198	10,211	10,192	6,061

Robust clustered standard errors in parentheses. * denotes significance at the 95% level, **denotes significance at the 99% level, and *** denotes 0.001 significance at the 99.9% level. These results are from five individual probit models that use the same explanatory variables and five different measures for innovation as a dependent variable. Each equation includes fixed effects for country, sector, and year (reported).

Table 6-2 reports results from the instrumental variable approach for the univariate case. For clarification, equations (1) and (2) in Table 6-2 successfully replicate the results from GS. The instrumental variable methods were implemented using a conditional maximum likelihood estimator. This was carried out using the *ivprobit* function in STATA. Results from the first-stage regressions of the conditional maximum likelihood are included in the appendix (see Appendix B). Two-stage least squares approach was also conducted with similar results.

With the instrumental variable (IV) approach, the coefficient estimates for financial constraint are negative and statistically significant for product, process and production license innovations (see Table 6-2). To further assess the appropriateness of the instrumental variables, I conduct a Wald test for exogeneity on each innovation model, as described in Newey (1987). The Wald test is a test on the correlation between errors of the first and second stage of the IV regression. The Wald test uses a chi-squared distribution to evaluate whether this correlation is different from zero (Newey, 1987). The null hypothesis of the Wald test is that correlation between errors of the first and second stage of the IV regression is zero, *i.e.*, there is no endogeneity that is "picked up" by the instrumental variables. In the case of models (1), (2), and (4), the null is rejected in favour of the existence of endogeneity in the model. The significance of the Wald test also provides evidence supporting the appropriateness of the instrumental variables. However, exogeneity (no endogeneity) could not be rejected for the organizational and marketing innovation models ((3) and (5)). This may partly explain why the coefficient estimates for financial constraint remain positive in the organizational and marketing innovation models. That is, it is possible that the chosen instruments are not appropriate for marketing and organizational innovation or that financial constraint is not a significant determinant of the likelihood to introduce marketing and organizational innovations.

Table 6-2: Single equation probit models with instrumental variables

	(1)	(2)	(3)	(4)	(5)
Explanatory Variables	Product Innovation	Process Innovation	Organization Innovation	Production License	Marketing Innovation
Fin. Constrain	-0.369***	-0.561***	0.114	-0.713***	0.255
	(0.099)	(0.075)	(0.133)	(0.045)	(0.179)
Exports to MNE	0.146**	0.093	0.332***	0.132	0.129
	(0.071)	(0.090)	(0.103)	(0.082)	(0.173)
Imports	0.275***	0.289***	0.248***	0.170***	0.398***
	(0.041)	(0.034)	(0.055)	(0.043)	(0.072)
Ln (L)	0.260***	0.260***	0.274***	0.134***	0.718***
	(0.043)	(0.047)	(0.051)	(0.042)	(0.072)
$(\text{Ln L})^2$	-0.024***	-0.022***	-0.011*	-0.012**	-0.042***
	(0.006)	(0.005)	(0.006)	(0.005)	(0.011)
Skilled L	0.040	0.009	-0.182**	-0.050	-0.249***
	(0.053)	(0.060)	(0.078)	(0.053)	(0.077)
Educated L	0.148**	0.115**	0.298***	0.155**	0.320***
	(0.061)	(0.055)	(0.074)	(0.067)	(0.103)
Markup	0.238*	0.428***	0.237*	-0.021	0.670***
	(0.125)	(0.096)	(0.122)	(0.081)	(0.224)
Age	-0.081***	-0.063***	0.023	-0.063***	-0.015
	(0.020)	(0.021)	(0.031)	(0.017)	(0.053)
Year (2005)	-0.095	0.005	0.027	-0.156**	-0.478
	(0.072)	(0.055)	(0.102)	(0.063)	(0.291)
Optimal L	-0.013	0.008	0.131	-0.098	-0.042
	(0.097)	(0.120)	(0.097)	(0.117)	(0.164)
Temporary L	0.163*	0.145*	0.100	0.275***	-0.042
	(0.090)	(0.085)	(0.107)	(0.080)	(0.196)
CU	-0.034	-0.187***	-0.074	-0.107**	-0.074
	(0.044)	(0.047)	(0.060)	(0.054)	(0.083)
Competition	0.032	0.065	-0.436***	-0.164***	-1.684***
	(0.048)	(0.048)	(0.051)	(0.048)	(0.275)
Wald Test Statistic	7.84**	27.86***	0.23	79.53***	1.54
Observations	10,291	10,198	10,211	10,192	6,061

Robust clustered standard errors in parentheses. * denotes significance at the 95% level, **denotes significance at the 99% level, and *** denotes 0.001 significance at the 99.9% level. These results are from five individual *ivprobit* models that use the same explanatory variables and five different measures for innovation as a dependent variable. Instruments are implemented using 2sls and the first stage regression is reported in Appendix B (Table B-1). Each equation includes fixed effects for country, sector, and year (reported).

6.3. Multivariate Probit Results

The study expands on GS by estimating a multivariate probit model for the first four categories of innovation. *Marketing Investment* is not included in the multivariate model primarily because of many missing values. Including *Marketing Investment* in the multivariate analysis would decrease the effective sample size, increase standard errors, and increase the probability of type II error in the multivariate model (Greene, 2003). Furthermore, it is unclear whether the missing observations are random or non-random. If the missing values are non-random, then, this raises concerns about sample selection bias (Griliches et al., 1987). Thus, including *Marketing Investment* may introduce potential sample selection bias. For completeness, the multivariate probit models is re-estimated with the inclusion of marketing investment. These results are displayed in Appendix B (Tables 8-2 and 8-3). Aside from increasing the standard errors of many of the estimates, the inclusion of *Marketing Investment* does not largely alter the results.

Table 6-3: MVP model without control functions

	(1)	(2)	(3)	(4)
Explanatory Variables	Product Innovation	Process Innovation	Organization Innovation	Production License
Financial Constraints	0.0163	-0.00268	0.0440*	0.0271
	(1.23)	(-0.18)	(2.45)	(1.66)
Exports to MNE	0.209*	0.173	0.305**	0.286*
	(2.54)	(1.89)	(2.89)	(2.44)
Imports	0.251***	0.259***	0.251***	0.110*
	(5.63)	(6.68)	(4.97)	(2.17)
Ln (Labour)	0.289***	0.347***	0.270***	0.260***
	(6.89)	(7.61)	(5.23)	(6.03)
$(\text{Ln Labour})^2$	-0.0241***	-0.0252***	-0.0114	-0.0176**
	(-3.88)	(-4.42)	(-1.77)	(-2.93)
Skilled Labour	0.0433	0.0136	-0.183*	-0.0996
	(0.98)	(0.21)	(-2.32)	(-1.47)
Educated Labour	0.196**	0.222***	0.280***	0.339***
	(2.98)	(3.80)	(3.75)	(4.77)
Markup	0.282*	0.495***	0.238*	-0.0622
	(2.32)	(4.99)	(1.99)	(-0.42)
Age	-0.0781***	-0.0683**	0.0237	-0.0904***
	(-3.33)	(-2.69)	(0.75)	(-3.93)
Year (2005)	-0.0555	0.0488	0.0148	-0.186
	(-0.70)	(0.67)	(0.15)	(-1.56)
Optimal Labour	0.00355	0.0878	0.0987	-0.0760
	(0.03)	(0.62)	(0.95)	(-0.46)
Temporary Labour	0.0495	-0.0776	0.0714	0.0888
	(0.50)	(-0.71)	(0.63)	(1.01)
Capacity Utilization	0.0136	-0.165**	-0.0952	-0.0108
	(0.28)	(-3.06)	(-1.49)	(-0.14)
Competition	0.0995*	0.193***	-0.435***	-0.0947
	(2.06)	(4.66)	(-10.13)	(-1.95)
CF residuals	--	--	--	--

ρ_{21}	ρ_{31}	ρ_{41}	ρ_{32}	ρ_{42}	ρ_{43}
0.38255***	0.2361***	0.1599***	0.1680***	0.2702***	0.1530***
(16.52)	(11.91)	(8.11)	(8.18)	(10.41)	(6.16)

t statistics in parentheses; * denotes significance at the 95% level, **denotes significance at the 99% level, and *** denotes 0.001 significance at the 99.9% level; N = 9899. This table reports the results from the multivariate probit model while not implementing the instrumental variables. Each equation includes fixed effects for country, sector, and year (reported).

Table 6-4: Marginal effects from MVP model without control functions

	(1)	(2)	(3)	(4)
Explanatory Variables	Product Innovation	Process Innovation	Organization Innovation	Production License
Financial Constraints	0.0059	-0.0008	0.0078*	0.0036
Exports to MNE	0.0764*	0.0510	0.0540**	0.0380*
Imports	0.0917***	0.0766***	0.0444***	0.0146*
Ln (Labour)	0.1058***	0.1025***	0.0478***	0.0345***
$(\text{Ln Labour})^2$	-0.0088***	-0.0075***	-0.0020	-0.0023**
Skilled Labour	0.0158	0.0040	-0.0325*	-0.0132
Educated Labour	0.0715**	0.0657***	0.0496***	0.0450***
Markup	0.1031*	0.1464***	0.0421*	-0.0082
Age	-0.0285***	-0.0202**	0.0042	-0.0120***
Year (2005)	0.0364	0.0570	-0.0770	-0.0126
Optimal Labour	0.0652	0.0281	0.0440	0.0141
Temporary Labour	0.0073	-0.0263	-0.0169	0.0317
Capacity Utilization	-0.0814	-0.0802**	-0.1182	-0.0304
Competition	0.0580*	0.0736***	0.0293***	0.0366

N = 9899; * denotes significance at the 95% level, **denotes significance at the 99% level, and *** denotes 0.001 significance at the 99.9% level. Marginal effects are calculated manually from the coefficients in Table 6-5. The marginal effect for each observation and variable is calculated, and the average of the marginal effects is reported

Table 6-3 reports the main results from the estimation of a multivariate probit model without accounting for endogeneity bias. Table 6-4 reports the average marginal effect of the independent variable on the probability of adoption of innovation. For example, the coefficient for financial constraint is -0.715 for new good or service. This value suggests that a 1% increase in the share of educated labour force in a firm would be associated with a 7.15%. increase in the likelihood of a firm introducing a new good or service Similar to the single-equation models, the positive coefficient estimates for *Financial Constraint* may suggest the presence of potential endogeneity bias.

The bottom of Table 6-3 also presents estimates of the off-diagonal elements of the variance-covariance matrix along with corresponding test statistics. Each ρ is an estimate of the correlation between the error terms of two different innovation equations, *i.e.,* it is the correlation between the unexplained variation for two separate innovation processes (Cappellari and Jenkins, 2003). The ρ estimates are calculated using a simulated maximum likelihood that exploits the fact that a multivariate normal distribution function can be expressed as the product of sequentially conditioned univariate normal distribution functions (Cappellari and Jenkins, 2003). In Table 6-3, each of the ρ estimates are positive and statistically significant. The significance of these terms supports the suitability of the multivariate probit model. This is because the alternative method of using univariate probit models assumes independence between the various error terms, *i.e.,* that each of the ρ terms are equal to zero. The positive sign on the ρ estimates indicates that if a firm implements one kind of innovation, it becomes more likely that the firm has also introduced another kind of innovation simultaneously. The results in Table 6-3 suggests that the complementary relationship is particularly stronger between good/service innovation and a production innovation as the estimate for ρ_{21} has the largest value.

Table 6-5: MVP model with control functions

Explanatory variables	(1) Product Innovation	(2) Process Innovation	(3) Organization Innovation	(4) Production License
Financial Constraints	-0.396***	-0.651***	0.0961	-0.927***
	(-3.47)	(-4.94)	(0.72)	(-6.59)
Exports to MNE	0.161	0.0955	0.311**	0.175
	(1.90)	(1.05)	(2.82)	(1.42)
Imports	0.284***	0.313***	0.247***	0.184***
	(6.54)	(7.68)	(4.71)	(3.47)
Ln (Labour)	0.263***	0.307***	0.273***	0.200***
	(6.58)	(6.81)	(5.19)	(4.32)
$(\text{Ln Labour})^2$	-0.0244***	-0.0256***	-0.0114	-0.0181**
	(-3.95)	(-4.52)	(-1.76)	(-2.91)
Skilled Labour	0.0425	0.0116	-0.183*	-0.104
	(0.96)	(0.18)	(-2.31)	(-1.51)
Educated Labour	0.145*	0.142*	0.287***	0.224**
	(2.14)	(2.33)	(3.58)	(2.97)
Markup	0.260*	0.464***	0.240*	-0.110
	(2.17)	(4.71)	(2.01)	(-0.76)
Age	-0.0727**	-0.0595*	0.0231	-0.0767**
	(-3.21)	(-2.35)	(0.71)	(-3.28)
Year (2005)	0.0413	0.101*	-0.427***	-0.233***
	(0.79)	(2.24)	(-8.62)	(-4.59)
Optimal Labour	0.237***	0.187***	0.241***	0.241***
	(4.57)	(3.54)	(4.26)	(3.61)
Temporary Labour	0.103	0.0415	-0.107	0.429***
	(0.94)	(0.34)	(-1.06)	(3.93)
Capacity Utilization	-0.357***	-0.481***	-0.650***	-0.539***
	(-4.77)	(-5.89)	(-5.92)	(-5.59)
Competition	0.160***	0.251***	0.165**	0.281***
	(4.59)	(6.86)	(3.28)	(5.04)
CF residuals	0.417***	0.655***	-0.0532	0.965***
	(3.58)	(4.88)	(-0.39)	(6.79)

ρ_{21}	ρ_{31}	ρ_{41}	ρ_{32}	ρ_{42}	ρ_{43}
0.3804***	0.2369***	0.1560***	0.1692***	0.2641***	0.1554***
(16.37)	(11.79)	(7.80)	(8.14)	(10.05)	(6.25)

t statistics in parentheses; * denotes significance at the 95% level, **denotes significance at the 99% level, and *** denotes 0.001 significance at the 99.9% level.; N = 9899. This table reports the results from the multivariate probit model while implementing the instrumental variables through control functions. Each equation includes fixed effects for country, sector, and year (reported).

Table 6-6: Marginal effects from MVP model (Table 6-5) with control functions

	(1)	(2)	(3)	(4)
Explanatory variables	Product Innovation	Process Innovation	Organization Innovation	Production License
Financial Constraints	-0.1451***	-0.1924***	0.0168	-0.1229***
Exports to MNE	0.0585	0.0276	0.0547**	0.0227
Imports	0.1040***	0.0925***	0.0437***	0.0244***
Ln (Labour)	0.0964***	0.0907***	0.0483***	0.0267***
(Ln Labour)^2	-0.0089***	-0.0076***	-0.0020	-0.0024**
Skilled Labour	0.0155	0.0032	-0.0324	-0.0138
Educated Labour	0.0528*	0.0421*	0.0507***	0.0299**
Markup	0.0950	0.1370***	0.0423*	-0.0151
Age	-0.0266**	-0.0177*	0.0041	-0.0102*
Year (2005)	0.0151	0.0300*	-0.0756***	-0.0310***
Optimal Labour	0.0865***	0.0555***	0.0428***	0.0319***
Temporary Labour	0.0381	0.0124	-0.0186	0.0573***
Capacity Utilization	-0.1308***	-0.1426***	-0.1152***	-0.0716***
Competition	0.0586***	0.0743***	0.0292**	0.0371***
CF residuals	0.1529***	0.1938***	-0.0092	0.1279***

N = 9899; * denotes significance at the 95% level, **denotes significance at the 99% level, and *** denotes 0.001 significance at the 99.9% level. Marginal effects are calculated manually from the coefficients in Table 6-5. The marginal effect for each observation and variable is calculated, and the average of the marginal effects is reported.

Similar to the results in Table 6-1 and Table 6-2 for the single-equation models, the control function multivariate probit model yields coefficient estimates on *Financial Constraint* that are negative and significant for product, process and production license innovations. The IV approach was also implemented using two-stage least squares for comparison. The two-stage least squares method produced results that are similar to the control function approach (See Appendix B, Table B-4). Table 6-5 reports parameter estimates based on the control function approach. In a multivariate model, it is more difficult to perform a Wald test to assess the suitability of the instrumental variables for each equation (Cappellari and Jenkins, 2003). However, with the control function approach, the t-test on the coefficient of the control function residuals is a valid exogeneity test (Wooldridge, 2015). From Table 6-5, exogeneity is rejected for good/service, process, and production license innovations. For organizational innovation, exogeneity could not be rejected. These results are consistent with the Wald tests that were performed on the univariate models.

Table 6-6 presents the marginal effects. Table 6-6 indicates that adoption of new production technology is most affected by financial constraints. The coefficient estimate for *Financial Constraint* is not significant for organizational innovation. One potential explanation for this result is that organizational innovations may require less financial capital and instead be determined by factors such as the education of employees. This explanation is corroborated by the fact that, relative to the other innovation types, the magnitude of the estimate of the marginal effects for *Educated Labour* is the largest absolute value for the organizational innovation.

Comparing the estimates of the other explanatory variables in equation (3) against the same estimates in equations (1), (2), and (4) suggests some other differences between the factors influencing organizational innovation versus from product, process, and production license innovation. First, the share of exports to multinational corporations (*Exports to MNE*) was only positive and significant in the organization equation. Additionally, equation (3) was the only equation to not have significance on the (*Ln Labour*)^2 coefficient. This suggests that the increase in the likelihood of innovation from firm size may not be diminishing (to a certain extent) in the case of organizational innovation. Furthermore, although statistically significant, the marginal effect of competing in international markets (*Competition*) was the smallest in model (3) and the largest impact of educated labour (*Educated Labour*) is also in equation (3). These observations support the possibility that, in addition to financial constraint, the process of introducing an organizational innovation may differ from product, process, and production license innovation.

While the role of financial constraint in the adoption of organizational innovation is still unclear, the estimates of ρ_{31}, ρ_{32}, and ρ_{43} are all significant and positive. Thus, there is still evidence for complementarity between organizational innovation and good/service, production technology, and production license innovations. Furthermore, the estimate of the correlation between the product and process innovation residuals (ρ_{21}) has the largest value in the model that accounts for endogeneity bias. This suggests that product and process innovation have the strongest complementary relationship. It is worth noting that none of the ρ estimates are negative after implementing the IV's which would suggest substitutability. This strengthens the argument that different types of innovation are complementary.

For robustness, the multivariate probit model is re-estimated with the full sample i.e., including publicly owned firms. The results from this estimation are included in Appendix B (Table B-5). In short, the estimates on financial constraint are no longer negative and significant with the full sample. This suggests that financial constraint may influence publicly owned firms differently from private firms. The results also indicate that publicly owned firms are significantly less likely to innovate than private firms. Lastly, all the ρ estimates were still positive and significant when using the full sample. This strengthens the argument for the existence of complementary relationships between product, process, organizational, and production license innovation

6.4. Productivity Model Estimation

In this section, I examine the effect of innovation on productivity using labour productivity measures from the BEEPS data. As described in the previous chapter, this will be accomplished using OLS.

$$\begin{aligned}\text{Ln}(q_{isct}) &= \alpha_0 FC_{isct} + \pi_0 I_{isct} + \beta_1 logL_{isc,t-3} + \beta_2 (logL_{isc,t-3})^2 + \beta_3 Edu_{isc,t-3} \\ &+ \beta_4 Skill_{isc,t-3} + \beta_5 Log(Age_{isct}) + \beta_6 CMN_{isct} + \beta_7 Markup_{isct} + \beta_8 SMNE_{isct} \\ &+ \beta_9 Import_{isct} + \beta_{10} CU_{isc,t-3} + \beta_{10} Temporary_{isct} + \beta_{11} Optimal_{isct} \\ &+ \gamma Loc_{isct} + \tau_s + \delta_c + \theta_t + error \qquad (6.2)\end{aligned}$$

This model uses the same set of control variables as the innovation model (see section 6.1. for a brief description of each variable) except for innovation dummies I_{isct} that are added as explanatory variables here. Financial constraint is also included as an explanatory variable. The rationale for this is that, in addition to innovation, financial constraint may influence productivity through other channels such as firm-level employment demand (Popov and Rocholl, 2015; Siemer, 2019).

Moreover, to further investigate the complementarity of different types of innovation, the innovation variables are interacted with each other. Six versions of this model are estimated to investigate various pairwise relationships between the different types of innovations. The first model considers a single innovation variable (*Any Innovation*) which is equal to one if the firm reported any one of the four innovation types and zero otherwise. The second model includes four innovation variables, one for each type of innovation. The third model adds all possible pairwise innovation interaction terms. There are six of these interaction terms (see Table 6-7). Because the inclusion of all interaction terms may dilute the potential relationship between certain innovations and labour productivity, models four, five, and six are estimated and each include two different interaction terms. Model four interacts product and process innovations along with organizational and production license innovation. Model five interacts product and organizational innovation in addition to process and production license innovation. Lastly, model six interacts product and production license innovation along with process and organizational innovation. For robustness, these productivity models are re-estimated with the full sample that includes government-owned firms (See Table B-6). The results using the full sample are similar the results presented on the next page, which use a sample that is restricted to privately-owned firms.

Table 6-7: Productivity models

Dep. Variables	(1)	(2)	(3)	(4)	(5)	(6)
Financial Constraints	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Any Innov.	0.043*					
	(0.022)					
Product Innov.		0.028*	0.017	0.026	0.020	0.025
		(0.016)	(0.028)	(0.024)	(0.021)	(0.017)
Process Innov.		0.023	0.021	0.021	0.015	0.028
		(0.021)	(0.032)	(0.028)	(0.024)	(0.025)
Organization Innov.		0.095***	0.086**	0.095***	0.075**	0.102***
		(0.029)	(0.039)	(0.030)	(0.036)	(0.036)
Prod. License		0.013	-0.007	0.014	-0.006	0.005
		(0.035)	(0.058)	(0.040)	(0.049)	(0.048)
Product Innov. and Process Innov.			0.003	0.004		
			(0.043)	(0.042)		
Product Innov. and Organization Innov.			0.051		0.042	
			(0.060)		(0.057)	
Product Innov. and Prod. License			0.002			0.018
			(0.066)			(0.061)
Process Innov. and Organization Innov.			-0.037			-0.020
			(0.063)			(0.061)
Process Innov. and Prod. License			0.048		0.044	
			(0.069)		(0.068)	
Organization Innov. and Prod. License			-0.006	-0.004		
			(0.067)	(0.065)		
N	7,831	7,786	7,786	7,786	7,786	7,786
R-squared	0.564	0.568	0.568	0.568	0.568	0.568

* denotes significance at the 90% level, **denotes significance at the 95% level, and *** denotes significance at the 99% level; Robust clustered (year and country clusters) standard errors are reported in parentheses. This table reports the results from six separate linear regressions. Labour productivity is the dependent variable for each regression. All the explanatory variables from the innovation models are included as explanatory variables in these regressions. That is, the regressions differ only by the different innovation interaction terms. The coefficient estimates of the remaining explanatory variables are included on the next page. Each regression includes fixed effects for country, sector, and year (reported). Model (1) uses the variable *Any Innov.* which is equal to one if the firm reported any one of the four innovation types and zero otherwise.

Table 6-7 (continued): Productivity models

Dep. Variables	(1)	(2)	(3)	(4)	(5)	(6)
Exports to MNE	0.212***	0.200***	0.200***	0.200***	0.200***	0.200***
	(0.052)	(0.052)	(0.053)	(0.052)	(0.052)	(0.053)
Imports	0.182***	0.182***	0.182***	0.182***	0.182***	0.182***
	(0.039)	(0.039)	(0.039)	(0.039)	(0.039)	(0.039)
Ln (Labour)	0.079	0.082	0.082	0.082	0.082	0.081
	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)
(Ln Labour)2	-0.017**	-0.018**	-0.018**	-0.018**	-0.018**	-0.018**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Skilled Labour	-0.060**	-0.056*	-0.055*	-0.056*	-0.056*	-0.055*
	(0.029)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Educated Labour	0.240***	0.226***	0.227***	0.226***	0.227***	0.226***
	(0.051)	(0.050)	(0.050)	(0.049)	(0.050)	(0.050)
Markup	-0.136	-0.138	-0.137	-0.138	-0.137	-0.138
	(0.086)	(0.086)	(0.087)	(0.087)	(0.086)	(0.086)
Age	0.067**	0.064**	0.064**	0.064**	0.064**	0.064**
	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Year	0.693***	0.709***	0.709***	0.709***	0.709***	0.708***
	(0.044)	(0.043)	(0.043)	(0.043)	(0.043)	(0.043)
Optimal Labour	-0.042	-0.047	-0.048	-0.047	-0.048	-0.047
	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
Temporary Labour	-0.951***	-0.952***	-0.954***	-0.952***	-0.954***	-0.953***
	(0.072)	(0.072)	(0.071)	(0.071)	(0.072)	(0.071)
CU	0.065	0.077	0.077	0.077	0.077	0.077
	(0.059)	(0.058)	(0.058)	(0.058)	(0.059)	(0.059)
Competition	0.094***	0.093***	0.094***	0.093***	0.094***	0.093***
	(0.029)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)
Observations	7,831	7,786	7,786	7,786	7,786	7,786
R-squared	0.564	0.568	0.568	0.568	0.568	0.568

* denotes significance at the 90% level, **denotes significance at the 95% level, and *** denotes significance at the 99% level; Robust clustered (year and country clusters) standard errors are reported in parentheses. These regression results are a continuation of the results presented in Table 6-7. In each of the equations, labour productivity is the dependant variable. The difference between the equations are the different innovation explanatory variables that are included. Each regression includes fixed effects for country, sector, and year (reported).

Table 6-7 reports the estimation results of the productivity model. In all six models, the financial constraint variable is negative but not statistically significant. Thus, this analysis does not find evidence that financial constraint directly impacts labour productivity. However, turning to the estimates of the coefficients of innovation variables and their interactions, it is interesting to observe that the variable *Any Innovation* is positive and statistically significant at the 10% level. This would suggest that there is at least some correlation between firm innovation and labour productivity. Breaking down the innovations by type, models (2)-(6) all indicate that organisational innovation appears to have a strong relationship with labour productivity as coefficient estimates are positive and significant at the 1% level (with the exception model (3) which is significant at the 5% level). *Product Innovation* is also positive and significant at the 10% level in model (2). Also note that none of the interaction terms were significant.

It is important to acknowledge that the cross-sectional nature of the data limits the inferences on the relationship between innovation and labour productivity which can be drawn from the productivity regressions. One of the main limitations of this model is that productivity data and innovation data are collected from the firm at the same time. This is a concern because innovations may have a lagged effect on productivity. By regressing current innovation on current productivity, this model is assuming either that innovations have an immediate effect on firm productivity or that firms which are currently innovative were also innovative in the past. This is a strong assumption, and so it should be kept in mind that the regression results capture the correlation between innovation and labour productivity and not necessarily causation.

6.5. Discussion

Gorodnichenko and Schnitzer (2013) found that financial constraints have a negative impact on product and process innovation. While accounting for complementarity between types of innovation, this thesis also finds that financial constraints have a negative impact on product and process innovations. Additionally, financial constraints were found to negatively influence the likelihood of a firm obtaining a new production license. Proxies for liquidity shocks were used as instrumental variables (IV's) to obtain these results. After implementing the IV's, however, there is still no evidence to support financial constraints having an impact on organizational innovation or marketing investment. There was evidence that product, process, organizational, production license, and (to a lesser degree) marketing innovation are complementary to each other. This complementary relationship appears to be strongest between product innovation and process innovation. This evidence for complementarity between different types of innovation supports the findings of studies such as Athey and Schmutzler (1995), Kim and Mauborgne (2004), Brewin et al. (2009), and Schmidt and Rammer (2007) that also suggest complementarity.

A statistically significant relationship between financial constraint and organizational innovation may not have been observed because organizational innovation may require less financial investment to implement. In this case, a financial constraint should not impede organizational innovation. However, organizational innovation may be indirectly affected by financial constraint if organizational innovation is complementary to product, process, and production license innovations. That is, a change to a firm's organisational system may be especially beneficial for a firm that has introduced a new product or process. With that said, the evidence for complementarity between organizational innovation and product, process, and production license innovations was statistically significant but not as strong as the complementarity between other types of innovation (e.g., product and process innovation). Thus, while organizational innovation may not be influenced by financial constraint, firms that introduce product, process, and production license innovation tends to also introduce an organizational innovation.

To recap the labour productivity model, the analysis finds that organizational innovation has a positive correlation with labour productivity. An unexpected finding from the estimation of this model is that organizational innovation is the strongest predictor of labour productivity out of all the types of innovation. This would suggest that organisational innovation may be an important component that influences the outcome of innovations. From the perspective of the firm, this suggests that when introducing a product or process innovation, introducing a new organisational system may be important for the success of the other innovations. In some circumstances, it may be possible that maintaining an old organisation system in the face of a new product or production method may even hurt productivity if there are conflicts between practices from the old and new production systems. For example, if a firm installs new production equipment to automate a previously manual production process but does not drastically alter its labour organization, the old labour composition may be ill-equipped to operate the new machinery. As such, the firm could experience a decrease in efficiency.

Additionally, from the estimation of the productivity models, product innovation was positive and statistically significant at the 10% level. However, this relationship appears to be relatively weak and no significance on product innovation is found after the interaction terms are added to the model. The lack of significance on product and process innovations could also be the result of the omitted lag effect of innovations on productivity. Product and process innovations may take time to have an impact on productivity, but the measures of productivity and innovation in the BEEPS data were collected at the same time. Thus, the measure for productivity that is used in in this thesis may not capture the long-term effects of innovation on productivity. It is also noteworthy that none of the interaction terms from the productivity model were statistically significant. This result would be in-line with Hall et al. (2009) who also find no evidence of complementarity between innovations in their productivity model. However, in the case of this thesis, my results may have been impacted by the omission of the lag effect of innovation that was just discussed. Although, it is difficult to draw conclusions from the lack of significance on the interaction terms, it can be stated that this analysis did not find evidence of complementarity between innovations in terms of their impact on productivity.

To improve the robustness of the productivity model, future research could estimate the effect of lagged innovation on current productivity levels. Given available data, different measures of productivity, such as total-factor productivity, could be considered in addition to labour productivity. Future research could also estimate the effect of innovation and financial constraints on productivity within a Crepon-Duguet-Mairesse (CDM) framework using tests described by Mohnen and Röller (2005) (Crepon et al., 1998). The CDM model could not be estimated in this thesis due to data limitations.

Chapter 7 : Conclusion

7.1. Summary

Innovation is an important factor that influences productivity growth (Loof and Heshmatti, 2006). Because innovation often involves up-front investment, access to finance plays an important role in firm innovation decisions. Certain financial indicators such as cash flow have been linked to innovation related activates such as R&D (Hao and Jaffe, 1990). However, there are few studies that examine the relationship between financial constraint and innovation. There is also a limited literature that examines the relationship between financial constraints and innovation while accounting for complementarity between innovation types. This thesis has assessed the impact of financial constraint on five types of innovations: product, process, organizational, marketing, and production license innovation. This thesis also investigated the relationship between different types of innovation and labour productivity.

There are three research questions that this thesis addressed: (1) do financial constraints influence the likelihood of firm innovation; (2) is there complementarity between types of innovation; and (3) does innovation influence labour productivity? To investigate question (1), a theoretical model developed by Gorodnichenko and Schnitzer (2013) was used, and results from this model predict a negative relationship between financial constraint and a firm's likelihood to innovate. This prediction was tested empirically using the Business Environment and Enterprise Performance Survey (BEEPS) from 2002 and 2005. After implementing measures of liquidity shocks as instrumental variables, a multivariate probit model indicated that financial constraint has a negative impact on the likelihood of firm innovation for product, process, and production license innovation. The results also indicated that the impact of financial constraint does depend on the type of innovation.

To investigate question (2), a multivariate probit innovation model was used and indicated that product, process, organizational, and production license innovation tend to be implemented together. This result is consistent with the complementarity theory. The complementary relationship came from product and process innovations. In the productivity model, there was no evidence of complementarity in terms of the effect of innovation on productivity; however, this result may be influenced by omitted variable bias.

Question (3) was addressed using a linear regression with labour productivity as the dependant variable. Financial constraint was not a significant explanatory variable for variations in labour productivity. Organizational innovation and the interaction of product and process innovations were found to be positively correlated with labour productivity.

7.2. Limitations and Suggestions for Future Research

There are some limitations to this study that should be noted. First, only one measure of financial constraint was considered due to data availability. The measure that was used in this study was also a survey response variable. A more objective measure of financial constraint, *e.g.*, debt-to-asset ratio, may be worthwhile to test in the future as a robustness check. Future research could test multiple measures of financial constraints to see if the results change with different measures. Another limitation is that the types of innovation that were considered in this thesis were somewhat limited. It may be interesting to distinguish between in-house and external process innovation as done by Brewin et al. (2009). Other innovation types such as marketing innovation could also be considered by other research.

The labour productivity model also made assumptions that may not have been realistic. For example, this model assumed that the benefits to innovation were immediately realized. Yet, benefits of innovation may take decades to realize. A potential solution to this problem would be to use a larger panel data set and obtain past measures of innovation along with many years of productivity measures. Past innovations could then be regressed on firm productivity growth to compare innovative firms with non-innovative firms. Another potential improvement on the productivity model is using different measures of productivity such as total factor productivity. Labour is not the only input used by firms, and innovations may improve the efficiency in terms of other inputs. To obtain more robust results, alternative productivity measures should be considered.

7.3. Policy Implications

This thesis is relevant to policy in that it suggests that countries may benefit from policies that support innovative activities in firms that are especially susceptible to financial frictions. By relieving financial constraints, innovation-based tax incentives (*e.g.,* Canada Small Business Financing Program) and research grants may encourage the adoption of new innovations. Small firms may especially benefit from such programs as lack of collateral can make small firms more susceptible to financial constraints. In countries with less developed financial markets, reforms in banking and financial sectors may also help to improve firm access to finance and to relieve financial constraints. However, the benefits of external finance that derive from careful screening and monitoring should also be kept in mind. A prudent strategy would be to discriminately increase access to financing and incorporate enhanced screening, better information systems, and well-maintained property records to help with collateralization.

Given the evidence suggesting complementarity between types innovation, programs that encourage innovation should consider that innovations may be complements to one another. Complementarity among innovations may make it more difficult for financially constrained firms to successfully implement innovations. If two innovations are complementary, then they will have a greater impact on firm profits if they are introduced together. However, introducing both innovations together means that both innovations need to be financed together. For firms in poorer countries that are more likely to face financial constraint, the need to finance multiple innovations at the same time, may discourage firms from innovating at all. This effect may have implications at a macro level because firms in poorer countries that have limited access to finance may not be able to be able to finance the collection of innovations that are needed to develop their economies.

Governments can also foster innovation by creating innovation hubs with market conditions that are favourable for innovation (*e.g.,* well developed financial markets and tax breaks for innovation-related spending). Innovation hubs (or innovation corridors, for example, the Toronto-Waterloo Innovation Corridor) can expose firms to many different types of innovations, thus, potentially helping firms to introduce different innovation simultaneously. Furthermore, while more research is needed in this area, encouraging firms to introduce multiples types of innovation together may enhance the influence of innovation on productivity and firm competitiveness. If this is true, it may be worthwhile to devote public resources to encourage firms to introduce innovations simultaneously.

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Appendix: A (Mathematical Appendix)

This appendix provides details regarding some of the results displayed in the conceptual framework (Chapter 3). Start by considering a monopolistic competition model, as outlined in Dixit and Stiglitz (1977) and Gorodnichenko and Schnitzer (2013). In this model, firms sell slightly differentiated goods and individual consumers exhibit a constant elasticity of substitution (CES) utility functions. The utility function of a representative consumer subject to a budget constraint is then maximised to obtain the demand that each firm faces. The representative consumer's utility maximisation problem can be written as

$$\max_{x} U = \left(\sum_i x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \quad s.t. \quad \sum_i x_i p_i \leq Y, \tag{A.1}$$

where total wealth of the consumer is Y, the price of x_i is p_i, and the elasticity of substitution is σ. Second order conditions are satisfied for CES utility functions and the CES function guarantees that the solution is such that any solution to this problem x^* is such that $x_k^* > 0, \forall\, x_k^* \in x^*$ because the marginal utility of good k approaches infinity as x_k tends to zero. Proceeding, the Lagrangian function and corresponding first order conditions are:

$$\mathcal{L} = \left(\sum_i x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} - \lambda\left(\sum_i x_i p_i - Y\right) \tag{A.2}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = 0 = -\left(\sum_i x_i p_i - Y\right) \;\; \rightarrow \;\; \sum_i x_i p_i = Y \tag{A.3}$$

$$\frac{\partial \mathcal{L}}{\partial x_k} = 0 = \left(\sum_i x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{1}{\sigma-1}} x_k^{-\frac{1}{\sigma}} - \lambda p_k \qquad for\ k = 1, \dots, N \tag{A.4}$$

Where there are *N* firms and, thus, *N* differentiated goods. Thus, for any x_k and x_j we can combine the corresponding first order conditions to write

$$\frac{\left(\sum_i x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{1}{\sigma-1}} x_k^{-\frac{1}{\sigma}}}{\left(\sum_i x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{1}{\sigma-1}} x_j^{-\frac{1}{\sigma}}} = \frac{\lambda p_k}{\lambda p_j}, \tag{A.5}$$

which simplifies to

$$\frac{x_k^{-\frac{1}{\sigma}}}{x_j^{-\frac{1}{\sigma}}} = \frac{p_k}{p_j} \tag{A.6}$$

$$x_j p_j = p_k^{\sigma} x_k p_j^{1-\sigma}. \tag{A.7}$$

Because any two goods can be related in this way, we have that for any x_k

$$\sum_i x_i p_i = \sum_i p_k^{\sigma} x_k p_i^{1-\sigma} = p_k^{\sigma} x_k \sum_i p_i^{1-\sigma} = p_k^{\sigma} x_k P^{1-\sigma}, \tag{A.8}$$

where $P = (\sum_i p_i^{1-\sigma})^{\frac{1}{1-\sigma}}$ is an aggregate price index. From A.3, this implies that

$$Y = p_k^{\sigma} x_k P^{1-\sigma} \tag{A.9}$$

$$x_k^* = \frac{Y p_k^{-\sigma}}{P^{1-\sigma}}. \tag{A.9}$$

Now consider the case of a single firm that produces at a constant marginal costs c and is considering introducing a process innovation. If the firm innovates, the marginal cost of production will decrease to $\alpha c < c$, with $0 < \alpha < 1$. If production in stage 2 is financed using external funds, then the cost of increases by a factor of γ, with $\gamma > 1$. If there is no innovation and the firm finances production with internal funds, baseline profits can be expressed as

$$\pi_0 = px - cx. \tag{A.10}$$

Assuming that firms in monopolistic competition set prices to maximize profits, the first order condition is

$$\frac{d\pi_0}{dp} = x + (p - c)\frac{dx}{dp} = 0, \tag{A.11}$$

and from (A.9) we have that

$$\frac{dx}{dp} = -\sigma \frac{Yp^{-\sigma-1}}{P^{1-\sigma}} \tag{A.12}$$

since the aggregate price index does not change if a single firm changes it price due to the continuum of firms. Now, to determine the profit maximising price, equations (A.12) and (A.9) are inserted into (A.11) to yield the following

$$\frac{d\pi_0}{dp} = \frac{Yp^{-\sigma}}{P^{1-\sigma}} - \sigma \frac{Yp^{-\sigma-1}}{P^{1-\sigma}}(p-c) = 0, \tag{A.13}$$

which simplifies to

$$p = c\frac{\sigma}{\sigma-1}. \tag{A.14}$$

This yields the following maximised profit function

$$\pi_0^* = \frac{Y}{\sigma}\left(\frac{p}{P}\right)^{1-\sigma} \tag{A.15}$$

With p defined according to equation (A.13). If external finance was used, then the only difference from this base case is that marginal costs change from c to γc. The optimal price for this case is, therefore, $\gamma c\frac{\sigma}{\sigma-1}$. Thus, maximised profits using external financing are written as

$$\pi_\gamma^* = \gamma^{(1-\sigma)}\pi_0^* \tag{A.16}$$

Using similar logic, the maximised profits for scenarios where the firm innovates can be expressed as

$$\pi_0^I = (\alpha)^{(1-\sigma)}\pi_0^* \tag{A.17}$$

$$\pi_\gamma^I = (\alpha\gamma)^{(1-\sigma)}\pi_0^* \tag{A.18}$$

where π_0^I indicates maximised profit under internal funding if the firm has innovated and π_γ^I denotes maximised profit when the firm uses external funding and has innovated. Now, assumption 1 can be evaluated for this model keeping in mind the restrictions on the defined parameters $\alpha, \sigma \in (0,1)$ and $\gamma > 1$.

$$\pi_\gamma^I - \pi_0^I = \left((\alpha)^{(1-\sigma)}\pi_0^*\right)(\gamma^{1-\sigma} - 1) \tag{A.19}$$

$$\frac{d(\pi_\gamma^I - \pi_0^I)}{d\gamma} = (1-\sigma)\gamma^{-\sigma}(\alpha^{1-\sigma} - 1)\pi_0^* < 0 \quad \text{(A.20)}$$

Appendix: B (Additional Tables)

Table B-1: Single equation probit models with instrumental variables (first stage)

	(1)	(2)	(3)	(4)	(5)
Explanatory Variables	Product Innovation	Process Innovation	Organization Innovation	Production License	Marketing Innovation
Overdue Payment	0.296***	0.292***	0.337***	0.328***	0.347***
	(0.033)	(0.032)	(0.032)	(0.033)	(0.045)
Debt swap/barter	0.152***	0.132***	0.105***	0.144***	0.115*
	(0.042)	(0.050)	(0.034)	(0.049)	(0.063)
Lost Sales	0.414	0.554**	0.371*	0.541*	0.340
	(0.257)	(0.254)	(0.221)	(0.306)	(0.294)
Exports to MNE	-0.075	-0.078	-0.078	-0.072	0.010
	(0.065)	(0.065)	(0.065)	(0.064)	(0.068)
Imports	0.131***	0.133***	0.131***	0.134***	0.108**
	(0.038)	(0.038)	(0.038)	(0.039)	(0.049)
Ln (L)	-0.041	-0.040	-0.038	-0.039	-0.019
	(0.039)	(0.039)	(0.038)	(0.037)	(0.041)
(Ln L)2	-0.003	-0.003	-0.003	-0.003	-0.007
	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
Skilled L	0.023	0.016	0.022	0.025	0.017
	(0.063)	(0.063)	(0.063)	(0.065)	(0.095)
Educated L	-0.050	-0.050	-0.042	-0.039	-0.005
	(0.046)	(0.047)	(0.047)	(0.048)	(0.075)
Markup	-0.009	0.008	-0.010	-0.013	0.019
	(0.108)	(0.111)	(0.107)	(0.106)	(0.168)
Age	-0.021	-0.020	-0.018	-0.023	-0.030
	(0.019)	(0.020)	(0.019)	(0.019)	(0.026)
Year (2005)	-0.133***	-0.131***	-0.128***	-0.125***	-0.152***
	(0.046)	(0.045)	(0.046)	(0.045)	(0.048)
Optimal L	0.163***	0.159***	0.162***	0.164***	0.173***
	(0.040)	(0.042)	(0.041)	(0.040)	(0.046)
Temporary L	0.210**	0.221***	0.217***	0.213**	0.266**
	(0.084)	(0.085)	(0.084)	(0.086)	(0.105)
CU	-0.245***	-0.252***	-0.251***	-0.244***	-0.232***
	(0.060)	(0.060)	(0.060)	(0.061)	(0.073)
Competition	-0.009	-0.014	-0.011	-0.020	-0.086
	(0.090)	(0.093)	(0.090)	(0.089)	(0.085)
F-statistic	11.61	11.31	11.79	11.47	9.32
N	10,291	10,198	10,211	10,192	6,061

* denotes significance at the 95% level, **denotes significance at the 99% level, and *** denotes 0.001 significance at the 99.9% level; Robust clustered standard errors are reported in parentheses. This table presents the first stage regression results from the univariate innovation models with IV's. The IV's were implemented using conditional maximum likelihood estimation in this case. The dependant variable in each equation is financial constraint. Each equation includes fixed effects for country, sector, and year (reported).

Table B-2: MVP model without control functions and with marketing innovation

Explanatory variables	(1) Product Innovation	(2) Process Innovation	(3) Organization Innovation	(4) Production License	(5) Marketing Innovation
Fin. Constrain	0.0232	0.00209	0.0588**	0.0232	0.0299
	(1.35)	(0.13)	(2.60)	(0.99)	(1.43)
Exports to MNE	0.224*	0.204	0.384***	0.231	0.154
	(1.96)	(1.87)	(3.35)	(1.75)	(0.96)
Imports	0.232***	0.220***	0.239***	0.115	0.442***
	(4.29)	(4.64)	(3.60)	(1.88)	(6.93)
Ln (L)	0.310***	0.348***	0.241***	0.250***	0.739***
	(5.93)	(6.49)	(4.73)	(3.62)	(10.98)
$(\text{Ln L})^2$	-0.0274***	-0.0260***	-0.00857	-0.0150	-0.044***
	(-3.74)	(-3.84)	(-1.32)	(-1.68)	(-4.26)
Skilled L	0.0333	-0.0396	-0.197*	-0.0356	-0.297***
	(0.49)	(-0.52)	(-2.34)	(-0.51)	(-3.71)
Educated L	0.182*	0.140	0.213*	0.305***	0.305**
	(1.98)	(1.80)	(2.27)	(3.39)	(2.88)
Markup	0.264	0.531***	0.251	-0.00898	0.675**
	(1.60)	(4.26)	(1.47)	(-0.05)	(3.08)
Age	-0.0632*	-0.0594	0.0290	-0.0859*	-0.0210
	(-2.06)	(-1.65)	(0.76)	(-2.54)	(-0.44)
Year (2005)	0.0182	0.158***	-0.483***	-0.139**	-1.793***
	(0.30)	(3.76)	(-10.45)	(-2.77)	(-6.16)
Optimal L	0.102	0.106	0.257***	0.114	0.125*
	(1.60)	(1.34)	(4.16)	(1.57)	(2.16)
Temporary L	-0.0510	-0.189	-0.120	0.155	-0.0465
	(-0.41)	(-1.20)	(-1.15)	(1.16)	(-0.30)
CU	-0.280**	-0.274**	-0.718***	-0.261*	-0.429**
	(-2.93)	(-3.08)	(-6.02)	(-2.52)	(-3.08)
Competition	0.160***	0.224***	0.198**	0.231***	0.161*
	(3.51)	(5.11)	(3.20)	(3.84)	(2.18)
CF residuals	--	--	--	--	--

ρ_{21}	ρ_{31}	ρ_{41}	ρ_{51}	ρ_{23}
0.374***	0.205***	0.150***	0.121***	0.152***
(12.23)	(7.84)	(6.49)	(3.71)	(5.76)
ρ_{24}	ρ_{25}	ρ_{34}	ρ_{35}	ρ_{45}
0.230***	0.121***	0.107***	0.0939**	0.0497
(7.41)	(6.05)	(3.69)	(3.08)	(1.55)

N = 5810; * denotes significance at the 95% level, **denotes significance at the 99% level, and *** denotes 0.001 significance at the 99.9% level; t-statistics reported in parentheses. Each equation includes fixed effects for country, sector, and year (reported).

Table B-3: MVP model with control functions and with marketing innovation

Explanatory variables	(1) Product Innovation	(2) Process Innovation	(3) Organization Innovation	(4) Production License	(5) Marketing Innovation
Fin. Constrain	-0.302*	-0.528***	0.268	-1.031***	0.0993
	(-2.33)	(-3.69)	(1.79)	(-5.78)	(0.48)
Exports to MNE	0.185	0.139	0.410***	0.106	0.164
	(1.58)	(1.27)	(3.51)	(0.79)	(1.03)
Imports	0.257***	0.261***	0.224**	0.188**	0.436***
	(4.76)	(5.47)	(3.28)	(2.89)	(6.87)
Ln (L)	0.290***	0.316***	0.253***	0.186*	0.744***
	(5.69)	(5.89)	(4.84)	(2.53)	(10.71)
$(\text{Ln L})^2$	-0.0277***	-0.0264***	-0.00839	-0.0156	-0.044***
	(-3.81)	(-3.95)	(-1.29)	(-1.68)	(-4.25)
Skilled L	0.0338	-0.0399	-0.196*	-0.0367	-0.297***
	(0.50)	(-0.52)	(-2.33)	(-0.51)	(-3.71)
Educated L	0.141	0.0729	0.238*	0.177	0.314**
	(1.48)	(0.92)	(2.40)	(1.85)	(2.74)
Markup	0.252	0.515***	0.256	-0.0463	0.679**
	(1.55)	(4.14)	(1.51)	(-0.26)	(3.07)
Age	-0.0592*	-0.0526	0.0265	-0.0722*	-0.0216
	(-1.99)	(-1.46)	(0.68)	(-2.14)	(-0.45)
Year (2005)	-0.0267	0.0843	-0.454***	-0.289***	-1.784***
	(-0.42)	(1.90)	(-8.44)	(-5.05)	(-6.22)
Optimal L	0.146*	0.178*	0.229***	0.256**	0.115
	(2.09)	(2.23)	(3.52)	(3.22)	(1.88)
Temporary L	0.0134	-0.0851	-0.161	0.361**	-0.0616
	(0.11)	(-0.51)	(-1.58)	(2.78)	(-0.39)
CU	-0.384***	-0.442***	-0.651***	-0.593***	-0.409**
	(-3.58)	(-4.50)	(-4.80)	(-5.33)	(-2.67)
Competition	0.162***	0.227***	0.196**	0.239***	0.160*
	(3.52)	(5.24)	(3.22)	(3.86)	(2.15)
CF residuals	0.329*	0.537***	-0.213	1.067***	-0.0700
	(2.49)	(3.63)	(-1.38)	(5.79)	(-0.35)

$\boldsymbol{\rho_{21}}$	$\boldsymbol{\rho_{31}}$	$\boldsymbol{\rho_{41}}$	$\boldsymbol{\rho_{51}}$	$\boldsymbol{\rho_{23}}$
0.373***	0.207***	0.149***	0.122***	0.154***
(12.30)	(7.86)	(6.43)	(3.68)	(5.84)
$\boldsymbol{\rho_{24}}$	$\boldsymbol{\rho_{25}}$	$\boldsymbol{\rho_{34}}$	$\boldsymbol{\rho_{35}}$	$\boldsymbol{\rho_{45}}$
0.225***	0.121***	0.112***	0.0944**	0.0501
(7.18)	(5.98)	(3.86)	(3.08)	(1.55)

N = 5810; * denotes significance at the 95% level, **denotes significance at the 99% level, and *** denotes 0.001 significance at the 99.9% level; t-statistics reported in parentheses. Each equation includes fixed effects for country, sector, and year (reported).

Table B-4: Two-stage least squares estimation of multivariate probit

	(1)	(2)	(3)	(4)
Explanatory Variables	Product Innovation	Process Innovation	Organization Innovation	Production License
Fin. Constraint	-0.392***	-0.659***	0.0898	-0.932***
	(-3.45)	(-5.05)	(0.68)	(-6.55)
Exports to MNE	0.160	0.0962	0.314**	0.179
	(1.89)	(1.05)	(2.86)	(1.43)
Imports	0.285***	0.315***	0.248***	0.188***
	(6.56)	(7.75)	(4.72)	(3.46)
Ln (L)	0.264***	0.302***	0.272***	0.197***
	(6.52)	(6.65)	(5.22)	(4.21)
$(\text{Ln L})^2$	-0.0244***	-0.0252***	-0.0112	-0.0176**
	(-3.93)	(-4.38)	(-1.74)	(-2.80)
Skilled L	0.0431	0.0115	-0.184*	-0.104
	(0.97)	(0.18)	(-2.35)	(-1.49)
Educated L	0.147*	0.142*	0.289***	0.225**
	(2.20)	(2.33)	(3.60)	(2.95)
Markup	0.259*	0.464***	0.242*	-0.109
	(2.16)	(4.69)	(2.02)	(-0.75)
Age	-0.0730**	-0.0603*	0.0206	-0.0795***
	(-3.23)	(-2.42)	(0.63)	(-3.44)
Year (2005)	0.0435	0.102*	-0.428***	-0.235***
	(0.84)	(2.24)	(-8.64)	(-4.59)
Optimal L	0.234***	0.188***	0.245***	0.241***
	(4.56)	(3.63)	(4.27)	(3.58)
Temporary L	0.105	0.0440	-0.0995	0.436***
	(0.94)	(0.37)	(-0.97)	(3.91)
CU	-0.353***	-0.494***	-0.660***	-0.542***
	(-4.73)	(-5.97)	(-6.02)	(-5.58)
Competition	0.161***	0.255***	0.165***	0.277***
	(4.64)	(6.94)	(3.33)	(4.91)

ρ_{21}	ρ_{31}	ρ_{41}	ρ_{32}	ρ_{42}	ρ_{43}
0.362***	0.207***	0.148***	0.151***	0.222***	0.136***
(14.62)	(10.74)	(8.39)	(7.18)	(8.49)	(6.10)

t statistics in parentheses; * denotes significance at the 95% level, **denotes significance at the 99% level, and *** denotes 0.001 significance at the 99.9% level; N = 9899. This table reports the results from the multivariate probit model that uses two-stage least squares instead of control functions to implement the instrumental variables. Each equation includes fixed effects for country, sector, and year (reported).

Table B-5: Replication of Table 6-5 with full sample

	(1)	(2)	(3)	(4)
Explanatory Variables	Product Innovation	Process Innovation	Organization Innovation	Production License
Financial Constraints	-0.200	-0.197	0.503***	0.204
	(-1.83)	(-1.71)	(4.71)	(1.71)
Exports to MNE	0.188*	0.157	0.329***	0.345***
	(2.56)	(1.95)	(3.56)	(3.45)
Imports	0.282***	0.311***	0.219***	0.122**
	(7.79)	(8.01)	(4.77)	(2.63)
Ln (Labour)	0.219***	0.287***	0.344***	0.290***
	(6.36)	(7.58)	(8.14)	(7.68)
$(\text{Ln Labour})^2$	-0.0162**	-0.0193***	-0.0201***	-0.0207***
	(-3.24)	(-4.00)	(-4.06)	(-4.25)
Skilled Labour	0.0471	0.0110	-0.163*	-0.0624
	(1.20)	(0.21)	(-2.21)	(-1.12)
Educated Labour	0.179**	0.165**	0.356***	0.325***
	(2.89)	(2.89)	(5.22)	(4.94)
Markup	0.197	0.411***	0.202	-0.0492
	(1.69)	(4.23)	(1.73)	(-0.34)
Age	-0.0646**	-0.0597**	0.0253	-0.0802***
	(-3.16)	(-2.94)	(0.89)	(-3.70)
Year (2005)	0.0625	0.154***	-0.342***	-0.0466
	(1.21)	(3.64)	(-7.77)	(-0.90)
Optimal Labour	0.191***	0.118*	0.189***	0.0698
	(4.18)	(2.35)	(3.83)	(1.19)
Temporary Labour	0.124	-0.0141	-0.172	0.220*
	(1.16)	(-0.12)	(-1.92)	(2.15)
Capacity Utilization	-0.301***	-0.306***	-0.456***	-0.250**
	(-4.49)	(-4.28)	(-4.58)	(-2.86)
Competition	0.139***	0.213***	0.158***	0.263***
	(3.79)	(5.93)	(3.35)	(5.26)
State Owned	-0.247***	-0.188**	-0.239***	-0.164**
	(-4.15)	(-3.00)	(-4.45)	(-3.02)
CF residuals	0.221*	0.199	-0.469***	-0.177
	(2.01)	(1.75)	(-4.32)	(-1.51)

ρ_{21}	ρ_{31}	ρ_{41}	ρ_{32}	ρ_{42}	ρ_{43}
0.355***	0.197***	0.154***	0.159***	0.231***	0.133***
(13.84)	(9.42)	(9.30)	(7.85)	(9.59)	(6.02)

t statistics in parentheses; * denotes significance at the 95% level, **denotes significance at the 99% level, and *** denotes 0.001 significance at the 99.9% level; N = 11,574. This table reports the results from the multivariate probit model with instrumental variables that are implemented with control functions. Each equation includes fixed effects for country, sector, and year (reported). This regression does not restrict the sample to privately owned firms, i.e., firms that have been previously or are currently owned by the government are included in this sample. With this sample, the coefficient on financial constraint is no longer significant for product (1), process

(2), and production license innovation (4). However, the coefficient estimates for being a state-owned firm (State Owned) are negative and highly significant for all equations. Thus, financial constraints may influence innovation of state-owned firms differently from private firms, and state-owned firms are significantly less likely to innovate than their private counterparts

Table B-6: Productivity model including publicly owned firms

Dep. Variables	(1)	(2)	(3)	(4)	(5)	(6)
Financial Constraints	-0.012	-0.012	-0.012	-0.012	-0.011	-0.012
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Any Innov.	0.045**					
	(0.018)					
Product Innov.		0.034*	0.026	0.034	0.028	0.032*
		(0.017)	(0.026)	(0.023)	(0.023)	(0.018)
Process Innov.		0.031	0.031	0.030	0.028	0.031
		(0.019)	(0.029)	(0.023)	(0.022)	(0.024)
Organization Innov.		0.075***	0.066*	0.078***	0.060*	0.074**
		(0.022)	(0.037)	(0.023)	(0.034)	(0.031)
Prod. License		0.011	0.006	0.016	0.005	0.003
		(0.033)	(0.052)	(0.037)	(0.044)	(0.045)
Product Innov. and Process Innov.			-0.002	0.001		
			(0.039)	(0.039)		
Product Innov. and Organization Innov.			0.033		0.031	
			(0.058)		(0.055)	
Product Innov. and Prod. License			0.013			0.017
			(0.061)			(0.057)
Process Innov. and Organization Innov.			-0.006			0.002
			(0.057)			(0.054)
Process Innov. and Prod. License			0.013		0.014	
			(0.062)		(0.060)	
Organization Innov. and Prod. License			-0.024	-0.019		
			(0.065)	(0.062)		
N	8,908	8,860	8,860	8,860	8,860	8,860
R-squared	0.556	0.559	0.559	0.559	0.559	0.559

* denotes significance at the 90% level, **denotes significance at the 95% level, and *** denotes significance at the 99% level; Robust clustered (year and country clusters) standard errors are reported in parentheses. This table reports the results from six separate linear regressions. Labour productivity is the dependent variable for each regression. All the explanatory variables from the innovation models are included as explanatory variables in these regressions. That is, the regressions differ only by the different innovation interaction terms. The coefficient estimates of the remaining explanatory variables are included on the next page. Each regression includes fixed effects for country, sector, and year (reported). Model (1) uses the variable *Any Innov.* which is equal to one if the firm reported any one of the four innovation types and zero otherwise.

Table B-6 (continued): Productivity model including publicly owned firms

Dep. Variables	(1)	(2)	(3)	(4)	(5)	(6)
Exports to MNE	0.241***	0.230***	0.230***	0.230***	0.230***	0.230***
	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)
Imports	0.191***	0.189***	0.189***	0.189***	0.189***	0.189***
	(0.035)	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)
Ln (Labour)	0.052	0.052	0.051	0.051	0.052	0.052
	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)
(Ln Labour)2	-0.012*	-0.013*	-0.013*	-0.013*	-0.013*	-0.013*
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Skilled Labour	-0.068***	-0.064**	-0.064**	-0.064**	-0.064**	-0.064**
	(0.025)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
Educated Labour	0.249***	0.237***	0.237***	0.237***	0.237***	0.237***
	(0.051)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)
Markup	-0.092	-0.096	-0.095	-0.096	-0.095	-0.096
	(0.078)	(0.079)	(0.079)	(0.079)	(0.079)	(0.078)
Age	0.045*	0.043*	0.043*	0.043*	0.043*	0.043*
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
Year	-0.560**	-0.569**	-0.568**	-0.569**	-0.568**	-0.569**
	(0.218)	(0.213)	(0.213)	(0.213)	(0.213)	(0.213)
Optimal Labour	0.190**	0.203**	0.204***	0.203**	0.204***	0.203***
	(0.079)	(0.076)	(0.075)	(0.076)	(0.075)	(0.076)
Temporary Labour	0.090	0.055	0.054	0.055	0.054	0.055
	(0.078)	(0.072)	(0.072)	(0.072)	(0.073)	(0.072)
CU	-0.022	-0.018	-0.017	-0.018	-0.017	-0.018
	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)
Competition	0.691***	0.702***	0.702***	0.702***	0.703***	0.702***
	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)	(0.041)
Observations	8,908	8,860	8,860	8,860	8,860	8,860
R-squared	0.556	0.559	0.559	0.559	0.559	0.559

* denotes significance at the 90% level, **denotes significance at the 95% level, and *** denotes significance at the 99% level; Robust clustered (year and country clusters) standard errors are reported in parentheses. These regression results are a continuation of the results presented in Table 6-7. In each of the equations, labour productivity is the dependant variable. The difference between the equations are the different innovation explanatory variables that are included. Each regression includes fixed effects for country, sector, and year (reported).