KDI Journal of Economic Policy

KDI Journal of Economic Policy

Statement of Purpose

The KDI Journal of Economic Policy (KDI JEP) is a professional journal published on a quarterly basis. The Journal publishes papers on the academic and policy issues related to the development of Korea's economy. The KDI Journal of Economic Policy welcomes innovative and insightful academic papers on all areas of economics with an emphasis on empirical analysis that contain solid policy implications. KDI JEP is published in English starting in 2015, volume 37 number 1.

The Journal aims to disseminate research outcomes and policy recommendations not only to experts at academia and research institutes but also to policy-makers and the general public. First published in March 1979, the original objective was to circulate ongoing- and past researches conducted in KDI, a leading economic think-tank of South Korea. Starting in August, 2001, the Journal has accepted manuscripts from outside in order to provide the readers more diverse perspectives on Korea's policy initiatives. The Journal now actively seeks and welcomes submissions by researchers at home and from abroad who have genuine interests in the Korean economy.

The contents of papers published in KDI JEP contain personal views of the authors, and thus do not represent the objectives of the Journal or the mission statements of KDI.

KDI Journal of
Economic Policy

Articles

An Empirical Study of the Effect of the Internet on Fares in the U.S. Airline Industry

By HWA RYUNG LEE*

A reduction in search costs is generally believed to make markets more competitive. However, the effect may be mitigated or amplified if consumers must pay costs for switching products. This paper investigates how search costs affect prices in the presence of switching costs using U.S. domestic airfare data for 2000–2010. The airline industry experienced a dramatic decrease in search costs with increasing Internet use in the 2000s. At the same time, the industry is known for its frequent flyer programs (FFPs), which increase switching costs for consumers. We use the average network size of airlines in a market as a proxy for switching costs related to FFPs and Internet usage as a proxy for (the inverse of) search costs. The results show that increasing Internet usage lowers airfares but that the effect is smaller for markets with a larger average network size.

I. Introduction

Search costs are dramatically reduced in the Internet era, as consumers can easily and quickly compare products on the web. Firms have feared whether the decrease in search costs associated with increasing Internet use would intensify competition. The airline industry is one of the industries greatly affected by the rapidly increasing use of the Internet, and previous research has found that Internet use has led to lower airfares (Brunger 2010, Orlov 2011, Verlinda and Lane 2004). However, the industry is also known for successful loyalty programs called frequent flyer programs (FFPs), which create artificial switching costs. When consumers incur costs when switching products, the effect of the search cost reduction on prices may be smaller. This paper discusses theoretical ambiguities in relation to this and assesses this problem empirically in the context of the effect of the Internet on airfares.

The presence of switching costs offers less flexibility to consumers and renders market power to firms. Search costs have similar effects in that consumers become less responsive to prices. Accordingly, it appears natural to expect that a decrease in search costs will intensify price competition but that switching costs will hinder the competition arising from the reduced search costs.

In a dynamic setting, however, the effect of search and switching costs can be more complicated. Given that switching costs provide firms with market power over locked-in customers, the equilibrium price will be driven by two opposing forces: exploiting the existing customer base with high prices ("harvest") or winning market share with low prices in anticipation of ripping off those customers later ("invest"). Similarly, if consumers tend to seek out the products they previously purchased before searching for other products,[1] search costs give firms additional power to lock in customers and present a contrast between investing and harvesting incentives. In sum, it is ambiguous as to whether switching costs would raise prices, whether a reduction in search costs would lower prices, and whether switching costs would mitigate or amplify the effect of search cost reduction.

We use U.S. domestic airfare data for 2000–2010 to assess the price effects of search and switching costs empirically. The average Internet usage in the endpoint cities of a route is used as a proxy for (the inverse of) search costs in the market (i.e., the route).[2] We measure the size of the route network in three different ways and use those measures as proxies for switching costs related to FFPs.[3] This is motivated by the fact that the value of an FFP is highly dependent on the size of an airline's route network; the more destinations an airline has, the easier it is for customers to accumulate mileage and use it to get where they want to go.

A regression analysis of market average fares suggests that switching costs reduce the price competition arising from a decrease in search costs. Specifically, we find that fares decrease with Internet use but that the fare reduction is less with a larger average network size of competing airlines on a route. This result suggests that switching costs allow firms to stay in a less competitive pricing regime when search costs decrease.

The results have implications on potential policies. Although this work implicitly takes search and switching costs as exogenously given, firms may be able to affect those costs strategically. For example, as a response to declining search costs with the increasing use of the Internet, firms may attempt to increase switching costs to stifle competition arising from declining search costs. A policy aiming to reduce one of the costs may also evoke reactions by firms to offset the effect of the cost decrease. Thus, the dynamic interaction between the two costs and the potential reactions of firms should be considered to improve the effectiveness of policies.

The rest of this paper is organized as follows. Section 2 provides an overview of related literature. Section 3 discusses the ambiguity related to the combined effect of search and switching costs. Section 4 describes the empirical model and data.

---

[1]Alternatively, we can think of the case in which consumers are better-informed about the products they previously purchased and need to incur extra costs to get information about the other products.

[2]Throughout this paper, we use "route" and "market" interchangeably.

[3]Borenstein (1989) noted the presence of a hub premium related to FFPs and Lederman (2007) disentangled the value of FFPs from the advantages of being a dominant firm. They attribute the price premium to switching costs arising from FFPs.

Section 5 discusses the estimation results. Concluding remarks are given in Section 6.

II. Literature Review

This paper is related to three streams of literature: studies on switching costs; studies on search costs, especially in the context of the effect of the Internet on competition; and studies on airline competition in the Internet era. There is a large body of literature on both search costs and switching costs. Empirical studies have noted that many industries exhibit some type of switching costs. In the market for bank loans, consumers who switch lose the value of the relationship with a bank arising from information asymmetry (Kim, Kliger, and Vale 2003); in the market for toll-free services, prices fell as 800-numbers became portable (Viard 2007); in the markets for refrigerated orange juice and margarine, consumers behave as if they obtain additional utility from purchasing products they previously purchased or, equivalently, they suffer psychological costs when switching brands (Dubé, Hitsch, and Rossi 2010); and so on.[4]

A large body of theoretical literature on switching costs contrasts the opposing incentives in a dynamic setting, including the incentive to win new customers by lowering prices and the incentive to exploit locked-in customers by raising prices. In these studies, predictions of the relationship between switching costs and competition are ambiguous. Klemperer (1987) and Beggs and Klemperer (1992) demonstrate that markets are generally less competitive with rather than without switching costs, as forward-looking consumers expect that switching costs will make them less flexible in the future and that firms will exploit them by charging high prices. As a result, consumers become less sensitive to current prices; thus, the investment incentive dominates. On the other hand, Cabral and Villas-Boas (2005) demonstrate that switching costs can make markets more competitive, as the strategic effect (that is, competition to win market share) outweighs the direct effect (that is, price increases to exploit existing customers) of switching costs as an example of the "Bertrand Supertrap." Dubé, Hisch, and Rossi (2009) establish a U-shaped relationship between price and switching costs using the infinite-horizon model, in which the lock-in factor is allowed to be imperfect. Shin and Sudhir (2009) and Cabral (2009) came up with simpler models that produce some empirical implications given by Dubé, Hisch and Rossi (2009). Shin and Sudhir (2009) recover the U-shaped relationship between price and switching costs using a two-period Hotelling model when firms cannot discriminate between locked-in and non-locked-in consumers. Meanwhile, Cabral (2009) highlights the result from Cabral (2008), which showed that price is decreasing in switching costs when switching costs are low. Cabral (2008, 2009) allows for price discrimination and determines whether the investing effect or the harvesting effect dominates. Farrell and Klemperer (2007) conduct an extensive survey on switching costs.

The literature on search costs is mostly interested in their relationship with price

---

[4]There are numerous other industry studies that identify switching costs or the effect of switching costs. For example, see Borenstein (1991) for the market for gasoline, Greenstein (1993) for mainframe computers, Elzinga and Mills (1998) for cigarettes, Shy (2002) for the bank deposit industry and the wireless industry, and Honka (2014) for the auto insurance industry.

dispersion.[5] In terms of price levels, theories on search costs generally predict a positive relationship between search costs and prices in a static setting. Important exceptions include Lal and Sarvary (1999), who demonstrate that a search cost reduction can raise prices as consumers can identify the characteristics of products better in a vertically differentiated market. There are numerous empirical works that examine competition in the Internet era, in which the increasing use of the Internet is generally interpreted as a decrease in search costs. The literature mostly examines the effect of the Internet on price levels and price dispersions, or the price differential between online and offline stores. For example, in the airline industry, Brunger (2010) finds that "clearly leisure"[6] travelers pay lower average fares when purchasing a ticket through internet-based online travel agencies as compared to offline travel agencies. Orlov (2011) examines U.S. airline data and finds that, with Internet use, airfares decrease and the degree of intrafirm fare dispersion increases, whereas the degree of interfirm fare dispersion is unaffected. Verlinda and Lane (2004) investigate the effect of search costs on price dispersion characteristics from the angle of price discrimination using U.S. airfare data. They find evidence that the Internet toughens competition and increases the price dispersion between restricted and unrestricted tickets, which is consistent with price discrimination through brand differentiation. However, the airline industry can also be characterized by switching costs arising from FFPs (Borenstein 1989, Lederman 2007). This paper assesses the effect of the Internet on airfares with a focus on the interaction between search and switching costs.

Given the vast literature on both search costs and switching costs and the similar characteristics of the two costs as types of market friction, there have been relatively few attempts to include search and switching costs in one framework. Knittle (1997) includes both search and switching costs to explain why competition arising from the divestiture of AT&T has not lowered the rates of long distance calls, finding supporting evidence that the presence of those costs are major sources of market power. In the theory section of the paper, he considered both costs and showed that they can result in higher prices in a simple static setting. Wilson (2009) offers a unified analysis of search and switching costs in one theoretical framework, also in a static setting.

Farrell and Klemperer (2007) note that researchers often do not distinguish between search and switching costs and that search costs can be modelled in a manner similar to that of switching costs. Some empirical works note the potential dynamic effect of search costs as an alternative explanation of switching costs in creating consumer inertia. Moshkin and Shachar (2000) show that both search and switching costs can result in persistent market share in a dynamic setting and suggest how the two costs can be distinguished from each other empirically. They assume a consumer may incur one of the two costs, but not both. In their model, past consumption can affect current purchase decisions through either switching costs or search costs. Dubé, Hitsch, and Rossi (2010) attempt to identify the reason for consumer inertia by testing predictions considering the three different factors of

---

[5]See Baye, Morgan, and Scholten (2005) for a survey on search costs and price dispersion.
[6]Travelers are defined as "Clearly Leisure" if their travel characteristics correspond to leisure rather than business travel, in particular, if tickets were purchased more than 14 days before departure, and their itinerary included an extended stay over a weekend.

switching costs, search costs, and learning. They find evidence consistent with consumer behavior in the presence of switching costs rather than search costs or learning. Honka (2014) includes both types of cost in her model to quantify search and switching costs using data from the U.S. auto insurance industry. However, these prior works do not consider the interaction between search and switching costs in determining prices. Here, in contrast, the interaction between the two costs is the main interest. The price effect of a reduction in search costs in the presence of switching costs is theoretically ambiguous and becomes an empirical question.

III. Conceptual Framework

Search costs and switching costs are types of market friction that work in a similar fashion. In a static setting, the two costs make demand less elastic. In a dynamic setting, firms are faced with two opposing forces - investing incentives and harvesting incentives - in the presence of switching costs. A similar dynamic effect arises with search costs if previous purchases induce consumers to seek out the same products again before other products, as consumers are better informed about products they previously purchased. Search costs are distinguished from switching costs, as they affect even consumers not locked into any product.

It is also important to note that search costs and switching costs can influence both search and switching behavior. To switch, consumers would need to search for other products. If consumers are unlikely to switch, they would not search, even with low search costs. Search costs and switching costs jointly shape consumer behavior and determine market prices. In sum, the effect of search costs on firms' pricing decisions in the presence of switching costs would differ depending on which incentive, investment or harvesting, overwhelms.

Suppose that switching costs are so large that no one switches. Locked-in consumers who would never switch would never search for other products in the first place. Any search cost reduction is then irrelevant to those locked-in consumers, and the dynamic, lock-in effect of search costs can thus be ignored.

On the other hand, a decrease in search costs would make firms act more aggressively to win those consumers without purchase histories, that is, those who are not locked into any product. Firms have a strong incentive to lure non-locked-in consumers as, once consumers buy their products, those consumers will be fully locked in to them in the future and the firms will enjoy a monopolist position. This effect will be greater in the presence of larger switching costs, as the monopolist profit a firm can extract from locked-in consumers increases with switching costs. Thus, a decrease in search costs will make markets even tougher in the presence of larger switching costs.

Now suppose that consumers do not incur any costs when switching. Consumers may still be locked into the product they purchased previously if they have to pay costs to become informed about other products. Consumers would not search and switch if the search is a costly process. As in the presence of switching costs, firms will then be faced with the incentive to exploit their customer base as well as the incentive to invest in market share. In addition, search costs make demand less elastic and so may curb the incentive to earn customers by cutting prices. In sum, a

decrease in search costs undermines firms' abilities to harvest, while it has an ambiguous effect on the investing incentive.

The price effect of a reduction in the search cost is complicated by the presence of switching costs. Unless switching costs are high enough to guarantee full lock-in, switching costs and search costs jointly determine the degree of lock-in. Let us suppose that switching costs are relatively low such that consumers may actually switch from one product to another, for example, to seek a better match with their tastes. As long as the combination of search and switching costs creates enough friction to lock consumers into the product previously purchased, firms will be able to sustain a monopolist position over those locked-in consumers. Thus, while search costs are declining, firms are more likely to sustain their lock-in power in the presence of larger switching costs. At the same time, however, both the harvesting incentive and the investing incentive will be enhanced by switching costs, as the extent to which firms can exploit locked-in consumers increases with switching costs.

The market price will be determined as a result of the balance between the incentive to exploit locked-in consumers and the incentive to retain the customer base and poach rivals' customers. As discussed previously, which incentive would overwhelm depends on the respective sizes and the combined size of the search costs and switching costs. The overall effect of a search cost reduction in the presence of switching costs is theoretically ambiguous and becomes an empirical question, as noted earlier.

IV. Empirical Specification and Data

A. *Empirical Specification*

The previous section discussed the ambiguity of the price effect of a search cost reduction in the presence of switching costs. The airline industry is particularly suitable for assessing this effect. The airline industry experienced a dramatic decrease in search costs with increasing Internet use in the 2000s. Consumers can sort tickets by prices or other ticket characteristics and find attractive alternatives with only a few clicks. They can also check out other travel agency websites, price comparison sites, and airline websites for better deals quickly and easily. The increase in Internet use is an external shock to the industry that reduces search costs and is unrelated to the level of switching costs. We use the average Internet use at the endpoint airports of a route as a proxy for search costs (as measured inversely). Internet use may not reduce the total time spent on searching, as the Internet may idle people. Here, we may interpret search costs as the minimum time and effort needed to find relevant information. As consumers are better informed, their consideration sets will be widened and they will become more flexible.

The airline industry is also characterized by the presence of significant switching costs. Major airlines have FFPs that encourage repeated purchases. These have been regarded as one of the most successful marketing strategies. FFPs reward a consumer who accumulates mileage to a certain level with a bonus ticket. In other words, a consumer has to forgo the opportunity to gain a bonus ticket when buying

from another airline. Those switching costs arising from FFPs are proportional to the extensiveness of the route network, as consumers would find it easier to accumulate and redeem mileage when an airline serves more destinations. In this sense, we use different measures of the average network size of airlines on a route as a proxy for switching costs in the market.

Markets are defined as a trip from an origin airport to a destination airport. The data used in this analysis presents both cross-sectional and over-time variations in Internet use and in the airline network size. This allows us to identify the effects of search costs, switching costs, and the interaction between the two costs on the average market fare.

In particular, we estimate the following fixed-effect model:

$$\log(Fare_{rt}) = \alpha + X_{rt}\beta + \gamma_1 Internet_{rt} + \gamma_2 Network_{rt}$$
$$+\gamma_3 Internet_{rt} \cdot Network_{rt} + \delta_{rq} + \delta_t + \epsilon_{rt}$$

Here, $Fare_{rt}$ denotes the number-of-passengers weighted-average fare in market r at time t; $Network_{rt}$ is the average network size of the airlines competing in market r at time t, measured in a number of different ways; $Internet_{rt}$ is the average internet penetration rate in the two endpoint regions of market r at time t; X_{rt} is a set of control variables; δ_{rq} is a fixed effect for the pair of market r and quarter q of time t; δ_t is a fixed effect for time t; and ϵ_{rt} is a random error with zero mean.

Market-quarter fixed effects (δ_{rq}) are included to control for the unobserved, time-invariant component of a route and route-specific seasonality; and time-fixed effects (δ_t) are included to account for time-specific components - common demand/supply shocks - unobserved by researchers.

Specifically, the Internet penetration rate in the region where an airport is located is measured by the proportion of people having Internet access in the region. The Internet penetration rate differs across regions and over time. *Internet* denotes the average Internet penetration rate in the two endpoint regions of a given market, i.e.,

$$Internet_{rt} = (Internet_{ot} + Internet_{dt})/2,$$

where $Internet_{ot}(Internet_{dt})$ is the proportion of people having Internet access at time t in the region where the origin (destination) airport of market r is located.

An airline's network size at an airport is measured by the number of destinations that the airline serves originating from the airport, and the airline's network size in a market is measured by the average network size of the airline at the endpoint airports of the market. In particular, we devise a network size variable, $Network_{rt}$, by taking the average of the direct network size of airlines. Specifically, we first compute the simple average of the number of destinations to which a carrier operates a direct flight at each of the two endpoint airports of a given market, after which we take the average of the values across all airlines serving the market multiplied by the number-of-passengers weights, i.e.,

$$Network_{rt} = \sum_{c \in C}(S_{crt} \cdot \frac{1}{2}(Y_{crt}^{origin} + Y_{crt}^{dest}))/2,$$

where S_{crt} is the market share of carrier c in market r at time t; C is the set of carriers competing in market r at time t; and $Y_{crt}^{origin}(Y_{crt}^{dest})$ is the number of destinations to which carrier c operates a direct flight from the origin (destination) airport of market r at time t.

As robustness checks, two alternative measures of network size are considered with different variables for Y_{crt}^{origin} and Y_{crt}^{dest}. First, consumers may consider the number of destinations they can reach regardless of the identity of an operating airline and whether they can take a direct flight or not. To reflect this point, we additionally consider the destinations served by only connecting flights and code-sharing flights. In this case, Y_{crt}^{origin} represents the number of destinations that carrier c serves from the origin (destination) airport of market r at time t. Second, consumers may care about the frequency of flights rather than the number of destinations when evaluating FFPs because it would be easier for them to accumulate and use mileages when there are more flights. We consider this by constructing an alternative measure of *Network* based on the number of direct flights operated by an airline from the endpoint airports.[7] Specifically, Y_{crt}^{origin} is the number of direct flights of carrier c from the origin (destination) airport of market r at time t.

X_{rt} is a set of control variables that accounts for the average product characteristics and market structure. Suppressing the market and time notations (r, t), the average product characteristics include the fraction of direct flights among all itineraries (*Direct*); the fraction of round-trip tickets among all itineraries (*Round*); and the average extra miles flown of all itineraries (*ExtraMiles*). *ExtraMiles* is zero if an itinerary is served by a non-stop, direct flight. For connecting flights, the variable is measured by taking the difference between the actual flown miles and the non-stop miles flown. Variables of the market structure include whether a low-cost carrier (LCC) serves market r at time t ($LCCin_{rt}$); the number of LCCs serving market r at time t ($NumLCC_{rt}$); and the market concentration as measured by the Herfindahl-Hirschman Index (HHI) in market r at time t (HHI_{rt}). LCC-related variables are included because LCCs tend to have a smaller network size and offer less expensive tickets than legacy carriers; LCC entry can result in a spurious positive relationship between the average network size and the average fare in a market.

B. *Data*

There are two main data sources for the empirical analysis. First, the airline data is obtained from the Bureau of Transportation Statistics of the U.S. Department of Transportation (DOT). The Airline Origin and Destination (O&D) Survey Data Bank 1B (DB1B) is a 10% random sample of tickets used during each quarter and

---

[7]We do not know the total number of flights that a carrier serves from an origin airport to a destination airport because capacity data is available only for direct flights.

contains information on fares and other ticket characteristics, such as origins, destinations, ticketing carriers, numbers of passengers, numbers of connections (i.e., the number of coupons used in an itinerary), whether a ticket is a round-trip ticket, and so on, at the itinerary level. Capacity data such as the number of available seats and the number of flights are obtained from the T-100 database. Unlike the O&D data, only direct flights are counted in the capacity data. Second, data on Internet use is obtained from various supplements to the Current Population Survey (CPS) of the U.S. Census Bureau. This survey has asked questions about Internet use sporadically since 1997.

This paper examines air travel between airports in the 50 most populated Metropolitan Statistical Areas (MSAs) during the 2000s, when Internet use increased rapidly. The list of MSAs ranked by population as of 2000 is available from the U.S. Census Bureau. All major airports in the MSAs and any minor airports within a 75-mile radius of the major airports are included. Data on Internet use is available for six years between 2000 and 2010 (2000, 2001, 2003, 2007, 2009, and 2010). The surveys asked whether anyone in a household had Internet access at any location. The Internet penetration rate is computed as the fraction of people answering "yes" to this question. In addition, for 2001 and 2003, the surveys also asked whether the respondent searched for a product online. Internet use varies across MSAs and over time. As a robustness check, we measure the proportion of people who engaged in online searches for products instead of the proportion of people having Internet access. We restrict our attention to six years in the 2000s, specifically 2000, 2001, 2003, 2007, 2009 and 2010.

The selection criteria are not related to the level or the change in search and switching costs, and the sample is large enough to cover over 70% of passengers in a quarter. Figure 1 shows that, over time, the average Internet use increases and the average fare decreases, whereas the average network size does not change much. Summary statistics of the variables used in the empirical analysis are shown in Table 1.

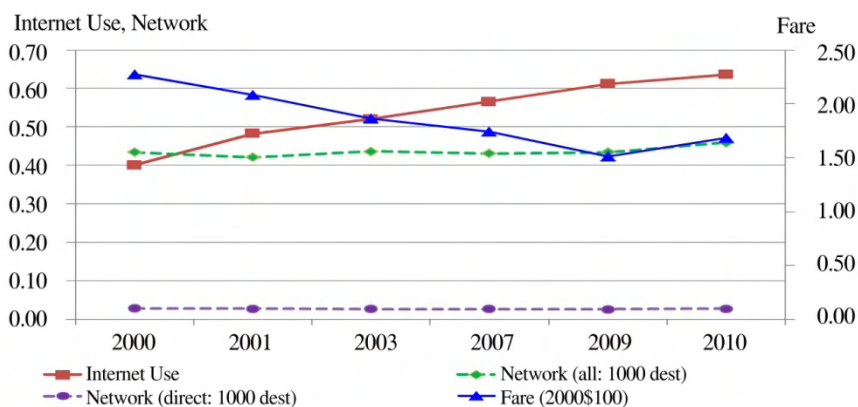FIGURE 1. INTERNET PENETRATION RATES, NETWORK SIZES, AND FARES OVER TIME

Notes: Internet Use is the Internet penetration rate, Network (direct) is the average number of destinations of airlines served by a direct flight, and Network (all) is the average number of destinations of airlines served by any flight (including connecting services). Details about the variables are given in Section IV.A.

TABLE 1—SUMMARY STATISTICS

	Variable	Mean	SD	Min.	Max.	No. obs
	Fare (2000$100)	1.86	0.73	0.22	18.39	114,727
	Internet	0.54	0.09	0.30	0.73	
	Network (100 destinations)	0.10	0.08	0.00	0.51	
	Internet·Network	0.05	0.04	0.00	0.28	
Average product characteristics	ExtraMiles (1000 miles)	0.08	0.09	0.00	2.31	
	Direct	0.37	0.39	0.00	1.00	
	Round	0.74	0.16	0.00	1.00	
Market Structure	LCCin	0.59	0.49	0.00	1.00	
	NumLCC	0.83	0.84	0.00	6.00	
	HHI	0.53	0.26	0.05	1.00	
	Distance (1000 miles)	1.17	0.70	0.02	2.72	
	Distance_sqrd	1.86	1.93	0.00	7.42	
Alternative measures of network size						
Total No. of destinations (both direct/connecting flights)	Network (100 destinations)	0.44	0.09	0.01	0.68	
Total No. of direct flights	Network (1000 flights)	0.38	0.37	0.00	2.69	
Different measures of internet use						
	OnlineSearch	0.34	0.04	0.24	0.50	38.577
	OnlineSearch·Network	0.15	0.04	0.00	0.28	

V. Results and Discussion

Main regression results are presented in Table 2. We estimate different specifications regarding the inclusion of network and Internet variables. All specifications include market-quarter fixed effects and time fixed effects, although the related estimates are not reported in the table.

In specification (1), we see the effect of Internet penetration rates, excluding the average network size. The average fare is found to be significantly and negatively associated with the average Internet penetration rate; a 10 percentage point increase in the average Internet penetration rate is associated with a lower average fare by approximately 4.4%.

In specification (2), we disregard Internet penetration rates and note the effect of the average network size. The result shows that the route-average fare is significantly higher with a larger average network size of airlines on a route. When all competing airlines on a route serve ten more destinations with direct flights (that is, Network increases by 0.1), the average fare is expected to increase by 8.2%, holding all other factors constant.

TABLE 2—MAIN REGRESSION RESULTS

	Specification	(1)	(2)	(3)	(4)
	Variable	Dependent variable: Log (Fare)			
	Network (100 destinations)		0.816*** (0.0310)	0.811*** (0.0309)	0.232*** (0.0762)
	Internet	-0.441*** (0.0339)		-0.427*** (0.0338)	-0.506*** (0.0361)
	Internet·Network				1.156*** (0.135)
Average product characteristics (No. of passengers weighted)	ExtraMiles (1000 miles)	0.119*** (0.0245)	0.102*** (0.0243)	0.102*** (0.0243)	0.115*** (0.0243)
	Direct	-0.126*** (0.00833)	-0.197*** (0.00839)	-0.197*** (0.00838)	-0.198*** (0.00837)
	Round	-0.241*** (0.0121)	-0.229*** (0.0121)	-0.233*** (0.0121)	-0.242*** (0.0122)
Market structure	LCCin	-0.106*** (0.00402)	-0.109*** (0.00398)	-0.109*** (0.00397)	-0.109*** (0.00397)
	NumLCC	-0.0424*** (0.00185)	-0.0402*** (0.00181)	-0.0402*** (0.00181)	-0.0392*** (0.00182)
	HHI	0.151*** (0.00847)	0.108*** (0.00868)	0.111*** (0.00869)	0.109*** (0.00870)
	Constant	1.152*** (0.0183)	0.932*** (0.0121)	1.105*** (0.0183)	1.156*** (0.0202)
	Observations	114,727	114,727	114,727	114,727
	R-squared	0.351	0.358	0.360	0.361
	Number of market-quarter pairs	19,981	19,981	19,981	19,981

Notes: Robust standard errors in parentheses; year-quarter dummies included
   *** significant at the 1 percent level.
   ** significant at the 5 percent level.
   * significant at the10 percent level.

In specification (3), we include both *Internet* and *Network* in one specification. The result shows that the respective coefficient estimates on the two variables are unaffected, implying that *Internet* and *Network* are uncorrelated.

Lastly, in specification (4), we add an interaction term between the Internet penetration rate and the network size. The coefficient estimate of *Network* becomes much smaller. Meanwhile, the estimate of the effect of the Internet is greater (that is, more negative) and the interaction term (*Internet · Network*) is positive and significant. When evaluated at the mean value of *Internet*, an increase in *Network* by 0.1 corresponds to an increase in the average fare by 8.5%.[8] A large fraction of the positive impact of the network size on fares seems to come from the moderation of the negative impact of the Internet. When evaluated at the mean value of *Network*, an increase in *Internet* by 0.1 (that is, an increase of 10 percentage points) corresponds to a decrease in the average fare by 3.9%. The result implies that the pure Internet effect is likely to be underestimated when the network size is not taken into account.

---

[8]This value is computed as "Estimated coefficient on Network+estimated coefficient on Internet·Network× mean value of Internet."

Recall that the average Internet penetration rate is used to capture search costs (as measured inversely) and that the average network size of all airlines on a route is used as a proxy for switching costs. We then interpret the regression results in the context of the price effects of search and switching costs. We find that prices tend to increase with search costs and switching costs. When the interaction between search costs and switching costs is considered, a search cost reduction is found to have a greater, negative impact on prices. The significant and positive effect of the interaction term implies that switching costs lessen the negative effect of the search cost reduction on prices.

The results imply that switching costs are not high enough to lock in consumers fully. If people never switch due to high switching costs, reduced search costs should only increase the investing incentive, while the harvesting incentive would remain unaffected. Considering that the investing incentive increases with the switching cost, decreasing search costs will lead to a deeper price cut in the presence of larger switching costs. We then expect to find a negative coefficient for $Internet \cdot Network$, which is not the case in this empirical analysis.

We interpret the positive relationship between fares and the interaction term as an indication that (1) switching costs are not substantial such that switching may take place; (2) switching costs still allow firms to sustain their lock-in power longer and thus maintain higher prices while search costs are declining; and (3) the investing incentive enhanced by switching costs does not outweigh the increased harvesting incentive. In sum, the empirical results support the general belief that the reduction in search costs associated with increasing Internet use would intensify competition, but switching costs would moderate the impact.

The other estimates appear reasonable. With more actual miles flown, fares are higher on average (see $ExtraMiles$). This may arise because it is more costly to operate a flight or because the competitive pressure is generally low when consumers have to offset a longer distance with connecting flights on average. A higher proportion of direct-flight or round-trip tickets is negatively associated with the route-average fare (see $Direct$ and $Round$), which reflects that direct flights and round-trip tickets are generally offered to consumers at the same or lower prices as compared to connecting flights and one-way tickets respectively. The signs of the estimated coefficients on market-structure variables are as predicted: the presence of LCCs tends to lower the average fare (see $LCCin$ and $NumLCC$); and the average fare tends to be higher in a more concentrated market (see HHi).

At this stage, we determine if there are other explanations for the results. First, consumers may exhibit different degrees of lock-in. For example, business travelers fly more frequently, and they also tend to be less price-sensitive as compared to leisure travelers. The value of FFPs (here, the network size) will be more relevant to business travelers. Thus, the positive relationship between *Network* and fares could indicate price discrimination. If airlines tend to provide a more extensive network in a market with more business travelers, the positive coefficient on the interaction term between Network and Internet may be driven by the fact that business travelers are not heavily affected by the Internet (as they are less price-sensitive). We control for consumer heterogeneity across markets by adding route-quarter fixed effects. By doing so, we address consumer heterogeneity to the extent to which it varies across markets but is constant over time. Aggregate

shocks to consumer heterogeneity are taken into account by including year dummies.

Table 3 presents the estimation results with additional variables to consider other factors that may be related to the interaction between *Internet* and *Network*.

Specification (A1) adds a linear time trend (Time) and an interaction term between the linear time trend and the average network size (Network · Time) to the main specification. In the 2000s, legacy network carriers' market power weakened and fares decreased, whereas the Internet penetration rate increased. Thus, the negative effect of the Internet may be capturing the trend of decreasing fares, and the negative effect of the interaction term between Internet use and the average network size may be a spurious relationship arising from the decreasing market power of legacy carriers. We include time-trend variables to account for

TABLE 3—ROBUSTNESS CHECKS - TIME TREND AND LCC PRESENCE

Specification Variables	Main	(A1) Time trend	(A2) LCC presence
Network	0.232***	-0.221**	0.202***
(100 destinations)	(0.076)	(0.109)	(0.077)
Internet	-0.506***	-0.614***	-0.617***
	(0.036)	(0.043)	(0.039)
Internet ·Network	1.156***	2.236***	1.028***
	(0.135)	(0.237)	(0.134)
ExtraMiles	0.115***	0.113***	0.120***
(1000 miles)	(0.024)	(0.024)	(0.024)
Direct	-0.198***	-0.198***	-0.192***
	(0.008)	(0.008)	(0.008)
Round	-0.242***	-0.239***	-0.237***
	(0.012)	(0.012)	(0.012)
LCCin	-0.109***	-0.109***	-0.278***
	(0.004)	(0.004)	(0.018)
NumLCC	-0.039***	-0.039***	-0.005
	(0.002)	(0.002)	(0.009)
HHI	0.109***	0.110***	0.110***
	(0.009)	(0.009)	(0.009)
Time		-0.019***	
		(0.001)	
Network ·Time		-0.026***	
		(0.006)	
LCCin ·Internet			0.317***
			(0.033)
NumLCC ·Internet			-0.065***
			(0.016)
Market-quarter FE	included	included	included
Observations	114,727	114,727	114,727
R-squared	0.361	0.361	0.362

Notes: Robust standard errors in parentheses; year-quarter dummies included
  *** significant at the 1 percent level.
  ** significant at the 5 percent level.
  * significant at the10 percent level.

this potential problem. Indeed $Time$ and $Network \cdot Time$ are negatively associated with the average fare, but including time-trend variables does not change the main finding that the fare decrease associated with increasing Internet use is lessened by high switching costs.

Specification (A2) includes the interaction between the Internet and the variables related to the presence of LCCs. Network is negatively associated with the presence of LCCs, and so $Internet \cdot Network$ may capture the Internet effect in the presence of LCCs. On the one hand, consumers may be able to find the inexpensive products of LCCs more easily using the Internet; thus, the effect of the Internet on prices may be more prominent when LCCs are present. On the other hand, because the products of LCCs are generally known to be inexpensive, consumers may search for the price information of LCCs anyway and thus the Internet may have less of an impact on consumer search behavior in the presence of LCCs. These factors can potentially lead to biased estimations of the effects of the interaction term; it will be overestimated in the former case and underestimated in the latter case. The result shows that the effect of Internet use tends to be smaller in the presence of LCCs. However, as the number of LCCs increases, Internet use appears to drive down prices. After allowing for different effects of Internet in the presence of LCCs, we still have similar estimates of the effects of Internet, Network, and the interaction between those variables, finding that the Internet lowers prices but that the price drop is smaller when the average network size is larger.

The regression results are dependent on the measure of the network size and on the measure of Internet use. We used different measures of these variables in the robustness checks, and these results are presented in Table 4. As a proxy for switching costs in relation to FFPs ($Network$), we also use the average number of destinations served by airlines by any flight - direct, indirect, and code-sharing flights - (Specifications (B1) and (B2)) and the average number of direct flights at the endpoint airports (Specifications (B3) and (B4)). Details are given in Section Ⅳ.A. The difference in the estimates of the Internet with and without $Internet \cdot Network$ is much larger, and the estimate of $Network$ is insignificant when we take into account all destinations (as compared to main results (3) and (4) in Table 2). Unlike the measure based on the direct network size, this measure (based on all destinations) is likely to capture the pro-competitive effects of code-sharing and a hub-and-spoke system as well. Firms may achieve major cost reductions through code-sharing, and code-sharing on complementary routes may resolve the double marginalization problem. In this sense, this result suggests that network size including all destinations (through direct, indirect, or code-sharing flights) captures more of the effect of double marginalization, while the effect of inhibiting the competitive effect of the Internet remains. The main finding is also confirmed when the number of direct flights is used (Specifications (B3) and (B4)).

We use the proportion of people having Internet access as a proxy for low search costs. For 2001 and 2003, however, we have extra information regarding Internet use. The survey additionally asks if the respondent searched for a product online to purchase at any point over the past year. We use the average of the proportion of people engaging in an online search in the regions in which the endpoint airports of a market are located as a proxy for low search costs (Specifications (B5)~(B8)).

TABLE 4—ROBUSTNESS CHECK - DIFFERENT MEASURES OF $Network$ OR $Internet$

Specification Variables	(B1)	(B2)	(B3)	(B4)	(B5)	(B6)	(B7)	(B8)
	All destinations		Flight frequency			Online search		
	(100 destinations)		(1000 flights)					
	Dependent variable: Log (Average Fare)							
Network	0.583***	0.029	0.139***	0.069***		0.296***	0.332***	-0.438*
	(0.022)	(0.067)	(0.007)	(0.015)		(0.108)	(0.108)	(0.244)
Internet	-0.449***	-0.877***	-0.424***	-0.466***				
	(0.034)	(0.063)	(0.034)	(0.036)				
Internet ·Network		1.067***		0.149***				
		(0.126)		(0.028)				
OnlineSearch					-0.399***		-0.443***	-0.655***
					(0.118)		(0.118)	(0.134)
OnlineSearch ·Network								2.286***
								(0.695)
ExtraMiles (1000 miles)	0.123***	0.134***	0.107***	0.114***	0.143**	0.141**	0.137**	0.141**
	(0.024)	(0.024)	(0.024)	(0.024)	(0.064)	(0.063)	(0.063)	(0.063)
Direct	-0.089***	-0.081***	-0.169***	-0.170***	-0.184***	-0.203***	-0.205***	-0.206***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.025)	(0.024)	(0.024)	(0.024)
Round	-0.279***	-0.285***	-0.233***	-0.238***	-0.570***	-0.573***	-0.572***	-0.572***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.023)	(0.023)	(0.023)	(0.023)
LCCin	-0.097***	-0.098***	-0.109***	-0.109***	-0.149***	-0.148***	-0.149***	-0.148***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.010)	(0.010)	(0.010)	(0.010)
NumLCC	-0.035***	-0.034***	-0.039***	-0.038***	-0.028***	-0.028***	-0.027***	-0.027***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.005)	(0.005)	(0.005)	(0.005)
HHI	0.104***	0.104***	0.117***	0.115***	0.128***	0.116***	0.115***	0.113***
	(0.008)	(0.008)	(0.009)	(0.009)	(0.020)	(0.021)	(0.021)	(0.021)
Constant	0.935***	1.162***	1.112***	1.138***	1.432***	1.287***	1.429***	1.500***
	(0.020)	(0.034)	(0.018)	(0.020)	(0.045)	(0.025)	(0.045)	(0.050)
Observations	114,727	114,727	114,727	114,727	38,577	38,577	38,577	38,577
R-squared	0.363	0.364	0.357	0.357	0.272	0.272	0.272	0.273
No. of market-quarters	19,981	19,981	19,981	19,981	4,975	4,975	4,975	4,975

Notes: Robust standard errors in parentheses; year-quarter dummies included
    *** significant at the 1 percent level.
    ** significant at the 5 percent level.
    * significant at the10 percent level.

Suppressing a time notation, we compute

$$OnlineSearch_r = \frac{1}{2}(Online_r^{origin} + Online_r^{dest}),$$

where $Online_r^{origin}$ ($Online_r^{dest}$) denotes the proportion of people who search online in the region in which the origin (destination) airport of market r is located. The number of observations is reduced, as we cover only two years for which data about online searches is available. Although the estimate of $Network$ is negative, the interaction term $OnlineSearch \cdot Network$ is much larger and positive, as is the network effect evaluated at any value of Internet in the sample. The effect of $Internet$ is negative and the estimated coefficient of $OnlineSearch$ is

significantly   more   negative   when $OnlineSearch \cdot Network$ is   included (Specification (B8) as compared to Specification (B7)). Overall, the main findings are robust to this alternative measure and the use of a subsample.

The results have academic as well as practical implications. First, the comparison between the estimated coefficients of *Internet* with and without the interaction term, $Internet \cdot Network$ (that is, specifications (1) and (3) vs. specification (4)) suggests that estimation of the search cost effect ignoring the interaction with switching costs in determining the market price may be biased. Specifically, in the airline industry, we see that the negative effect of a search cost reduction on prices is underestimated when the interaction with switching costs is omitted.

Second, we take search and switching costs as exogenously given when interpreting empirical results in this paper. In some industries, however, firms may be able to affect these costs. In particular, Internet use is believed to have lowered consumers' search costs dramatically, and firms have feared that this would intensify competition. Firms may respond to the decrease in search costs by increasing switching costs. By doing so, firms will be more likely to maintain high prices, and the potential price cut from the decrease in search costs will not be fully realized.

In this sense, policymakers would need to take into account the possibility that the effectiveness of a policy affecting one of the costs can be undermined by firms' responses, altering the size of the other cost. In the context of the airline industry, switching costs are the product of firms' marketing strategies and are rather out of the reach of policymakers. Given this policy restriction, policymakers would find it easier to alter search costs. Let us suppose that policymakers attempt to lower search costs and that the search cost reduction is comparable to 10%p increase in the average Internet penetration rate. Taking the estimates from the main empirical result, we can compute the number of destinations firms need to add to offset the effect of the lowered search costs. As mentioned earlier, a 10%p increase in Internet use corresponds to a 3.9% fare cut. Roughly speaking, firms can offset the fare decrease by raising switching costs by an amount that is comparable to the addition of 4.6 more destinations.[9] This implies that the policy can be rather easily nullified by firms.

VI. Concluding Remarks

This paper investigates the price effect of reduced search costs in the presence of switching costs in the context of the effect of the Internet on airfares. How a decrease in search costs would affect prices and whether switching costs would amplify or mitigate the effect are theoretically unclear. Results with U.S. domestic airfares show that decreased search costs associated with increasing Internet usage has led to more competition, but switching costs measured in terms of the average

---

[9]This value is computed as "Estimated coefficient on Internet + estimated coefficient on Internet·Network× mean value of Network"×change in Internet use (here, 10%p) divided by "Estimated coefficient on Network + estimated coefficient on Internet·Network×mean value of Internet".

network size have moderated this effect. When the airline industry was deregulated in 1978, industry experts argued that network sizes would be the key strength of incumbent airlines to survive. This still applies to struggling legacy airlines in the current periods. In the Internet era, the empirical result suggests that their networks would help airlines to weather the storm.

The results of this paper suggest that search and switching costs work in a similar fashion and when combined, they determine prices. In this case, one of the costs can influence the price effect of the other cost. If we do not consider both costs when estimating the magnitude or significance of each cost or when predicting the effects of changes in these costs, the empirical results would likely be biased.

It is also suggested that policymakers give serious consideration to the interaction between search and switching costs when designing and implementing policies which affect one of these costs. Firms' reactions to offset the policy effect should be taken into account. Otherwise, the policy may become ineffective or have unexpected consequences.

We need to note that the interpretation of the empirical result was based on the assumption that search and switching costs are exogenously given. It would be easy to justify exogenous search costs related to the Internet. However, FFPs are endogenously determined by airlines, and their values are dependent on consumer usage. That is, airlines decide how many benefits to give (or not) to consumers based on their past usage. In this case, the literature shows that equilibrium prices decline over time (see Caminal and Matutes (1990) and Rhee (2014)). That is, consumers experience fare decreases throughout the consumption cycle as they accumulate miles and use them to earn free tickets. In this sense, the empirical result in this paper does not mean that consumer welfare will decrease, as the fare cuts associated with reduced search costs may not be fully realized in the presence of switching costs. The impact on consumer welfare is rather ambiguous when switching costs are endogenously determined.

This paper does not provide a formal theory. A formal theory that includes both search costs and switching costs in one framework will be useful to generate specific predictions of the price effects of search and switching costs. Whether and how a price effect of a search cost reduction will be affected by switching costs will become clearer. Moreover, a formal theoretical framework will enable us to conduct more robust empirical studies regarding this relationship.

REFERENCES

Baye, Michael R., John Morgan, and Patrick Scholten. 2006. "Information, Search, and Price Dispersion." In *Handbook of Economics and Information Systems*, edited by T. J. Hendershott, Amsterdam: Elsevier.

Beggs, Alan and Paul Klemperer. 1992. "Multi-period Competition with Switching Costs." *Econometrica* 60 (3): 651–666.

Borenstein, Severin. 1991. "Selling Costs and Switching Costs: Explaining Gasoline Margins." *Rand Journal of Economics* 22 (3): 354–369.

Brunger, William G. 2010. "The Impact of the Internet on Airline Fares: The 'Internet Price Effect'" *Journal of Revenue and Pricing Management* 9 (1–2): 66–93.

Cabral, Luís M. B. 2008. "Switching Costs and Equilibrium Prices." Centre for Economic

Policy Research (Great Britain) Discussion Paper 8970.

Cabral, Luís and Miguel Villas–Boas. 2005. "Bertrand Supertraps." *Management Science* 51 (4): 599–613.

Caminal, Ramon and Carmen Matutes. 1990. "Endogenous Switching Costs in a Duopoly Model." *International Journal of Industrial Organization* 8 (3): 353–373.

Dubé, Jean-Pierre, Günter J. Hitsch, and Peter E. Rossi. 2009. "Do Switching Costs Make Markets Less Competitive?" *Journal of Marketing Research* 46 (4): 435–445.

Dubé, Jean-Pierre, Günter J. Hitsch, and Peter E. Rossi. 2010. "State Dependence and Alternative Explanations for Consumer Inertia." *Rand Journal of Economics* 41 (3): 417–445.

Elzinga Kenneth G. and David E. Mills. 1998. **"**Switching Costs in the Wholesale Distribution of Cigarettes." *Southern Economic Journal* 65 (2): 282–293.

Farrell, Joseph, and Paul Klemperer. 2007. "Coordination and Lock-In: Competition with Switching Costs and Network Effects." In *Handbook of Industrial Organization*, Vol 3, Chapter 31, edited by M. Armstrong and R. Porter, 353–373, Amsterdam: North Holland.

Greenstein, Shane M. 1993. "Did Installed Base Give Incumbent Any (Measurable) Advantages in Federal Government Procurement?" *Rand Journal of Economics* 24: 19–39.

Honka, Elisabeth. 2014. "Quantifying Search and Switching Costs in the U.S. Auto Insurance Industry." Working Paper.

Kim, Moshe, Kliger, Doron, and Bent Vale. 2003. "Estimating Switching Costs: the Case of Banking." *Journal of Financial Intermediation* 12: 25–56.

Klemperer, Paul. 1987. "The Competitiveness of Markets with Switching Costs." *Rand Journal of Economics* 18 (1): 138–150.

Knittle, Christopher R. 1997. "Interstate Long Distance Rates: Search Costs, Switching Costs, and Market Power." *Review of Industrial Organization* 12: 519–536.

Lal, Rajiv and Miklos Sarvary. 1999. "When and How Is the Internet Likely to Decrease Price Competition?" *Marketing Science* 18 (4): 485–503.

Lederman, Mara. 2007. "Do Enhancements to Loyalty Programs Affect Demand? The Impact of International Frequent Flyer Partnerships on Domestic Airline Demand." *Rand Journal of Economics* 38 (4): 1134–1158.

Lee, Hwa Ryung. 2013. "Do Switching Costs Moderate the Price Effect of Search Cost Reduction? Internet Use and Fares in the U.S. Airline Industry." Working Paper.

Moshkin, Nickolay and Ron Shachar. 2000. "Switching Costs or Search Costs?" Working Paper.

Orlov, Eugene. 2011. "How Does The Internet Influence Price Dispersion? Evidence from the Airline Industry." *Journal of Industrial Economics* 59 (1): 21–37.

Rhee, Ki-Eun. 2014. "What Types of Switching Costs to Create Under Behavior-Based Price Discrimination?" *International Journal of Industrial Organization* 37: 209–221.

Sharpe, Steven A. 1997. "The Effect of Consumer Switching Costs on Prices: A Theory and its Application to the Bank Deposit Market." *Review of Industrial Organization* 12: 79–94.

Shin, Jiwoong and K. Sudhir. 2009. "Switching Costs and Market Competitiveness: Deconstructing the Relationship." *Journal of Marketing Research* 46 (4): 446–452.

Shy, Oz. 2002. "A Quick-and-Easy Method for Estimating Switching Costs." *International Journal of Industrial Organization* 20: 71–87.

Verlinda, Jeremy A. and Leonard Lane. 2004. "The Effect of Internet on Pricing in the Airline Industry." Working Paper.

Viard, V. Brian. 2007. "Do Switching Costs Make Markets More or Less Competitive? The Case of 800-Number Portability." *Rand Journal of Economics* 38: 146–163.

Wilson, Chris M. 2009. "Market Frictions: A Unified Model of Search and Switching Costs." Working Paper.

The Effect of the Global Financial Crisis on Corporate Investment in Korea: From the Perspective of Costly External Finance[†]

By DAEHEE JEONG[*]

This paper examines the effect of the global financial crisis on corporate investment in Korea. Specifically, the crisis was considered to have possibly constrained firm-level investment as the negative shock to the credit supply dramatically unfolded. As Duchin et al. (2010) demonstrated, if a negative supply-side shock is evident during a crisis period, larger cash holdings before the crisis will lead to fewer constraints to corporate investment, or vice versa. In order to investigate the supply-side effect of the crisis, we use firm-level financial data, including firms listed on the Korean stock market as well as small and medium-sized enterprises. We find that corporate investment declined significantly after the crisis, even if we control for factors associated with the demand side, such as contemporaneous capital productivity and cash flow. More importantly, the decline is positively and significantly related to cash holdings before the crisis, implying the negative effect of a credit supply shock. Small and medium enterprises experienced relatively sharp investment declines compared to those of larger firms, and the relationship between pre-crisis cash amounts and the degree of investment decline is greater than that in large firms. Additionally, we examine whether the negative effect persists up to the present, finding evidence that the cash-investment relationship continues in small and medium-sized enterprises.

Key Word: Financial crisis, corporate investment, credit supply, financial constraint, cash holdings
JEL Code: G01, G31, G32

---

* Fellow, Korea Development Institute (Email: dhjeong@kdi.re.kr)

I. Introduction

Concerns about the negative effects of the credit supply shock emerged during the global financial crisis. Although a current account surplus in Korea had been maintained before the crisis, domestic banks experienced large capital inflows from 2005 to 2007, especially in short-term debt. As the negative effects of the global crisis were fully manifested, financial institutions whose headquarters were located in distressed economies stopped rolling over short-term loans to Korean banks. As a result, financial market in Korea experienced high volatility due to the sudden lack of capital inflows. The won/dollar exchange rate rose rapidly, reaching 1,513 won in late November of 2008, up 38.9% from that August. CDS premiums also skyrocketed to 692bp, reflecting the increased credit risk to domestic banks. Stock prices lost roughly 50 percent of their value from the 2008 peak, market interest rates went up sharply, escalating the credit spread between corporate (AA-, three-year maturity) and government bonds (three-year maturity) to three times the level before the crisis. More importantly, domestic banks reduced their credit supply and became more conservative with regard to lending.

Classical models of financial friction predict that a negative shock to external finance would restrict the real activities of economic agents. Consumers are expected to reduce their consumption of durable goods because the relative marginal value of durable goods to nondurable goods and services increases when facing constraints to liquidity. Firms will cut their investment expenditures because the cost of external fund increases, making the planned investment less profitable. Moreover, financial friction may increase during a crisis period when collateral loses its value (i.e., real estate prices drop). In such a case, the negative effects of the credit crunch are amplified and become more persistent.

Our paper investigates the impact of the credit crunch during the global financial crisis on corporate investment. More specifically, we focus on cash reserves on firms' balance sheets in order to identify the supply-side effects of the crisis, as in Duchin *et al*. (2010). Typically, if the external finance of a firm is constrained, its investment expenditure will be reduced on account of financial constraints. However, if the firm has enough cash reserves to accommodate the negative shock to external funding, its investment expenditures will be less affected by the negative shock. In essence, the more cash reserves a firm has, the lower its investment constraints (i.e., from a credit crunch) will be. We can use this idea to examine whether firms were negatively affected by the credit shortage during the crisis period. In particular, if the relationship between pre-crisis the cash reserve level and the degree of investment decline is significantly negative, we may conclude that a firm's investments were negatively affected by the credit supply shortage during that period.

Additionally, the magnitude of negative supply-side effects on corporate investment may differ depending on the degree of a firm's financial constraints. In order to determine how much financial constraints matter, our study adds unlisted firms to the analysis. This is relatively unexplored in the literature, and doing this will highlight the differential negative supply effects on investments between large firms and small and medium enterprises (SMEs). Because a firm's financial

constraints may also depend on factors other than its size, we also use the factors of industry (three-digit) sales growth and ownership to identify financially constrained and unconstrained firms. In addition, we investigate whether the shrinkage of the credit supply during the crisis had persistent negative effects on corporate investment. If the negative shock of external funds persistently affected corporate investment, we would observe that the relationship between pre-crisis cash levels and the investment decline is significant not only for the immediate year after the crisis but also for all years since the crisis in the sample.

Our results show that the estimated average investment decline after the global financial crisis is 1.3%p (in terms of investments to the total asset ratio) for the firms in our sample. This decline is significant even if we control for investment demand, implying that the contraction in investment expenditure cannot be explained by the reduced investment opportunity after the crisis. More importantly, we find evidence that the investment decline is caused by the negative supply-side shock (or the credit supply shortage). Specifically, as a firm has more cash reserves before the crisis, its investment decline is significantly less. When we divide our estimation sample into two groups, i.e., firms which are more financially constrained and those which are less financially constrained, we find that the negative shock to the credit supply has in general a greater effect on financially constrained firms. For instance, the investment decline caused by the supply-side effect is more evident for SMEs. Other criteria pertaining to financial constraints, such as industry sales growth and ownership, also provide results which are qualitatively identical to those determined by the classification of financial constraints based on firm size. We also find evidence that the persistent investment contraction in SMEs after the crisis is related to the negative shock to the credit supply.

Our paper is organized as follows. In the next section, we introduce related studies, especially those on the real effects of the financial crisis. In Section 3, we briefly review the financial market in Korea during the global financial crisis and provide a preliminary analysis of the relationship between firms' pre-crisis cash levels and the degrees of the decline in corporate investment. In Section 4, we discuss the manner in which we construct our estimation sample from firms' financial data, the baseline hypothesis in which we are interested, and the empirical strategy that we use in order to address the endogeneity issue and secure robustness. We then move on to present the main results, which will shed light on the negative effects of the credit crunch. In the final section, we summarize our findings and describe their implications.

II. Related Literature

Since the global financial crisis of 2008, studies on the real effects of the financial crisis, specifically in developed economies, have been active. Many attempt to quantify the magnitude of the negative effects of the crisis based on the transmission mechanism through which financial contraction affects the real economy. In this section, we discuss the findings of related studies on the financial

crisis and introduce a number of empirical works which quantify the negative effects of the global financial crisis.

Classical theory assumes the existence of financial friction[1] when analyzing the relationships between real and financial variables. According to studies related to classical theory, financial friction would not only amplify the response of real activities to negative shocks, but also make it persistent.[2] For instance, a financial crisis involves a large negative shock of the external funding to debtors, in what is termed a credit crunch, as well as a sharp depreciation of asset prices. As a result, the fall in asset prices damages the debtor's net worth (or the collateral value), which makes it more difficult for the debtor to procure additional outside funds. This is the so-called 'vicious cycle', which produces an amplification mechanism which acts on the financial friction. Moreover, in the event the debtor was highly leveraged before the crisis, this amplification mechanism makes it more difficult for them to recover their financial soundness, allowing observations of a prolonged economic contraction after the crisis.

With regard to credit supply during the global financial crisis, Ivashina and Scharfstein (2010) report that during the fourth quarter of 2008, when the uncertainty from the financial crisis started to unfold, new loans by commercial banks fell by 47% relative to the prior quarter and by 79% relative to the peak of the credit boom (the second quarter of 2007). According to their analysis, banks' over dependence on short-term financial market leads to a large drop in the credit supply during the crisis period. Meanwhile, they also show that even if the total assets of the banking sector in the U.S. grew by 100 billion dollars from September to mid-October of 2008, it was a result of credit line drawdowns and not the creation of new loans.

Related to the real effect of the credit shortage during the global crisis, Campello *et al.* (2010) find that financially constrained firms cut employment and capital expenditure more compared to unconstrained firms. Based on a survey of chief financial officers (CFOs) in the U.S., Europe, and Asia, they studied whether firms' economic activity levels differ conditional on their degree of financial constraint. They find that the average constrained firm in the U.S. reduced employment by 11% and capital expenditures by 9%, while unconstrained firms' spending cuts were insignificant. Moreover, they report that constrained firms burned through approximately 20% of their pre-crisis cash, drew more from their credit lines for fear that banks would restrict access in the future, and sold more assets to fund their activities.

Meanwhile, Duchin *et al.* (2010) find that the corporate investment decline in the U.S. was significant and that the decline was more severe for firms with fewer cash reserves or more short-term debt. In addition, they investigate whether the credit crunch has had persistent effects on corporate investment, finding that the negative supply-side effect seems to have disappeared one year after the crisis. In fact, their result shows that the demand-side effect, e.g., decreased investment opportunities,

---

[1] Financial friction essentially refers to the cost of financial transactions; it can originate from information asymmetry or from moral hazard. For traditional models of financial friction, refer to Jaffee and Russell (1976), Stiglitz and Weiss (1981), and Holmstrom and Tirole (1997), among others.

[2] Brunnermeier *et al.* (2012) provides an excellent survey of the role of financial friction in business cycle theory.

mainly explains the sluggish investment after the crisis.

We also find qualitatively similar results in earlier studies.[3] For instance, Arslan *et al*. (2006) find that cash reserves in Turkish firms served as a form of self-insurance during the crisis period, as firms there with enough cash could cope with the negative shock to external finance and ultimately maintain their planned investment projects. Dell'Ariccia *et al*. (2008) studied banking crises cases across countries and showed that industries with higher dependence on external funding experienced slower recovery rates and delayed growth.

Recent studies of the impact of the global financial crisis on the Korean economy focus on the adequacy of the capital of banks or cash holdings of the corporate sector, as these variables can serve to buffer the negative shock from the crisis. Hahm and Kim (2011) find that the soundness of financial institutions in emerging economies can perform as a shock absorber as well. They concluded that greater soundness of a financial institution meant a shorter spell of a crisis and a smaller negative impact as well. Kim (2011) also finds that the economic downturn of Korea accompanying the 2008 crisis was much smaller than that of the 1997 currency crisis and that the recovery was also faster after the recent crisis. According to his assessment, the corporate sector has made significant improvement in restoring their financial soundness and managing the risks from assets and liabilities denominated in foreign currencies after the 1998 crisis, leading to relatively low amounts of damage from the more recent crisis.

In this paper, we focus on the roles of financial buffers in mitigating negative external shocks to corporate investment. While previous studies of the 2008 crisis mainly examine the impact of foreign financial shocks, we contrast the impact of the negative shock to the demand side with the negative shock to the credit supply by incorporating variables which reflect investment demand. Additionally, we investigate a sample which was relatively unexplored in previous studies by including small and medium enterprises (SMEs) to determine whether the negative supply-side effect stands out in our sample. Because the funding structure of large firms differs from that of SMEs, the negative shock from external finance would also have a different impact. If this is the case, we would observe a different real impact of the crisis depending upon the firm size.

Finally, our work is also related to studies of domestic firms' cash holdings. From the negative view[4] on firms' cash holdings, large cash holdings of corporate sector are interpreted as poor corporate governance or as misallocations of resources. On the other hand, Lim and Choi (2006) find evidence that the cash holdings of firms can be considered as precautionary savings[5] in response to operational uncertainty. Lee (2005) also finds in his work on publicly traded firms that higher sales uncertainty can lead to more cash holdings. Our view on these cash reserves is in line with the above studies, indicating a positive role of this cash,

---

[3]Refer to Fazzari *et al*. (1988), Hoshi *et al*. (1991) and Kaplan and Zingles (1997) among others, for more traditional studies on the negative effect of credit shrink to financially constrained firms.

[4]Classical literature on excess cash holdings by firms report that poor governance can create management incentives to accumulate cash assets, leading to misappropriations and excessive cash holdings (see, e.g., Dittmar *et al*. (2007), Harford *et al*. (2008) and Pinkowitz *et al*. (2006)).

[5]Regarding the precautionary saving motive by firms, refer to Opler *et al*. (1999), Almeida *et al*. (2004), and Bates *et al*. (2009), among others.

i.e., if firms hold enough cash reserves, they can mitigate negative shocks to the supply side.

III. The Relationship between Pre-Crisis Cash Reserves and Investment Decline: An Episode of the 2008 Global Financial Crisis

A. *A Foreign Liquidity Crisis May Lead to a Credit Crunch*

The global financial crisis can be symbolized as a global event which was accompanied by a world-wide credit shock. The crisis emerged from the massive defaults of U.S. subprime mortgages, and eventually unfolded to full scale in September of 2008, when Lehman Brothers filed for bankruptcy. Subprime mortgages, which were real-estate-backed loans to households with relatively poor credit ratings, had been growing at a fast pace due to the prolonged accommodative monetary policy and the appreciation of house prices. Newly underwritten subprime mortgage loans accounted for nearly 8.6% of all mortgage lending in 2001, but they increased rapidly to 20.1% by 2006. However, after the middle of 2006, mortgage interest rates increased as the Federal Reserve increased rates, driving up the delinquency rate of subprime mortgage borrowers. As a result, the prices of financial derivatives related to the subprime loans, such as mortgage-backed securities (or MBS) and collateralized debt obligations (or CDOs) fell drastically. Financial institutions which had considerable exposure to these assets experienced massive losses, and the credit worthiness of Monoline, a U.S. CDO guarantor, was seriously downgraded. In March of 2008, the U.S. investment bank Bear Sterns declared bankruptcy, and the government sponsored entities Fannie Mae and Freddie Mac, which reinforced the credit of mortgage-backed securities, saw their stock prices plunge. Eventually, in September of 2008, Lehman Brothers, one of the largest investment banks in the U.S., filed for bankruptcy protection.

The Lehman bankruptcy alerted against counterparty risk, and the preference for risky assets evaporated quickly. Many financial institutions had difficulty securing liquidity, and the liquidity problem quickly spread from one institution to the others. Banks in emerging economies, which usually serve as intermediaries for funds from banks in developed countries to domestic firms and consumers, were at this point in peril because they borrowed short-term foreign currency while lending in long-term domestic currency. As a result, many emerging-market banks experienced their own foreign liquidity crises when their counterparties in developing countries stopped lending (or rolling over the loans). Korean banks were not an exception to this turmoil.

In the Korean domestic financial market, the volatility in exchange rates, stock prices and interest rates increased sharply (see Figure 1). As foreign bank branches stopped supplying short-term foreign currency loans (or rolling over these loans), domestic banks faced extreme foreign liquidity problems. As their demand for foreign liquidity skyrocketed, banks took large long positions in the FX spot market. As a result, won/dollar exchange rate soared. The exchange rate started to rise at a steep pace in September of 2008, reaching 1,513 won in November of 2008, thus marking a rise of nearly 38.9% in only two months. During this process,

a vicious cycle emerged: as spot prices increased, the banks' ability to repay the foreign-currency-denominated debt weakened and the creditworthiness of domestic banks was hampered, making the foreign banks even more hesitant to supply
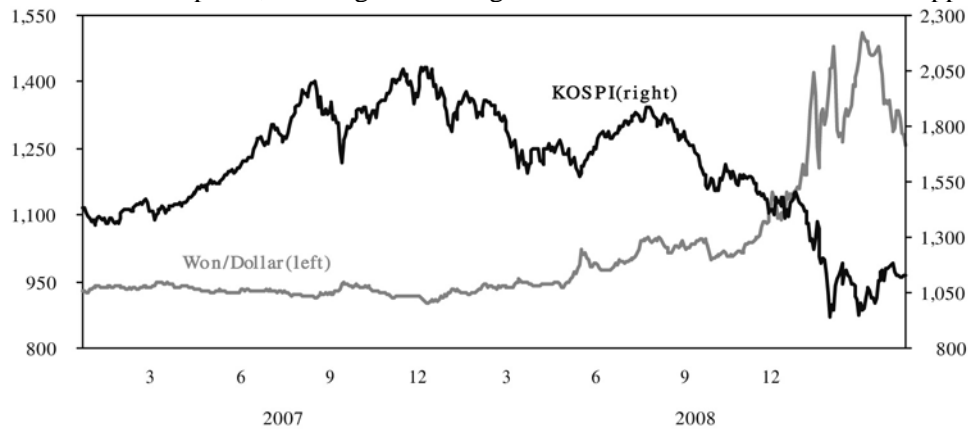

FIGURE 1. KOREA STOCK PRICE INDEX (KOSPI) AND THE WON/DOLLAR EXCHANGE RATE

Source: Bank of Korea

foreign currency loans to domestic banks. This caused the domestic bank's demand for foreign currency to increase even more. Although the Korean economy had maintained a current account surplus before the crisis, many factors pushed the exchange rate surprisingly upwardly. Together with the foreign liquidity problem of domestic banks, we also observed a large counterparty risk premium to emerging countries and a sudden draw of short-term portfolio capital as one of the driving forces behind the exploding exchange rates. Meanwhile, the KOSPI index was at 938.75p in October of 2008, the lowest level of the year and marking a 50.3% decline compared to the highest level of 1,888.88p in May of 2008. Market interest rates also showed steep increases before the effect of the policy rate cut by the Bank of Korea was reflected. For instance, the corporate bond rate (AA-, three-year maturity) soared from 6.64% in January of 2008 to 8.56% in November of 2008.

With regard to the impact of the global financial crisis on the real economy in Korea, we also observe that no major bankruptcy in the business sector was reported and that overall economic activity recovered in a relatively short period of time. However, this does not imply that the Korean economy did not suffer any negative influence of the liquidity shock. In fact, the following argument indicates that the credit crunch for financially constrained firms was real and affected them negatively. First, the foreign liquidity problem experienced by banks during the crisis contributed to the decrease in the credit supply to the business sector. As domestic banks found it more difficult to finance foreign currency, they sought alternative measure, such as selling their local currency assets and buying foreign currency on the spot market. As a result, households or firms found it more difficult to obtain new loans or were forced to repay their debts. Such a collapse of stock prices or asset prices can also affect the supply of credit negatively. The U.S. case can provide us valuable insight into this argument; as asset prices there

significantly declined, bank balance sheets worsened due to losses from their exposure to the troubled assets, which triggered a massive retrieval of their exposure (or sales of assets) in an effort to maintain their capital requirements. In this process, the reduction of banks' assets resulted in a decreased credit supply.

Figure 2 and Figure 3 show the results of a survey of loan officers and the net change in outstanding loans by banks, respectively. The net percentage of domestic banks tightening standards for industrial and household loans grew rapidly after mid-2008 (see Figure 2), and banks appeared to reduce their new lending during 2008, especially to SMEs (see Figure 3). This may reflect the domestic banks' weakening balance sheets and their efforts to recover their capital. Firms can also experience a negative shock to their net worth due to asset price declines and sluggish demand during crises periods. As their net worth begins to contract, their creditworthiness is also aggravated such that financial institutions will hesitate to supply loans which otherwise are available to firms.
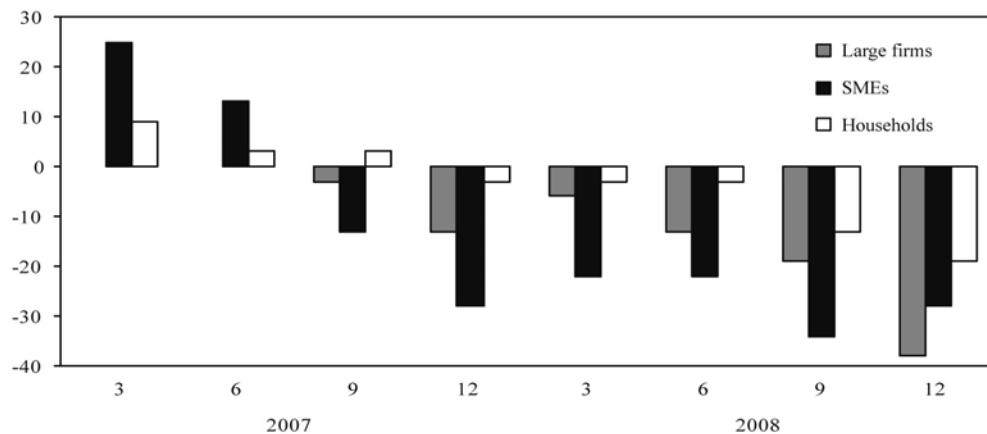

FIGURE 2. FINANCIAL INSTITUTIONS' ATTITUDES TOWARD LENDING

Notes: A positive (+) lending attitude means that there are more financial institutions with an 'easing' attitude to lending than those with a 'tightening' attitude.
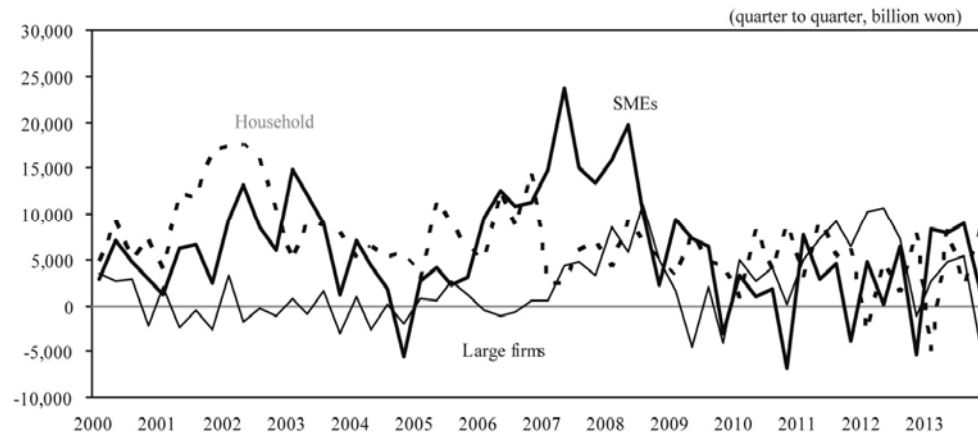
Source: Bank of Korea

FIGURE 3. CHANGES IN OUTSTANDING LOANS BY BANKS

Source: Bank of Korea

In sum, domestic banks in Korea were affected by the sudden halt in short-term debt (or the stoppage of roll-overs) during the 2008 crisis, and the magnitude of the foreign liquidity problem does not appear to be less than that of the 1997 crisis. While the Korean economy rode out the crisis relatively well and showed a rapid recovery after the crisis in an ex-post sense, it is hard to say that firms were quarantined from the negative shock to the credit supply during the crisis period. From this perspective, we investigate whether the shock to the credit supply affected economic activity, especially firm investments during the crisis period. In the following subsection, we examine the relationship between pre-crisis cash reserves and corporate investment declines in a simple analysis of negative supply-side effects.

B. *Corporate Investment during the Crisis and Pre-crisis Cash Reserves*

In order to examine the relationship between pre-crisis cash and the corporate investment decline, we categorize our sample firms[6] into three groups based on cash reserves (cash/total assets) as measured one year before the crisis year of 2008 and define low- and high-cash firms as the first and the third terciles, respectively. For both the low- and high-cash firms, we compare the sample means of corporate investment (capital expenditure/total assets) before and after the crisis and attempt to check whether high-cash firms show relatively low investment declines. Table 1 shows the differences in investments from 2007 to 2008 for both high- and low-cash firms. Before the crisis, the investment expenditure of an average firm matched 9.28% of its total assets, showing a decline by 0.99%p (10.6% relative to the pre-crisis investment level) to 8.29%, with the decline statistically significant at the 1% level. Meanwhile, when we compare the investment declines of low- and high-cash firms, the decline for low-cash firms was found to be 2.43%p, whereas it is only 0.20%p for high-cash firms, indicating that low-cash firms reduced their

---

[6]For more details on the construction of our sample, refer to Section 4.1.

investments more than high-cash firms.

TABLE 1—CASH RESERVES AND POST-CRISIS INVESTMENTS: LARGE FIRMS AND SMES

	Pre-crisis Cash	Pre-crisis Inv.	Post-crisis Inv.	Inv. decline	P-value
		(A)	(B)	(B-A)	
Overall	Low	10.291	7.857	-2.435	0.000
	High	7.760	7.968	0.208	0.836
	All	9.287	8.295	-0.992	0.000
Large firms	Low	7.766	5.838	-1.928	0.000
	High	5.480	5.881	0.401	0.831
	All	6.603	6.055	-0.548	0.026
SMEs	Low	10.614	8.112	-2.502	0.000
	High	8.208	8.398	0.189	0.787
	All	9.640	8.592	-1.048	0.000

Notes: 1) 'Low' and 'High' correspond to the first and third terciles, respectively. 2) The classifications of small and medium enterprises (SMEs) and large firms are based on KIS data. 3) The p-value is for the null hypothesis of an investment decline (B-A < 0).

Because SMEs are financially more constrained (or more exposed to the information asymmetry problem), one can expect that small firms experience greater investment declines even after controlling for pre-crisis cash reserves. In order to take into account the difference in financing constraints between large firms and SMEs, we divide the sample into two groups, e.g., large firms and SMEs, and perform the same analysis. For large firms, investments by low-cash firms drop by 1.92%p, while those of high-cash firms actually increase by 0.40%p. We find a similar relationship between cash and investment declines for SMEs, though the relationship between pre-crisis cash and the investment decline appears to be somewhat stronger than it is for large firms.

Figure 4 shows a scatterplot of the average pre-crisis cash reserves and the differences in investments for the 100th percentile cash group of large firms and SMEs. We confirmed that the negative relationship between pre-crisis cash and investment decline is greater for SMEs. Table 2 reports a simple regression result,
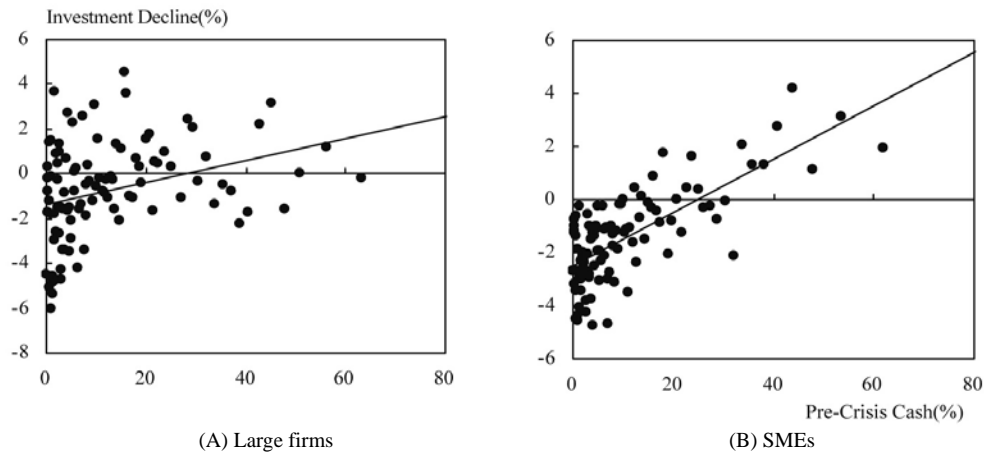

(A) Large firms   (B) SMEs

FIGURE 4. PRE-CRISIS CASH AND CORPORATE INVESTMENT DECLINES

Source: KIS data, author's calculations

TABLE 2—SIMPLE REGRESSION RESULTS FOR CORPORATE INVESTMENT DECLINES

	Overall	Large firms	SMEs
Cash	0.0947***	0.0487***	0.101***
	(0.00758)	(0.0150)	(0.00945)
Constant	-2.410***	-1.350***	-2.507***
	(0.130)	(0.284)	(0.160)
N. Obs.	100	100	100
R-squared	0.615	0.097	0.538

Notes: 1) This result is based on a simple regression of the difference in corporate investments with regard to pre-crisis cash reserves. Cash reserves are the 100th percentiles of 'cash and cash equivalents' for fiscal year 2007, and the differences in investments are calculated for the corresponding percentile group from fiscal years 2007 to 2008. 2) The classifications of small and medium enterprises (SMEs) and large firms are based on KIS data. 3) Numbers in parenthesis are the standard errors from the ordinary least squares. 4) ***, **, or * indicate that the coefficient estimate is significant at 1%, 5%, or 10% level, respectively.

showing the difference in corporate investments as the dependent variable and pre-crisis cash reserve as the independent variable. The estimated coefficients of cash for the pooled sample, for large firms, and for SMEs are all positive and statistically significant. However, the coefficient for the SMEs is more than two times greater than that of the large firms. For instance, SMEs with an additional 10%p of cash showed reduced investment drops by 1.01%p, while for large firms with 10%p more cash, this value was 0.48%p.

Overall, we find that firms with low amounts of cash before the crisis suffered more; their investment decline was greater than those of high-cash firms. Second, cash was more valuable to SMEs; their cash reserves played a greater role as an internal buffer in mitigating the negative shock to external finances as compared to those of large firms.

We will consider demand-side variables into our model, where unobservable firm-specific time-invariant effects are also considered.

IV. Empirical Analysis

A. *Data*

We use firm-level panel data on financial statements to construct our sample. The sample is extracted from the KIS VALUE database of the National Information & Credit Evaluation. In order to investigate corporate investments before and after the 2008 crisis, we use annual[7] data for firms with the fiscal year closing at the end of December.

We pay strong attention to corporate investment expenditures between fiscal years 2007 and 2008, presuming that the crisis was mainly a financial phenomenon, which is usually short-lived. Hence, we exclude data from 2009 from our main

---

[7]Because we include not only publicly traded firms but also SMEs in our sample, many observations are not available at quarterly frequencies.

sample.[8] Because there may be concern over sample selection bias, we check whether the main results from our sample are robust. We find that our empirical findings stand still after adding two or three years of data to the pre- and post-crisis sample and after changing the dating of the crisis from 2008 to 2009. Our sample includes not only publicly traded firms (listed on either the KOSPI or KOSDAQ markets) but also firms with external audit requirements and general firms[9] (see Table 3). The broad coverage of our dataset is helpful for examining whether SMEs were more vulnerable to the liquidity shock during the crisis. Typically, publically traded firms, which already meet stock market listing requirements such as years in operation, business size and performance level, are less exposed to the information asymmetry problem. Thus, they appear to be less financially constrained. However, small firms (or young firms) are more financially constrained such that their investment decline due to the credit supply shock is expected to be greater.

TABLE 3—COMPOSITION OF FIRMS IN THE SAMPLE

		N. Obs.	(%)	N. Firms	(%)
KOSPI	Listed	1,020	4.80	559	4.43
	Issues for admin.	17	0.08	17	0.13
KOSDAQ	Listed	1,283	6.04	777	6.16
	Registered	1,611	7.59	930	7.37
	Issues for admin.	102	0.48	95	0.75
External audit requirement		14,808	69.75	9,236	73.22
General firm		2,362	11.13	2,016	15.98
Govt. owned corporations and others		26	0.12	20	0.16
Total		21,229	100.00	13,650	108.21

Notes: 1) The table shows the composition of the sample after excluding outliers and those with missing values. 2) 'KOSDAQ registered' refers to the status in which a firm meets certain requirements of the Securities and Exchange Act while its stock is not yet traded in the market. 3) 'Issues for administration' refers to firms which may face a delisting from the stock market. 4) Firms can be counted twice if they changed their status regarding a stock market listing, e.g., the initial public offering of an external audit firm. For reference, the total number of firms in our sample is 12,614.

By dividing our sample into large firms and SMEs, we can compare the negative supply-side effect on investment expenditures for the two different groups and find implications pertaining to the relationship between corporate investment decline and financial constraint.

With regard to the SME sample, the following issues should be noted. First, we should consider a new proxy reflecting investment demand by individual firms, as the market value of non-public firms (and Tobin's q) is unobservable in practice. In this study, we use the sales-to-capital ratio[10] as a proxy for the marginal

---

[8]One may suggest using a different time span, e.g., from 2008 to 2009; however we see limitations on the use of this time span, as the negative shock to external finance may disappear quickly and may be more difficult to capture, as the government started to inject massive liquidity into the market via the emergency liquidity supply program.

[9]Here, general firms refer to corporations which do not meet the external audit criteria.

[10]Conceptually, Tobin's q is a theoretical value which is determined by summing all of the streams of present and future expected marginal productivity of capitalbased on information from management (Gilchrist and Himmelberg (1998)). Strictly speaking, one needs a theoretic model (or assumptions) on how management calculates marginal productivity and takes expectation to find the value of Tobin's q for individual firms. In our work, we calculate the marginal productivity of capital based on the assumption of the Cobb-Douglas production function, finding the expected value by presuming that productivity is dictated by an autoregressive Markov process.

productivity of capital instead of Tobin's q. Second, as Lim (2005) noted, we find that the financial statements of firms with external audit requirements or those of general corporations has many missing values about detailed items, compared to those of publicly traded firms, indicating that the credibility and usefulness of the included SME samples are relatively low.[11]

We measure corporate investment as cash outflows for items of purchase of tangible, intangible and leased asset on cash flow statements.[12] Our measurement of corporate investment has the following features. First, as Lim (2005) noted, our measure is free from distortions such as depreciation and asset revaluations compared to the alternative investment measure of the difference in tangible assets. Because the increase in tangible assets reflects investment expenditures as well as the difference in accumulated depreciation, it may undervalue a firm's investments. With regard to asset revaluations, tangible assets can increase even if there were no investment expenditures; in such a case, the alternative measure can overvalue corporate investments.

Second, our measure of corporate investment includes not only expenditures for property, plants, and equipment, which are typically termed 'capital expenditures', but also expenditures on land, buildings, and intangible assets (e.g., R&D expenditures). Hence, corporate investment in this paper is more comprehensive than capital expenditures. Practically, it is not very attractive or feasible to calculate capital expenditures in our case, as there are many missing values pertaining to expenditures for land, buildings, and intangible assets in our sample of SMEs.

Third, investment expenditures in our study did not adjust for an increase in cash due to asset sales, though Lim (2005) measures corporate investment as net cash outflows (cash outflows minus cash inflows) in items of purchases of tangible assets (excluding land and buildings). Because one of the objectives in his work was to compare corporate equipment investments as calculated from firm-level data with those from aggregate data, it appears to be reasonable to use the net cash decrease as equipment investments. However, our goal is to examine whether firms decrease investment expenditures in response to a negative credit supply shock. In this case, it is natural to focus on cash outflows.[13]

With regard to data purging, we exclude financial firms and utilities, defined as firms with Korea Standard Industry Classification (KSIC) codes 35-36 and 64-66 in the two-digit category. The financial statements of financial firms have different items and accounting standards; moreover, their investment expenditures (e.g., an increase in private loan) are not directly connected to real activities, which among the main variables of interest. Meanwhile, most utilities are accounted for in large public firms, where investment expenditures are related more to the government's plan to supply electricity, gas, water, and other such utilities, indicating that the

---

[11]The number of publicly traded firms in our sample is 1,336; firms with external audit requirements number 9,236, and general corporations stand at 2,016, whereas there were a total of 1,567 publicly traded firms, 14,594 firms with external audit requirements, and 91,454 general corporations in the original KIS database. For more details on the composition of firms in our sample, refer to Table 4-1.

[12]All variables used in our study were calculated from stand-alone financial statements.

[13]Alternatively, when we calculate corporate investments based on net cash outflows, we find qualitatively similar results, although the data coverage is reduced as the values on cash inflow from the sales of assets are largely missing or small.

exclusion of these firms provides more accuracy in our empirical analysis. We also handle outliers in investments, cash reserves,[14] and sales-to-fixed capital ratios by excluding extremely large or small firm-year observations[15] compared to the empirical distribution of those variables in the largest sample from 1993 to 2011.[16] For instance, we exclude observations with investments greater than the 99th percentile or smaller than the 1st percentile in all observations. Before calculating the percentile values, we exclude observations with variables which are nearly or precisely have a zero bound.[17]

Table 4 shows the summary statistics for of corporate investment, pre-crisis cash reserves, capital productivity, and cash flow amounts for the constructed sample. Except for the cash reserves, all of the variables are for the firm-year observations from 2007 to 2008. Large firms' investment expenditures amount to is 6.33% of over total assets, which is less smaller than the value of 9.12% of SMEs' investments.

TABLE 4—SUMMARY STATISTICS

		Mean	Std.	N. Obs.
Investment	Large firms	6.33	7.01	2,477
(%)	SMEs	9.12	9.86	18,752
	All	8.79	9.62	21,229
Cash	Large firms	12.75	13.53	1,136
(%)	SMEs	11.37	12.64	7,397
	All	11.55	12.77	8,533
Capital productivity	Large firms	9.33	15.29	2,477
(%)	SMEs	8.09	13.50	18,752
	All	8.23	13.72	21,229
Cash flow	Large firms	9.71	11.52	2,477
(%)	SMEs	8.57	13.35	18,752
	All	8.71	13.15	21,229

Notes: 1) 'Investment' denotes cash outflows due to the purchase of tangible, intangible and leased assets to the total assets ratio, 'Cash' is cash and cash equivalents over total assets during fiscal year 2004, 'Capital productivity' is the ratio of sales to tangible and intangible assets, and 'Cash flow' denotes operating income before depreciation and amortization over total assets. 2) The classifications of small and medium enterprises (SMEs) and large firms are based on KIS data.

The average cash position of large firms is 12.75% of total assets, while that of SMEs was found to be 11.37%. Capital productivity, which is measured in terms of sales over tangible and intangible assets, is also shown to be greater in large firms. The average capital productivity of large firms is 9.33%, while that of SMEs is 8.09%. The average yearly cash flows are 9.71% and 8.53% (of total assets) for large firms and SMEs, respectively.

B. *Methodology*

---

[14]Cash reserve is defined as cash and cash equivalents in balance sheet.

[15]Due to the exclusion of firm-year observations, our panel is unbalanced.

[16]Due to the reported lag of financial statements, we only observe a small number of firms for fiscal year 2012; therefore, we did not use the observations made in 2012.

[17]This arises because the raw distribution of our main variables is too skewed towards zero to find reasonable cut-off values for handling outliers. Though we arbitrarily exclude observations which have values which are very close or equal to zero, this clearly contributes to reducing unnecessary miscalculations from handling and comparing extremely small values.

Mainly, we follow the empirical strategy in Duchin *et al*. (2010). One of the key identifying assumptions in their approach is that the significantly positive relationship between the corporate investment decline and pre-crisis cash reserves will reflect the negative supply-side effect during the crisis period. Before digging further into the details, we introduce the main features of their method here. The specifications of Duchin *et al*. (2010) are designed to test whether the decline in the credit supply during the financial crisis had a negative effect on corporate investments. Intuitively, the method is similar to the difference in differences method, in which mainly the treatment effect of pre-crisis cash reserves is examined. If the negative supply-side effect actually matters, the larger a firm's cash holdings are, the smaller the constraint to investment would be, as cash holdings prior to a crisis can serve as an alternative funding source for investments. Hence, the regression model of investments by firms will exhibit a significantly positive coefficient of the interaction term between the crisis dummy and pre-crisis cash reserves, as far as the null hypothesis of the supply-side effect is evident.

Meanwhile, it appears to be necessary to include variables which reflect investment demand by firms, as corporate investment expenditures can also be affected individual firms' investment opportunities. After including variables regarding the investment opportunities of each firm, we can decompose how much of the investment decline is affected by financial and fundamental factors while also check the robustness of the results with regard to the specification for investment demand. The significantly positive relationship between investment and cash reserves will only be observed in firms which experienced a negative external funding shock due to the decline in the credit supply or a loss of their net worth during the crisis period. Also, if corporate investment declines are mainly driven by demand-side effects, then the significantly positive relationship will disappear after including variables pertaining to investment opportunities. The baseline model of Duchin *et al*. (2010) can be described as follows:

$$(1) \qquad y_{i,t} = c + \alpha D_t + \beta D_t Cash_{i,\tau} + \gamma' X_{i,t} + \upsilon_i + \varepsilon_{i,t},$$

Here, the subscripts i, t and τ are the firm, the year, and a fixed pre-crisis year, $y_{i,t}$ denotes investment expenditure over total assets, D_t is a crisis dummy, $Cash_{i,\tau}$ denotes pre-crisis cash reserves over total assets, $X_{i,t}$ represents variables which reflect investment opportunities, and υ_i indicates unobservable firm-specific fixed effects.

Though the methodology is simple and straightforward, the use of pre-crisis cash reserves in identifying supply-side effects requires much caution due to endogeneity and identification problem. Following Duchin *et al*. (2010), we provide a rationale for our selection of this instrument by comparing the estimation results. We also conduct various robustness checks of our baseline results. Specifically, the empirical strategy used here is as described below.

First, in order to address the possible endogeneity issue, we include lagged cash reserves of individual firms in our baseline specification. Our baseline specification can be expressed as follows:

(2) $y_{i,t} = c + \alpha D_t + \beta_0 D_t Cash_{i,\tau} + \sum_{k=1}^{K} \beta_k Cash_{i,t-k} + \gamma' X_{i,t} + \upsilon_i + \varepsilon_{i,t}.$

Lagged cash balances of firms are known to be related to their investment activities; therefore, this may impose the endogeneity problem (a non-zero correlation between cash reserves and unexplained investment demands) on pre-crisis cash should it be missing. For example, firms which expect greater investment opportunities in the future may retain more profits to increase corporate savings. In such a case, the investment at time t will be correlated with cash reserves at t-1; moreover, the coefficient estimate of the interaction term between pre-crisis cash and the crisis dummy will be biased due to the endogeneity problem. In order to address the issue, we add lagged cash as an additional variable reflecting investment demand.[18] Pre-crisis cash reserves represent valuable information regarding a firm's financial buffer prior to the crisis, though it is not greatly correlated with unexplained investment opportunities, i.e., after controlling for the lagged cash variables. Therefore, this will contribute to reducing the upward bias from the endogeneity problem. In order to show that our specification is in fact distant from the endogeneity issue, we compare the estimation results with a different order of lagged cash reserves. If the endogeneity problem is still evident in our specification, the results with a higher order of lagged cash will be much different.

Second, in order to deal with the possible spurious correlation between pre-crisis cash and investment decline, we run the same analysis with samples from a financially stable period. If a significantly positive coefficient of the interaction term is observed from the financially stable period, the interpretation of the significantly positive relationship between pre-crisis cash and post-crisis investment given the existence of the negative supply-side effect will be misleading.

Third, we examine whether firms which are financially more constrained experience higher investment declines, as expected from the negative supply-side effects. If the negative shock to the credit supply in fact matters during the crisis period, we would then find a greater influence (or greater sensitivity) of cash for financially constrained firms on investment. In order to do this, we mainly categorize small and medium enterprises (SMEs) as financially more constrained firms. Alternatively, we also use leverage, short-term debt, and stock market listing as alternative method of identifying firm's financial constraint.

Finally, we add recent firm-year observations to investigate whether the negative shock to external finance has any long-term effect on investment activity. Because our baseline model uses only two years (one pre- and one post-crisis observation for each firm) of observations, it is difficult to determine from our original sample whether the weak investment recovery thus far is related to supply-side effects. If the impact of the negative supply-side shock during the 2008 crisis still persists, then the estimated coefficient of interaction term between pre-crisis cash and time dummy for the recent years will also be significantly positive. On the other hand, if the negative effect is only short-lived, then the estimated coefficient of the

---

[18]Duchin *et al.* (2010) did not include lagged cash in their specifications. However, they use cash reserves one year (or four quarters) prior to the crisis to address the endogeneity issue. In this case, the omission of lagged cash up to an order of three would produce downward bias, as their pre-crisis cash reserves show lags in four periods.

interaction term would be insignificant or negative.

C. *Results*

1. *Corporate investment and pre-crisis cash reserve*

Table 5 presents the estimates of our baseline specification for cash reserves and corporate investment. We select the order of lagged cash reserves (or K in Equation (2)) as two years based on the information criteria[19] and use cash reserves one year[20] before the crisis (or 2007 cash) as pre-crisis cash. We also use capital productivity and cash flow as proxies for investment opportunities.

The results in Table 5 show that yearly investment expenditures decreased significantly after the global financial crisis. The coefficient estimate in the regression of corporate investment on the crisis dummy (see column (1)) shows a significantly negative value, and it remains close to this significantly negative value even if controlling for investment opportunities (see columns (2) to (6)).

TABLE 5—BASELINE RESULTS

	(1)	(2)	(3)	(4)	(5)	(6)
After	-1.760***	-2.993***	-1.847***	-1.286***	-1.251***	-1.304***
	(0.110)	(0.151)	(0.153)	(0.161)	(0.159)	(0.158)
After x Cash		0.107***	0.0590***	0.0375***	0.0386***	0.0372***
		(0.00771)	(0.00855)	(0.00914)	(0.00905)	(0.00898)
Cash (t-1)			0.144***	0.165***	0.161***	0.156***
			(0.0156)	(0.0174)	(0.0173)	(0.0170)
Cash (t-2)				0.0318**	0.0368**	0.0316**
				(0.0162)	(0.0161)	(0.0160)
Capital productivity					0.235***	0.253***
					(0.0243)	(0.0245)
Cash flow						-0.0729***
						(0.0121)
Constant	9.670***	9.484***	7.078***	5.784***	4.128***	4.814***
	(0.0550)	(0.0489)	(0.193)	(0.323)	(0.368)	(0.377)
N. Obs.	21,229	19,274	16,852	13,529	13,529	13,529
R-squared	0.029	0.046	0.051	0.047	0.074	0.083
N. Firms	12,614	10,659	9,897	7,796	7,796	7,796

Notes: 1) 'After' is a dummy variable which is one for fiscal year 2008 and zero otherwise, 'Cash' is cash and cash equivalents over total assets during fiscal year 2004, 'Capital productivity' is the ratio of sales to tangible and intangible assets, and 'Cash flow' denotes operating income before depreciation and amortization over total assets. 2) The numbers in parenthesis are the Huber-White standard errors clustered at the firm level. 3) ***, **, or * indicate that the coefficient estimate is significant at 1%, 5%, or 10% level, respectively.

This implies that the investment decline after the crisis is significant even after we control for demand-side effects, such as the decline in investment opportunities. The results in column (6) show that the yearly corporate investment expenditure of

---

[19]The Akaike and Bayesian information criteria were calculated from the baseline specifications to obtain the optimal lag length. We also run an alternative specification without the crisis dummy or pre-crisis cash for a stable period (from 2004 to 2007) and find that the BIC will give the same lag length.

[20]The selection of pre-crisis cash does not change the estimation results when $\tau \geq$ crisis year $- K - 1$ due to the two-stage least-squares argument; the residuals from the regression of $D_t Cash_{i,\tau}$ of the lagged cash are unchanged.

assets on average for firms declined[21] by 1.30%p following the global crisis period. This decline is 14.0% relative to the pre-crisis unconditional mean level of yearly investment expenditures of 9.28% (see Table 1).

More importantly, we find evidence that the negative supply-side effect is significant on post-crisis investments. The coefficient of the interaction term between the crisis dummy and cash reserves is estimated to be significantly positive with regard to the regression of corporate investments on the crisis dummy and the interaction term (column (2)); it also retains a significantly positive value even after we control for investment opportunities (columns (5) and (6)). This result coincides with our prediction that the investment decline will be positively correlated with pre-crisis cash if the negative credit supply shock matters during the crisis period. For example, as the supply of credit was reduced significantly following the onset of the crisis, firms with large amounts of cash could cope with the negative credit supply shock using their internal funds, resulting in less of an investment decline (or a positive relationship between pre-crisis cash and post-crisis investment). The empirical results show that the positive relationship between pre-crisis cash and investment remained even after controlling for investment demand, offering evidence that a significant portion of the investment decline was caused by the negative credit supply shock. From the result in column (6), a zero-cash firm suffered an investment decline of 1.30%p following the crisis, while for a mean-level (11.55%, see Table 4) cash firm, this value was 0.87%p; firms one standard deviation (12.77%) higher than the mean level cash firms saw an investment decline of only 0.39%p. A one-standard deviation increase in the cash balance softens the investment decline by 36.9% compared to the case of a zero-cash firm. Furthermore, cash reserves of 34.95% relative to total assets helped to eliminate the investment decline after the crisis, meaning that those who had the required cash balance to cancel out the investment decline perfectly was less than 5% of all firms.

2. *Higher order lagged cash and financially stable periods*

In order to investigate the endogeneity issue, we also additionally provide the estimation results from the specification with lagged cash up to order four (K=4). If the endogeneity problem resides in our baseline specification, a change in of unexplained investment opportunities will show a strong have large correlation with the pre-crisis cash variable. In this case, not only will the estimate be is very different from our earlier results, but it will also it will vary in its magnitude and sign depending upon the lag length.

The first four columns in Table 6 present the estimation results from the specification with a higher order of lagged cash reserves. First, it is important to note that the estimated coefficients of capital productivity and cash flow are very stable with regard to the choice of the lag length, implying that they are free from

---

[21]Since we measure the corporate investment as the investment expenditure to total assets, the investment expenditure may increase in its level after the crisis which can be observed in non-financial firms' fixed asset formation from national accounts.

TABLE 6—HIGHER ORDER LAGGED CASH AND CASH RESERVES THREE AND FIVE YEARS PRIOR

	Higher order lagged cash				τ=2005	τ=2003
After	-1.832***	-1.304***	-1.209***	-1.173***	-1.304***	-1.154***
	(0.150)	(0.158)	(0.170)	(0.182)	(0.158)	(0.141)
After x Cash	0.0587***	0.0372***	0.0386***	0.0397***	0.0372***	0.0341***
	(0.00842)	(0.00898)	(0.00969)	(0.0106)	(0.00898)	(0.00894)
Cash (t-1)	0.134***	0.156***	0.154***	0.153***	0.193***	0.182***
	(0.0153)	(0.0170)	(0.0191)	(0.0222)	(0.0161)	(0.0158)
Cash (t-2)		0.0316**	0.0235	0.0150	0.0689***	0.0516***
		(0.0160)	(0.0181)	(0.0210)	(0.0161)	(0.0154)
Cash (t-3)			0.00808	0.00457		
			(0.0159)	(0.0193)		
Cash (t-4)				-0.0188		
				(0.0167)		
Capital productivity	0.264***	0.253***	0.231***	0.228***	0.253***	0.250***
	(0.0217)	(0.0245)	(0.0300)	(0.0340)	(0.0245)	(0.0244)
Cash flow	-0.0769***	-0.0729***	-0.0590***	-0.0597***	-0.0729***	-0.0728***
	(0.0111)	(0.0121)	(0.0133)	(0.0141)	(0.0121)	(0.0120)
Constant	5.970***	4.814***	4.590***	4.790***	3.931***	4.285***
	(0.255)	(0.377)	(0.527)	(0.722)	(0.360)	(0.350)
N. Obs.	16,852	13,529	11,186	9,502	13,529	13,529
R-squared	0.089	0.083	0.073	0.070	0.083	0.082
N. Firms	9,897	7,796	6,344	5,310	7,796	7,796

Notes: 1) 'After' is a dummy variable which is one for the fiscal year 2008 and zero otherwise, 'Cash' is cash and cash equivalents over total assets for fiscal years 2003 (5-yr), 2004 (4-yr), 2005 (3-yr), 2006 (2-yr), and 2007 (1-yr), 'Capital productivity' is the ratio of sales to tangible and intangible assets, 'Cash flow' denotes operating income before depreciation and amortization over total assets, and 'Cash (t-1)' is one-period lagged cash and cash equivalents over total assets. 2) The numbers in parenthesis are the Huber-White standard errors clustered at the firm level. 3) ***, **, or * indicate that the coefficient estimate is significant at 1%, 5%, or 10% level, respectively. 4) The classifications of small and medium enterprises (SMEs) and large firms are based on KIS data.

the endogeneity issue. The estimates for the interaction term are approximately 0.04 with lagged cash reserves of two years or more, and these values are all statistically significant. Specifically, they are not very different from the estimates with one and two years of lagged cash, as shown in Table 4-3, indicating that our baseline specification is not likely to be affected by the endogeneity problem caused by omitting the lagged cash variable. We also report the results from pre-crisis cash reserves measured during fiscal years 2005 and 2003. On the same token, the estimation results will be very different if our proxy for pre-crisis cash is contaminated by the endogeneity problem. However, we note that the estimates of both the crisis dummy and the interaction term are very stable. This implies that the inclusion of lagged cash effectively removes any possible endogenous changes in cash reserves from pre-crisis cash.

With regard to the identification problem, one may be concerned about whether the significant relationship between pre-crisis cash and investment decline is spurious or driven by a demand-side effect. If the significantly positive relationship between pre-crisis cash reserves and post-crisis investments is a general feature of the data, it would be misleading to interpret our results as evidence of the existence of a negative supply-side effect. However, if the significantly positive relationship is only observed in the sample during a financially turbulent period, not in a financially stable period, we may argue that the findings in the previous analysis imply the existence of an investment constraint due to the credit supply shock.

In order to answer this question, we examine the coefficient estimate of the interaction term between cash reserves and the crisis dummy for 2000, for 2006

with placebo crises (stable periods), and during the 1998 currency crisis (a turbulent period). During stable periods, financial markets performed well; hence, investment expenditures by firms are less likely to be affected by the credit supply, resulting in a small or insignificant coefficient estimate of the interaction term. However, during the 1998 currency crisis, domestic banks underwent massive restructuring, and post-crisis investments by firms were more than likely constrained by the credit shortage. In that case, firms were forced to fund their investment via internal funds, implying that the coefficient estimate of the interaction term is significantly positive. We also provide estimation results for SMEs and for all firms because SMEs are considered to be more financially constrained. Thus, their reliance on internal funding will be more prevalent during this crisis period.

Table 7 presents the estimation results for the financially stable and turbulent periods. First, we confirm that pre-crisis cash reserves did not affect investment expenditures during financially stable[22] periods. The interaction terms between pre-crisis cash and the time dummy are estimated to be 0.017 and 0.010 for 2000 and the 2006 placebo crisis, respectively, and they are both statistically insignificant. Although the estimates for the financially stable periods are in line with our expectations, but it is noteworthy that the estimates are small but positive, which implies that our findings are not as strong as those of Duchin *et al*. (2010).[23]

TABLE 7—FINANCIALLY STABLE VS. TURBULENT PERIOD

	Crisis = Year 2000		Crisis = Year 2006		Crisis = Year 1998	
	All	SMEs	All	SMEs	All	SMEs
After	0.379*	0.408	-0.541***	-0.553***	-2.474***	-2.285***
	(0.221)	(0.272)	(0.178)	(0.204)	(0.224)	(0.276)
After x Cash	0.0171	-0.00276	0.0104	0.00232	0.0404**	0.0438**
	(0.0170)	(0.0188)	(0.0108)	(0.0120)	(0.0162)	(0.0183)
Cash (t-1)	0.0759**	0.124***	0.158***	0.174***	0.118***	0.113***
	(0.0305)	(0.0326)	(0.0199)	(0.0223)	(0.0244)	(0.0291)
Cash (t-2)	0.0479**	0.0696***	0.0614***	0.0583***	0.0321	-0.0140
	(0.0232)	(0.0252)	(0.0182)	(0.0201)	(0.0251)	(0.0287)
Capital productivity	0.223***	0.266***	0.285***	0.311***	0.145***	0.161***
	(0.0436)	(0.0522)	(0.0293)	(0.0349)	(0.0338)	(0.0447)
Cash flow	-0.0240	-0.0348	-0.0667***	-0.0660***	-0.0384***	-0.0298
	(0.0236)	(0.0258)	(0.0141)	(0.0147)	(0.0148)	(0.0199)
Constant	4.367***	3.802***	4.489***	4.552***	4.943***	5.065***
	(0.554)	(0.635)	(0.410)	(0.457)	(0.472)	(0.588)
N. Obs.	6,058	4,406	11,997	10,021	5,900	4,249
R-squared	0.046	0.057	0.066	0.069	0.120	0.104
N. Firms	3,298	2,428	6,785	5,746	3,374	2,489

Notes: 1) 'After' is a dummy variable which is one for the fiscal year 2008 and zero otherwise, 'Cash' is cash and cash equivalents over total assets during fiscal year 2004, 'Capital productivity' is the ratio of sales to tangible and intangible assets, and 'Cash flow' denotes operating income before depreciation and amortization over total assets. 2) The numbers in parenthesis are the Huber-White standard errors clustered at the firm level. 3) ***, **, or * indicate that the coefficient estimate is significant at 1%, 5%, or 10% level, respectively. 4) The classifications of small and medium enterprises (SMEs) and large firms are based on KIS data.

---

[22]Though the choice of financially stable periods (2000 and the 2006 placebo crises) is arbitrary, we find qualitatively similar results with alternative selections of placebo crises, except for the 1998 and 2008 crises.

[23]Duchin *et al*. (2010) find the estimates of the interaction term during placebo crises to be negative in general; therefore, the significantly positive estimates of the interaction term can be interpreted as strong evidence of a supply-side effect.

With regard to the results for the 1998 currency crisis, we find that the estimated coefficients of the interaction terms for both all firms and SMEs are significantly positive, indicating that they experienced a shortage of credit supply following the currency crisis. All in all, the results from financially stable and turbulent periods suggest that our baseline specification can be used to identify negative supply-side effects.

3. *Financial constraint and the supply-side effect*

Financially constrained firms may suffer more from a negative shock to the credit supply during a global financial crisis period. Essentially, a financial constraint, which usually arises from information asymmetry, is known to amplify the negative impact on constrained firms, e.g., a greater decline in investment expenditures following the crisis in our case. Though there are several ways to identify financially more constrained firms,[24] we use the classification as a small and medium enterprise (SME) for identifying financially more constrained firms. Together with the SME classification, we divide our sample into financially more and financially less constrained firms using alternative measures of financial constraint, in this case industry (three-digit) sales growth and ownership, and perform a similar analysis to test the robustness of our results.

The first two columns in Table 8 show the estimation results of our baseline specification for large firms and SMEs. The coefficient estimate of the crisis

TABLE 8—FINANCIAL CONSTRAINTS AND POST-CRISIS INVESTMENT: ALTERNATIVE CLASSIFICATION

	SME Category		Industry Sales Growth		Ownership	
	No	Yes	High	Low	Public	Private
After	-0.997***	-1.366***	-1.353***	-1.351***	-0.797***	-1.313***
	(0.264)	(0.183)	(0.315)	(0.297)	(0.295)	(0.188)
After x Cash	0.0264*	0.0415***	0.0243	0.0569***	0.0262*	0.0326***
	(0.0140)	(0.0107)	(0.0177)	(0.0185)	(0.0154)	(0.0115)
Cash (t-1)	0.0650***	0.170***	0.188***	0.136***	0.109***	0.167***
	(0.0252)	(0.0197)	(0.0384)	(0.0321)	(0.0330)	(0.0217)
Cash (t-2)	0.0435	0.0330*	0.0397	0.00998	0.0161	0.0493**
	(0.0271)	(0.0186)	(0.0313)	(0.0290)	(0.0310)	(0.0199)
Capital productivity	0.148***	0.292***	0.314***	0.267***	0.156***	0.300***
	(0.0351)	(0.0301)	(0.0500)	(0.0535)	(0.0529)	(0.0280)
Cash flow	-0.0664**	-0.0751***	-0.0850***	-0.0999***	-0.0522**	-0.0646***
	(0.0269)	(0.0127)	(0.0271)	(0.0252)	(0.0220)	(0.0152)
Constant	4.474***	4.763***	3.877***	5.702***	4.252***	4.539***
	(0.649)	(0.437)	(0.738)	(0.721)	(0.890)	(0.442)
N. Obs.	2,065	11,464	2,858	3,452	2,311	10,166
R-squared	0.068	0.089	0.103	0.079	0.052	0.088
N. Firms	1,130	6,723	1,429	1,726	1,274	6,039

Note: 1) 'Leverage' is liabilities over the capital ratio, 'Short-term Debt' is current liabilities over the total liabilities ratio, 'Stock listing' refers to KOSPI-listed or KOSDAQ-listed (or registered) firms, and 'Div. Payment' denotes firms with non-zero dividend payments. 2) 'After' is a dummy variable which is one for the fiscal year 2008 and zero otherwise, 'Cash' is cash and cash equivalents over total assets during fiscal year 2004, 'Capital productivity' is the ratio of sales to tangible and intangible assets, and 'Cash flow' denotes operating income before depreciation and amortization over total assets. 3) The numbers in parenthesis are the Huber-White standard errors clustered at the firm level. 4) ***, **, or * indicate that the coefficient estimate is significant at 1%, 5%, or 10% level, respectively.

---

[24]For more details, refer to Kaplan and Zingles (1997) and Whited and Wu (2006), among others.

dummy is significantly negative for both large firms and SMEs. However, the post-crisis investment decline is greater for SMEs. For instance, the coefficient estimate of the crisis dummy for large firms is -0.99, while the estimate for SMEs is -1.36. The coefficient estimates of the interaction term between cash and the crisis dummy are positive for both large firms and SMEs. However, we find that the estimate for large firms is less significant (with 10% level)[25] while the estimate for SMEs is much higher and significant at the 1% level. These results provide evidence that SMEs, which are more financially constrained due to information asymmetry, can experience greater investment declines following the onset of a financial crisis. Moreover, the results coincide with our previous analysis (in Section 3), which showed that pre-crisis cash has more of an impact on post-crisis investment levels for SMEs. When compared to the results for all firms, shown in Table 5, we find that the estimate of the interaction term for SMEs is 0.041, which is close to the estimate for all firms (0.037), implying that the overall estimate is largely driven by the SMEs in the sample. Compared to firms with no cash, the average cash holdings for large firms can mitigate an investment decline by 0.66%p, while the average cash holdings for SMEs can alleviate the decline by 0.89%p, implying that cash is more valuable for SMEs.

Table 7 (from column (3) to column (6)) presents the estimation results for financially more and less constrained firms by dividing the sample according to industry (three-digit) sales growth and ownership. We use industry sales growth one year prior to the crisis to capture the financial constraints and divide our sample into 'high' (above the third quantile) and 'low' (below the first quantile) groups. With regard to ownership, we classify KOSPI-listed, KOSDAQ-listed or registered firms as public firms, and others as private firms.

We find that the role of cash in mitigating the investment decline is greater for financially more constrained firms. The coefficient estimate of the interaction term for firms with low industry sales growth is 0.056, which is around twice the coefficient estimate for firms in the group showing high industry sales growth (0.024). Private firms also show greater sensitivity to of investment expenditures on cash reserves than public firms. Overall, the results imply that the corporate investment decline following the 2008 crisis is largely related to the level of financial constraint of a firm, supporting the view that negative credit supply-side effects on corporate investments were evident during the crisis period.

4. *Why do corporate investments remain sluggish?*

Related to recent investment activity in corporate sector, we observe that private fixed capital formation (in current prices) remains sluggish after showing an increase due to the base effect following the fourth quarter of 2009. In order to examine the impact of external finance shocks on recent corporate investments, we

---

[25]This result is robust even when (i) we include data from two and three years before and after the crisis in the sample, (ii) we include higher order lagged cash reserves as an explanatory variable, and (iii) we use Tobin's q rather than capital productivity for listed firms.

add recent firm-year observations[26] to our original sample. Next, we include an additional year dummy variable ('further after' crisis dummy) for the years from the first to the third year following the 2008 crisis, as well as an interaction term between pre-crisis cash and the 'further after' crisis dummy. If the credit crunch during the crisis has had a negative effect on corporate investments persistently, we would observe that the interaction term (between pre-crisis cash and the 'further after' crisis dummy) is significantly positive with the coefficient estimate for the 'further after' crisis dummy being significantly negative. Meanwhile, if post-crisis investments are mainly affected by investment demand, such as depressed investment opportunities, we would find that the interaction term between the 'further after' crisis dummy and pre-crisis cash reserves loses its significance.

Table 9 shows the estimation results for our extended sample with large firms and SMEs. Interestingly, the 'further after' crisis dummy for SMEs is estimated to be significantly negative. Moreover, the estimated coefficient of the interaction term is significantly positive, implying that the more pre-crisis cash a firm has, the less its investment decreased during 2009-2011 compared to 2007. For large firms, the result is less suggestive for the supply-side effect on corporate investment; while the 'further after' crisis dummy has a negative coefficient, the estimated coefficient of the interaction term is not significant.

In summary, the investment decline of SMEs after the crisis remains significant even if we include recent firm-year observations and is related to their levels of pre-crisis cash reserves. This indicates that the additionally depressed investments

TABLE 9—LONG-TERM EFFECT OF A NEGATIVE SUPPLY SHOCK AND FINANCIAL CONSTRAINTS

	Large firms			SMEs		
After	-0.876***	-0.893***	-0.898***	-1.364***	-1.368***	-1.376***
	(0.266)	(0.264)	(0.264)	(0.179)	(0.177)	(0.177)
After x Cash	0.0270*	0.0270**	0.0262**	0.0445***	0.0486***	0.0480***
	(0.0139)	(0.0134)	(0.0133)	(0.00979)	(0.00971)	(0.00968)
Further after	-1.119***	-1.109***	-1.124***	-2.479***	-2.434***	-2.452***
	(0.281)	(0.281)	(0.282)	(0.179)	(0.178)	(0.178)
Further after x Cash	0.0155	0.0152	0.0141	0.0684***	0.0699***	0.0691***
	(0.0146)	(0.0142)	(0.0142)	(0.00965)	(0.00980)	(0.00980)
Cash (t-1)	0.0737***	0.0674***	0.0676***	0.156***	0.143***	0.143***
	(0.0163)	(0.0158)	(0.0158)	(0.00933)	(0.00920)	(0.00921)
Cash (t-2)	0.0519***	0.0522***	0.0521***	0.0559***	0.0556***	0.0549***
	(0.0140)	(0.0137)	(0.0137)	(0.00825)	(0.00825)	(0.00827)
Capital productivity		0.0983***	0.102***		0.198***	0.202***
		(0.0202)	(0.0202)		(0.0151)	(0.0155)
Cash flow			-0.0245*			-0.0155
			(0.0149)			(0.0105)
Constant	5.135***	4.412***	4.640***	6.538***	5.400***	5.542***
	(0.267)	(0.329)	(0.351)	(0.169)	(0.195)	(0.215)
N. Obs.	6,287	6,287	6,287	28,746	28,746	28,746
R-squared	0.031	0.044	0.045	0.043	0.060	0.061
N. Firms	2,335	2,335	2,335	9,270	9,270	9,270

Note: 1) 'After' is a dummy variable which is one for the fiscal year 2008 and zero otherwise, 'Cash' is cash and cash equivalents over total assets during fiscal year 2004, 'Further after' is a dummy variable which is one for fiscal years 2008-2011 and zero otherwise, 'Capital productivity' is the ratio of sales to tangible and intangible

[26]Due to the time lag of financial statement disclosure, especially for unlisted small firms, the most recent financial statements which are up to date and which are consistent with our previous sample are for fiscal year 2011.

assets, and 'Cash flow' denotes operating income before depreciation and amortization over total assets. 2) The numbers in parenthesis are the Huber-White standard errors clustered at the firm level. 4) ***, **, or * indicate that the coefficient estimate is significant at 1%, 5%, or 10% level, respectively.

of SMEs after the crisis (from 2009 to 2011) are associated with the credit supply shock during the 2008 crisis and that the funding problem may have had a long-last negative impact on the investment activities of SMEs. However, we could not find any evidence that investment declines in large firms are related to a negative shock to their external finances, especially over the long term.

V. Conclusion

We study whether the corporate investments of domestic firms, including small and medium enterprises, are affected by the negative shock to the credit supply which arose during the global financial crisis. Following Duchin *et al*. (2010), we use pre-crisis cash reserves (or internal funds) held by firms to identify any negative supply-side effect of the crisis, as cash reserves can play an important role as a financial buffer to an external funding shock. In order to address possible the endogeneity issue, we include lagged cash reserves in our baseline specifications. As a robustness check, we compare the results from the specification with higher order lagged cash reserves as well as the results from financially stable periods. From our baseline specification, we can summarize our empirical findings as follows.

First, corporate investments (to the total asset ratio) significantly decreased following the onset of the global financial crisis, and the decline is found to be significant after controlling for investment demand. More importantly, we find that the investment decline is negatively related to pre-crisis cash reserves; the more cash a firm holds (or the greater the financial buffer), the less its post-crisis investment decline becomes in the data. The result implies that corporate investments are significantly affected by a negative shock to the external financing of a firm.

Second, large firms experienced less of an investment decline following the crisis compared to small and medium enterprises (SMEs). Because SMEs are more exposed to financial constraints, commonly driven by the problem of information asymmetry, a negative shock to the credit supply will have more of an impact on SMEs' investments than it will on those of large firms. Our results indicate that there exists a strong relationship between pre-crisis cash held by SMEs and their post-crisis investments, implying that the negative supply-side effect is mostly driven by the SMEs in the sample. When using alternative measures of financial constraints, such as industry sales growth and ownership, we find that the results are qualitatively identical; our empirical evidence is supportive of the existence of a negative supply-side effect.

Third, we find evidence that the recent investment depression from 2009 to 2011, mainly experienced by SMEs, is related to the negative shock to external funds during the crisis period.

Our empirical findings support the view that the post-crisis investment decline is

driven by the negative credit supply shock during the crisis, especially affecting more financially constrained firms such as SMEs. However, it is necessary to investigate why the negative supply-side effect on investments still matters to SMEs, even four years after the crisis ended. Possible explanations would be a change in the financing behavior of SMEs (e.g., towards more conservative capital management) or an aggravated information asymmetry problem, leading to higher financial constraints, among others. We leave the question to future studies.

REFERENCES

Almeida, H., M. Campello, and M. Weisbach. 2004. "The Cash Flow Sensitivity of Cash." *Journal of Finance* 59: 1777–1804.

Arslan, O., C. Florackis, and A. Ozkan. 2006. "The Role of Cash Holdings in Reducing Investment-cash Flow Sensitivity: Evidence from a Financial Crisis in an Emerging Market." *Emerging Markets Review* 7: 320–338.

Bates, T., K. Kahle, and R. Stulz. 2009. "Why Do U.S. Firms Hold So Much More Cash than They Used to?" *Journal of Finance* 64: 1985–2021.

Brunnermeier, M. K., T. M. Eisenbach, and Y. Sannikov. 2012. "Macroeconomics with Financial Frictions: A Survey." NBER Working Paper 18102.

Campello, M., J. R. Graham, and C. R. Harvey. 2010. "The Real Effects of Financial Constraints: Evidence from a Financial Crisis." *Journal of Financial Economics* 97 (3): 470–487.

Dell'Ariccia, G., E. Detragiache, and R. Rajan. 2008. "The Real Effect of Banking Crises." *Journal of Financial Intermediation* 17 (1): 89–112.

Dittmar, A. and J. Mahrt-Smith. 2007. "Corporate Governance and the Value of Cash Holdings." *Journal of Financial Economics* 83: 599–634.

Duchin, R., O. Ozbas, and B. A. Sensoy. 2010. "Costly External Finance, Corporate Investment, and the Subprime Mortgage Credit Crisis." *Journal of Financial Economics* 97 (3): 418–435.

Fazzari, S., R. Hubbard, and B. Petersen. 1988. "Finance Constraints and Corporate Investment." *Brookings Papers on Economic Activity* 1: 141–195.

Gao, W., L. Ng, B. Zhang, and F. Zhu. 2012. "Information Asymmetry and Capital Structure around the World." Working Paper.

Gilchrist, S. and C. Himmelberg. 1999. "Investment: Fundamentals and Finance." *NBER Macroeconomics Annual 1998*, MIT Press.

Hahm, J. and H. Kim. 2011. "Financial Sector Soundness and the Impact of External Shock." In *Korea's Capacity to Cope with Crises in a Globalized Environment*, edited by D. Cho and H. Kim, KDI Research Monograph 2011-03, Korea Development Institute. (in Korean)

Harford, J., S. Mansi, and W. Maxwell. 2008. "Corporate Governance and Firm Cash Holdings in the US." *Journal of Financial Economics* 87: 535–555.

Holmstrom, B. and J. Tirole. 1997. "Financial Intermediation, Loanable Funds, and the Real Sector." *Quarterly Journal of Economics* 112: 663–691.

Hoshi, T., A. Kashyup, and D. Scharfstein. 1991. "Corporate Structure, Liquidity, and Investment: Evidence from Japanese Industrial Groups." *Quarterly Journal of Economics* 106: 33–60.

Ivashina, V. and D. Scharfstein. 2010. "Bank Lending during the Financial Crisis of 2008." *Journal of Financial Economics* 97 (3): 319–338.

Jaffee, D. and T. Russell. 1976. "Imperfect Information, Uncertainty, and Credit Rationing." *Quarterly Journal of Economics* 90: 651–666.

Kaplan, S. and L. Zingales. 1997. "Do Investment-cash Flow Sensitivities Provide Useful Measures of Financing Constraints?" *Quarterly Journal of Economics* 112: 169–215.

Kim, D. 2011. "Corporate Sector Soundness and Economic Crisis." In *Korea's Capacity to Cope*

with Crises in a Globalized Environmentm, edited by D. Cho and H. Kim, KDI Research Monograph 2011-03, Korea Development Institute. (in Korean)

Lee, H. 2005. "The Impacts of Uncertainty on Investment: Empirical Evidence from Manufacturing Firms in Korea." *KDI Journal of Economic Policy* 27 (2): 89–116, Korea Development Institute. (in Korean).

Lim, K. 2005. "An Analysis on Changes of Equipment Investment Patterns of Korean Firms Using Micro and Macro Data." KDI Policy Study 2005-15, Korea Development Institute. (in Korean)

Lim, K. and Y. Choi. 2006. "A Study on the Pattern Changes and Determinants of Corporate Cash Holding." KDI Policy Study 2006-11, Korea Development Institute. (in Korean)

Opler, T., L. Pinkowitz, R. Stulz, and R. Williamson. 1999. "The Determinants and Implications of Corporate Cash Holdings." *Journal of Financial Economics* 52: 3–46.

Pinkowitz, L., R. Stulz, and R. Williamson. 2006. "Does the Contribution of Corporate Cash Holdings and Dividends to firm Value Depend on Governance? A Cross-country Analysis." *Journal of Finance* 61: 2725–2751.

Stiglitz, J. and A. Weiss. 1981. "Credit Rationing in Markets with Imperfect Information." *American Economic Review* 71: 393–410.

Whited, T. and G. Wu. 2006. "Financial Constraints Risk." *Review of Financial Studies* 19: 531–559.

Innovation Height and Firm Performance:
An Empirical Analysis from
the Community Innovation Survey†

By DAIYA ISOGAWA, KOHEI NISHIKAWA, HIROSHI OHASHI*

This study evaluates the economic impact of product innovation by using firm-level data from the Community Innovation Survey conducted in Japan. It accounts for possible technological spillover from innovation activities and examines the extent to which new-to-market product innovations contribute to firm performance. Econometric analysis using a simultaneous equation model reveals that new-to-market product innovation is likely to increase a firm's sales without cannibalizing those of existing products and generate more technological spillover to other firms. Moreover, such innovation is more likely to emerge from firms collaborating with academic institutions. The paper concludes by discussing policy implications of these findings as well as points to the importance of cross-country comparison between Korea and Japan.

I. Introduction

While there is widespread agreement that innovation matters for growth, there is no conclusive evidence on what types of innovation best foster growth or which factors determine the types of innovation achieved. This paper, drawing on a unique innovation survey conducted in Japan, attempts to answer these questions with a particular focus on product innovation. The innovation survey used here identifies

two types of product innovations: new-to-market (or radical) and new-to-firm (or incremental).[1] The latter covers the diffusion of an existing innovation to an additional firm; the innovation may have already been implemented by other firms but it is new to the firm in question. Firms that are the first to develop an innovation, in contrast, are classified as having achieved new-to-market innovation. Data on innovation types can help us assess whether there is a threshold level for the extent of innovation (i.e., "innovation height") that leads to higher growth. This paper is the first attempt to examine the causes and consequences of innovation heights using firm-level analysis within an Asian country. Improving collective knowledge on this aspect of innovation is crucial for designing relevant policies.

Innovation encompasses a wide range of activities and processes, including marketing, organizations, and knowledge transfers. Product innovation is, by definition, novel. The degree of novelty, however, differs by the product in question (Arundel and Hollanders 2005). Specifically examining new-to-market product innovation can add new insight to the existing literature in two respects. First, new-to-market product innovation may contribute to firm performance to a greater extent than lesser innovation, as it provides a firm with temporary market power (Petrin 2002). Second, new-to-market product innovation may entail technological spillover to other firms, spurring further innovative activities; this topic has attracted considerable attention both theoretically and empirically.[2] For example, recent studies of endogenous growth theory (e.g., Grossman and Helpman 1991; Aghion and Howitt 1992; Klette and Kortum 2004) indicate that spillover from firms at the technological frontier play an important role. If new-to-market product innovation results in significant positive spillover, policies to promote such innovation would be justified from a social-welfare perspective (Spence 1984).

Given this policy importance, this study quantitatively examines the nature of new-to-market product innovation in an effort to better understand its contribution to firm performance and its possible need for public policy attention. We propose an econometric model that comprises technological spillover, legal and non-legal protection measures, and other important variables relevant to new-to-market product innovation. Our model is similar to that proposed by Crépon, Duguet, and Mairesse (1998) (hereafter CDM) in that it also consists of a system of equations.[3] However, our estimation addresses possible endogeneity, an issue largely neglected in CDM. We then apply this model to firm-level data from the Japanese National Innovation Survey (JNIS).

Despite its economic importance, little empirical work has focused on the height and novelty of product innovation. To the best of our knowledge, Duguet (2006) is the only exception. The present study builds on Duguet (2006) but differs in three important ways. First, Duguet (2006) lumps together product and process innovations into one basket even though the economics underlying the two types of

---

[1] Since the former is novel only for the firm in question, new-to-market innovation encompasses new-to-firm innovation.

[2] Arrow (1962) points out that an innovating firm cannot appropriate the outcome of its innovation activities owing to the inherent technological spillovers. Ever since, researchers have tried to quantify the degree of spillover, especially in terms of the social rate of return on R&D investments (See Griliches, 1992, for details).

[3] The CDM approach has been adopted by other researchers, including Griffith, Huergo, Mairesse, and Peters (2006) with regards to France, Germany, Spain, and the UK and by Chudnovsky, López, and Pupato (2006) in a study of Argentina.

innovations is significantly different (e.g., Klepper 1996). In contrast, we focus solely on product innovation to clarify our analysis and interpretation. Second, we use sales, rather than productivity, as a measure of firm performance. It has been argued that productivity may be an inappropriate metric for assessing product innovation (e.g., Van Leeuwen and Klomp 2006; De Loecker 2011). Lastly, in order to capture the influence of technological spillover, we consider both technology outflow and inflow; Duguet (2006) focuses only on technology inflow. Incorporating technology outflow provides us with an unbiased picture of technological spillover in the context of JNIS.

The rest of this paper is organized as follows. Section II provides an overview of innovation activities across the major countries that conduct innovation surveys. Section III proposes a series of hypotheses on the relationship between new-to-market product innovation and firm performance (Section III.A), technological spillover (Section III.B), and other characteristics including information sources, legal and non-legal protections, and public financial support (Section III.C). Section IV crafts an econometric model to test the hypotheses and then presents the results of the estimations. Section V concludes the paper.

II. Surveys of Product Innovation[4]

While innovation is inherently difficult to quantify and measure, there have been several efforts to develop survey-based indicators. Traditional indicators of product innovation include R&D expenditures and patents. These indicators, however, are mere inputs into the innovation processes as they do not capture key aspects of innovation processes and outputs, as noted by Griliches (1987, cited in Smith 2005). As such, targeted innovation surveys have been developed to collect qualitative and quantitative data on innovation activities within firms and on the successful introduction of different types of innovations into the market. These surveys deliberately seek to obtain data on innovation outputs and inputs beyond the traditional indicators of innovation (OECD 2009).[5]

In innovation surveys, firms are asked to provide information on inputs, outputs, and behavioral dimensions of their innovation activities. On the input side, innovation surveys measure a firm's intangible assets; beyond R&D expenditures, these include spending on training and acquisitions of patents and licenses. On the output side, data are collected on whether a firm has introduced a new product or process and the share of sales attributable to new products. Other indicators capture the nature of the innovative activities, including their impacts, collaborations and linkages with other firms or public research organizations, perceived obstacles to innovation, and knowledge flows (OECD 2009).

To ensure the quality of innovation surveys, the Organization for Economic Cooperation and Development (OECD) developed a manual known as the Oslo

---

[4]The description in this section relies heavily on Smith (2005), Mairesse and Mohnen (2010), and OECD (2009).

[5]The JNIS results show that 47.3% of firms conducting innovation activities report that R&D expenditures are zero; similar phenomena are reported in Arundel, Bordoy, and Kanerva (2008) and have been observed in other countries.

Manual (OECD 1992) and synthesized the results of earlier innovation surveys—notably the Yale Survey on Industrial Research and Development and the Carnegie-Mellon University R&D Survey in the United States.[6] The OECD Oslo Manual identifies product and process innovations as technological innovations; product innovation is defined as the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user-friendliness, or other functional characteristics. Process innovation is defined as the implementation of a new or significantly improved production or delivery method, including significant changes in techniques, equipment, and/or software (OECD 2009).

The European Commission, via a joint initiative of Eurostat and the Directorate-General for Enterprise and Industry, followed up the OECD initiative to implement the Community Innovation Survey (CIS), which seeks to collect internationally comparable firm-level quantitative measures of innovation inputs and outputs. The basic CIS format has now been applied in many other countries, including South Korea and Japan. Figure 1 takes advantage of this rich set of data to list the countries with the highest proportions of respondent firms with either product innovation (left panel) or process innovation (right panel).[7] Casual observation indicates that those countries with the highest portions of firms product innovations also exhibit high shares for process innovations; indeed, the rank correlation is 0.71. While the data for Korea refers only to the manufacturing sector, its share of firms with product innovation (35.7%) far higher than that of Japan (20.3%). This order reverses for process innovation: 26.6% for Japan and 22.5% for Korea.
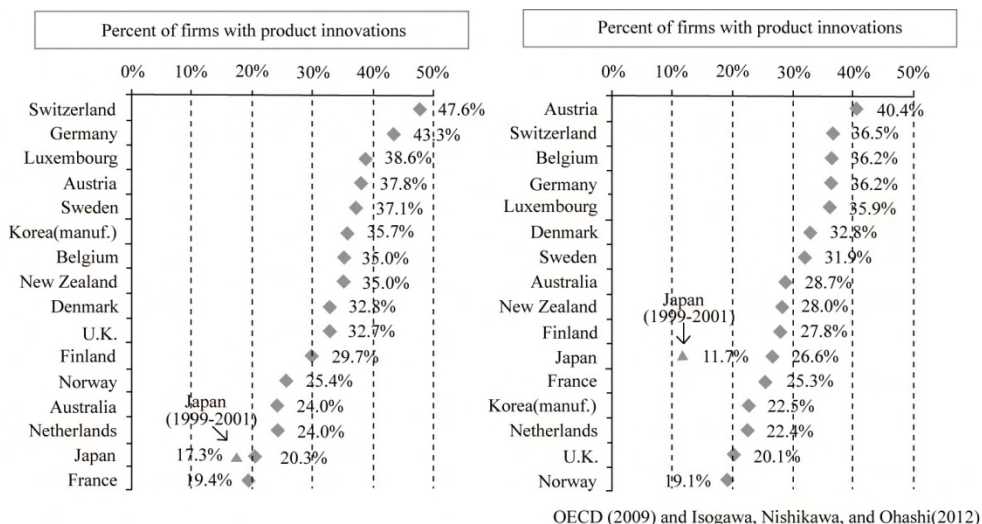

OECD (2009) and Isogawa, Nishikawa, and Ohashi(2012)

FIGURE 1: PRODUCT AND PROCESS INNOVATIONS: AN INTERNATIONAL COMPARISON

---

[6]See Smith (2005) and Mairesse and Mohnen (2010) for details of community innovation surveys.

[7]The national innovation surveys from which these results come were conducted between 2002 and 2004, except for Japan (2006 to 2008), Switzerland (2003 to 2005), and Australia and New Zealand (2004 to 2005). The proportions listed in the figure are adjusted based on country differences in terms of firm-size distributions to enable us to make an international comparison.
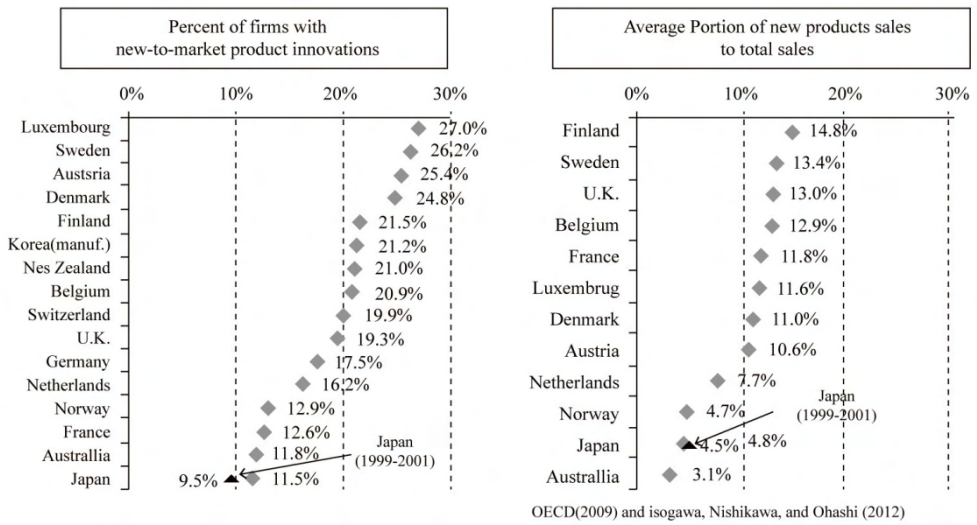
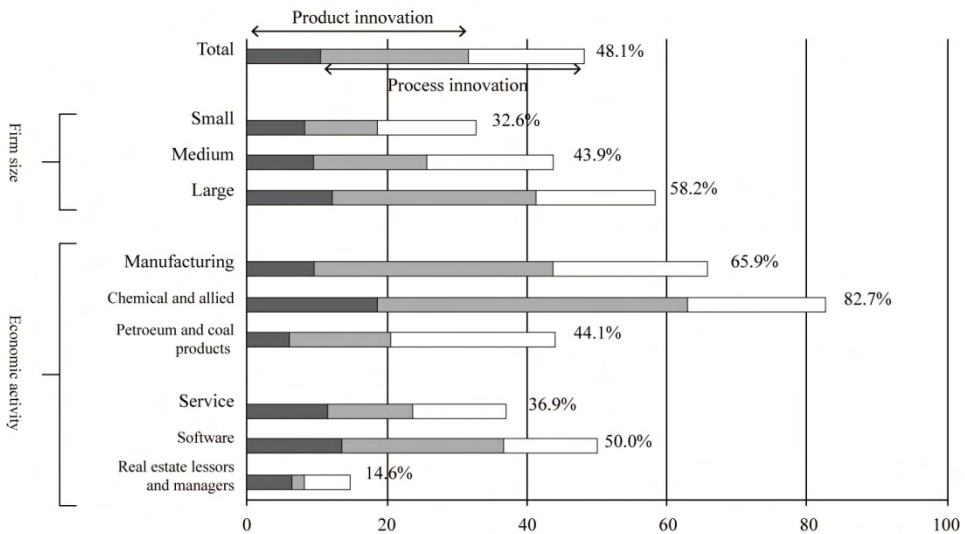FIGURE 2: PRODUCT INNOVATION HEIGHT AND SALES

FIGURE 3: SUMMARY STATISTICS OF FOR JNIS

The Oslo Manual distinguishes between the two types of innovation noted in the introduction: new-to-firm and new-to-market. We consider the height of product innovation to be represented by the new-to-market product innovation. Figure 2 thus considers this type of innovation. The left panel presents the proportion of respondent firms that achieved such innovations. The rank correlation between product innovation (the right panel of Figure 1) and new-to-market product innovation is 0.67. The right panel of Figure 2 shows the average share of total sales that are new product sales.[8]

---

[8]OECD (2009) lists Korea (only for the manufacturing sector) for the share of firms with new-to-market

The Japaneese National Innovation Survey (JNIS), the dataset used in this paper, follows the Oslo Manual with a reference period from April 1, 2006 to March 31, 2009. Using a stratified sampling technique, a sample of firms were selected from those listed in the Establishment and Enterprise Census 2006, which was conducted by the Statistics Bureau of Japan's Ministry of Internal Affairs and Communications. The sample used here is further restricted to firms with more than 10 employees. The response rate is 30.3%, corresponding to a sample of 4,579 firms. Figure 3 shows the proportions of respondent firms that succeeded in either product or process innovations (or both). The figure indicates that 48.1% of firms in the survey innovated, with a substantial share of those firms having succeeded in both types of innovation. The share of firms that innovated increases with firm size and is higher for the manufacturing sector than the service sector.

III. Hypotheses Related to New-to-Market Product Innovation

This section proposes eight hypotheses related to new-to-market product innovation, which will be tested in Section IV. The present section consists of three subsections. Section III.A discusses how new-to-market product innovation might improve firm performance. The second subsection focuses on technological spillover in innovation activities. Section III.C then discusses policy issues.

A. *Firm Performance*

First, we examine the effect of product innovation on firm performance. This can be analyzed by decomposing firm performance into two dimensions: sales of new and existing products. This is shown in Figure 4, where the horizontal axis represents changes in sales of a new product and the vertical axis measures changes in the sales of existing goods. It is often assumed that the introduction of a new product
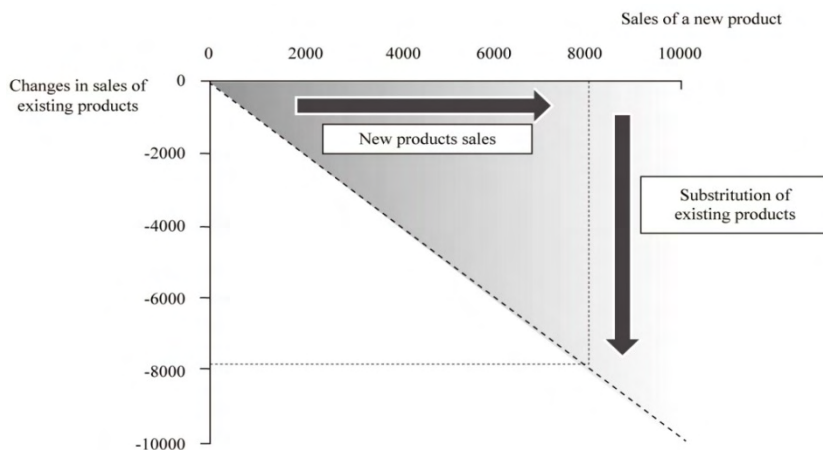

FIGURE 4: PRODUCT INNOVATION AND FIRM SALES

innovations, but no data for Korea is available for new product sales as a portion of total sales.

cannibalizes existing goods' sales. If demand for a new product is a perfect substitute for demand for existing goods, the net effect of product innovation on the firm's total sales is indicated by the (negative) 45-degree line in the figure. If the new good does not substitute for old goods whatsoever, the net total sales would be in the full area above the (negative) 45-degree line, as represented by the grey area in Figure 1.

Consistent with this view, Duguet (2006) shows that only new-to-market innovations (i.e., radical innovations) can improve a firm's net-performance. Barlet, Duguet, Encaoua, and Pradel (1998) also indicate that the novelty of an innovation can increase the share of sales that are innovation-related in situations where technology is important. The following hypothesis captures this effect:

Hypothesis 1: *The sales of a new product are larger for a firm achieving new-to-market product innovation than for a firm offering new-to-firm product innovation.*

According to JNIS sales information from JNIS,[9] the average sales value of new products in FY2008 was 5,586 million JPY for firms with new-to-market product innovations and 3,004 million JPY for other firms. Figure 5 shows a box-plot of the sales of a new product for firms with new-to-market product innovation and for those with new-to-firm product innovation. The top and bottom of the rectangle in each graph represent the 25th and 75th percentiles of the sales distribution, respectively, and the dashed line represents the median. Median sales are 196 million JPY for new-to-market product innovations and 164 million JPY for new-to-firm innovations. Moreover, it should be noted that the 75th percentile of sales value for new-to-market product innovation is much higher than that for new-to-firm product innovation.
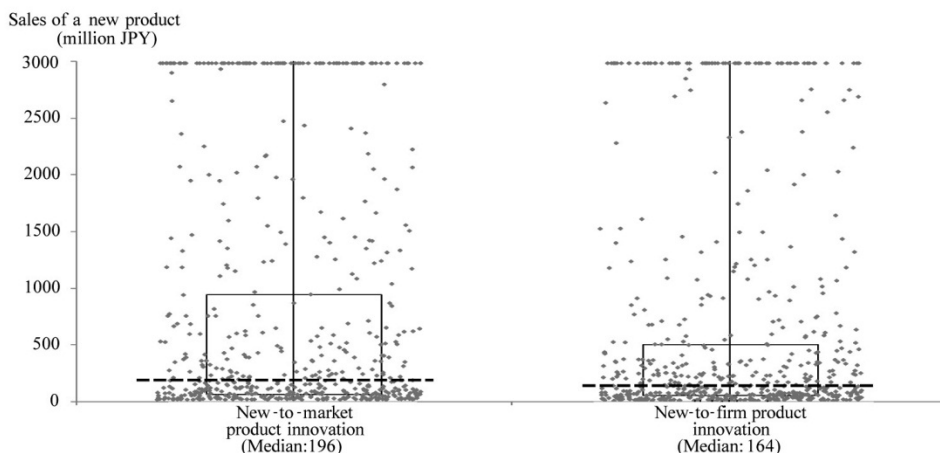

FIGURE 5: INNOVATION HEIGHT AND NEW PRODUCT SALES

[9]To be precise, JNIS asks each firm about the share of its new product sales. We recover the sales from the new product by multiplying the share by each firm's total sales reported in FY2008.

Next, we turn to sales of existing goods. Jefferson, Huamao, Xiaojing, and Xiaoyun (2006) point out that innovation does not necessarily improve firm performance, suggesting that cannibalization with a firm's existing products can severely deteriorate the firm's profitability. This leads to the following two hypotheses:

Hypothesis 2: *Higher sales of a new product decrease sales of a firm's existing products.*

Hypothesis 3: *The more innovative a new product, the more intense the cannibalization of sales of existing goods.*

To test Hypotheses 2 and 3, we must understand the impact of product innovation on the sales of a firm's existing goods. We thus calculate the changes in the sales of existing products from FY2006 to FY2008. The left-hand panel of Figure 6 plots the relationship between sales of a newly introduced product (including both new-to-market and new-to-firm product innovations) and changes in the sales of existing products, following the analytical framework discussed in Figure 4.[10] Sales arising from product innovation appear to cannibalize sales of existing goods. This observation is consistent with Hypothesis 2 in that the introduction of a new product substitutes the demand for existing goods. The change in total sales (i.e., the sum of the changes in the sales of existing goods and of those resulting from new-to-market product innovation) is uniformly positive and approximately 1,500 million JPY on average.

The right-hand side of Figure 6 plots the same relationship separately for firms with new-to-market product innovation and those with new-to-firm product innovation, showing a significant difference between the two. The average relationship for firms with new-to-firm product innovation lies almost on the (negative) 45-degree line, indicating that sales of these new-to-firm products fully
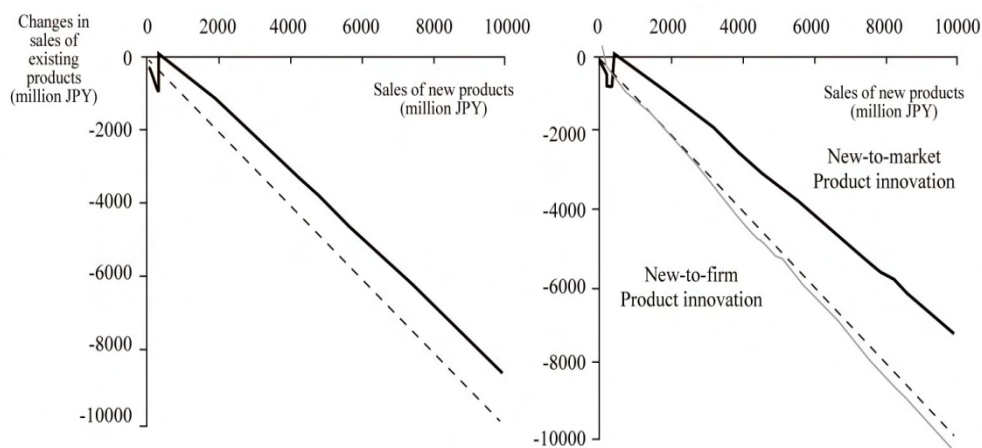

FIGURE 6: SALES OF NEW AND EXISTING PRODUCTS

---

[10]We use LOWESS (Locally Weighted Scatterplot Smoothing) to smoothen the algorithm.

cannibalize existing-good sales. On the contrary, the average relationship for firms with new-to-market product innovation lies well above the line; sales of a new-to-market product increase the firm's total sales. Instances of cannibalization between new and existing goods is thus less severe with regard to new-to-market product innovation than for new-to-firm product innovation. These observations are consistent with Hypothesis 3. Combining the insights of Figures 5 and 6 suggests that new-to-market product innovation increases a firm's total sales, even with the loss due to cannibalization.

B. *Technological Spillover*

Economics researchers, most notably Arrow (1962), point out that an innovating firm cannot fully appropriate all outcomes of its innovation activities owing to the existence of technological spillover. In contrast to the findings of several studies (e.g., Bloom, Schankerman, and van Reenen 2013), we directly collect self-reported data on technological spillover as extracted from information on a firm's technology acquisitions (i.e., inflows) and technology provisions (i.e., outflows). Of special importance are technology provisions through channels that are less likely to include monetary compensation, such as open-sourcing and consortia participation. If firms do not consider this type of spillover when deciding whether to undertake innovation activities, innovation could be under-supplied by the private sector.

A number of recent studies of endogenous growth theory (e.g., Grossman and Helpman 1991; Aghion and Howitt 1992; Klette and Kortum 2004) and some on dynamic estimation (e.g., Xu 2006) assume the presence of technological spillover arising from firms at the technological frontier through nonmonetary channels. Considering that the firms undertaking new-to-market product innovation are more likely to be situated near the technological frontier, we propose the following hypothesis:

Hypothesis 4: *Firms with new-to-market product innovation are more likely than firms with new-to-firm product innovation to provide their technology through open-sourcing or participation in consortia.*

Among the empirical studies focused on technology inflow, Kaiser (2002) considers incoming spillover effects to examine the relationship between research cooperation and research expenditures. His results indicate that horizontal spillover leads to firms to engage in aggressive investments in innovation through research collaborations. In a similar vein, Branstetter and Sakakibara (2002) examine research consortia using the approach taken by Katz (1986), finding that spillover effects in research consortia have a positive impact on firm performance. These findings suggest the following hypothesis:

Hypothesis 5: *Sales of a new product are greater for firms that acquire technology through consortia than for other firms.*
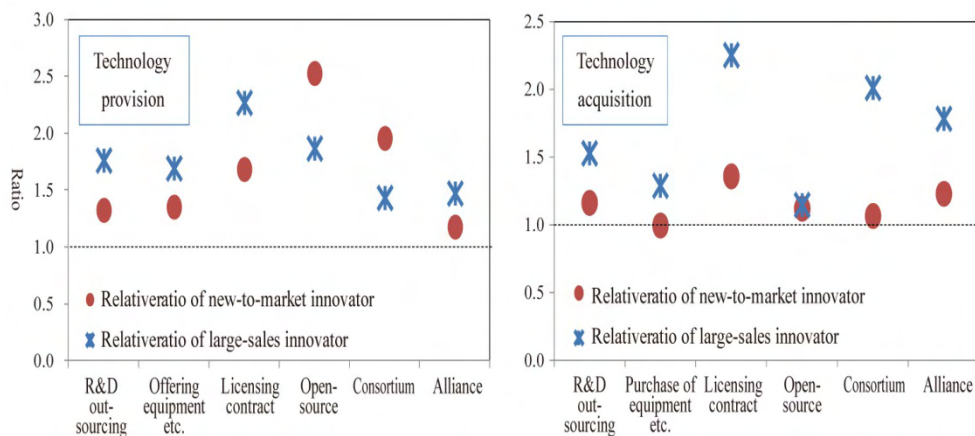
FIGURE 7: TECHNOLOGY ACQUISITION AND PROVISION

Figure 7 summarizes firms' technology acquisition and provision practices based on the information provided by JNIS. Following the Oslo Manual, the figure presents six channels: R&D outsourcing, offering equipment, licensing contracts, outsourcing, consortia, and alliances. The circle and asterisk plotted for each channel in the figure represent the relative firm ratios. The ratios plotted with circles are obtained by dividing the number of firms engaging in the given activity that have new-to-market product innovation by the number of firms engaging in the given activity with new-to-firm innovation. The asterisks refer to the ratio of the number of firms attaining sales at or above the median of the sales distribution (168 million JPY) to the number of firms with sales below the median. While product innovations among those with sales above the median appear to be more common for firms using the channels associated with monetary compensation (e.g., licensing), new-to-market product innovation seems clustered in nonmonetary channels, such as open-sourcing and participation in consortia. This finding is consistent with Hypothesis 4.

The right-hand panel in the figure considers firms' technology acquisition. There is little worth mentioning regarding new-to-market product innovation by means of technology acquisition, but firms with sales above the median tend to acquire technology through licensing and consortia participation in consortia, consistent with Hypothesis 5. Combining this observation with the results shown in the left-hand side of Figure 7 suggests that consortia participation plays a significant role in fostering technological spillover. Indeed, Figure 7 hints that firms with new-to-market product innovation provide their technology to other firms through consortia and that such technological spillover could contribute to higher sales following the introduction of new products.

C. *Other Characteristics of New-to-Market Product Innovation*

The basic analysis of the previous subsections has suggested that new-to-market product innovation leads to improvements in firm performance and exhibits strong technological spillover. This finding implies that public policies which encourage

firms to engage in new-to-market innovation would be justified from a social welfare standpoint. To implement such policies effectively, however, it is necessary to have a deeper understanding of the characteristics of new-to-market product innovation. As such, this subsection focuses on firm characteristics associated with new-to-market product innovation, considering information sources, means of protecting innovation benefits, and public financial support.

1. *Information sources*

Previous studies have examined the relationship between information sources and innovation height. Belderbos, Carree, and Lokshin (2004) examine the relationship between cooperative R&D and firm performance, finding that using information provided by consumers or universities has positive impacts on new product sales and that cooperation with universities likely fosters new-to-market product innovations. Mohnen and Hoareau (2003) also study the degree of firms' interaction between universities and the resulting propensity to generate new-to-market product innovation. However, their results suggest that such interaction does not necessarily result in fruitful outcomes. With a few exceptions,[11] most studies imply that information from universities positively affects innovation novelty, allowing us to summarize this in the following hypothesis:

Hypothesis 6: *Firms with new-to-market product innovation are more likely than those with new-to-firm product innovation to have obtained information from universities for their innovation activities.*

Figure 8 shows the ratios of the different types of firms (innovating and high-selling) utilizing different information sources for their innovation activities. Similar to the definition given in Figure 7, the circles denote the ratios of firms with new-to-market product innovation to firms without among firms using the given information source, and asterisks represent the equivalent for firms with
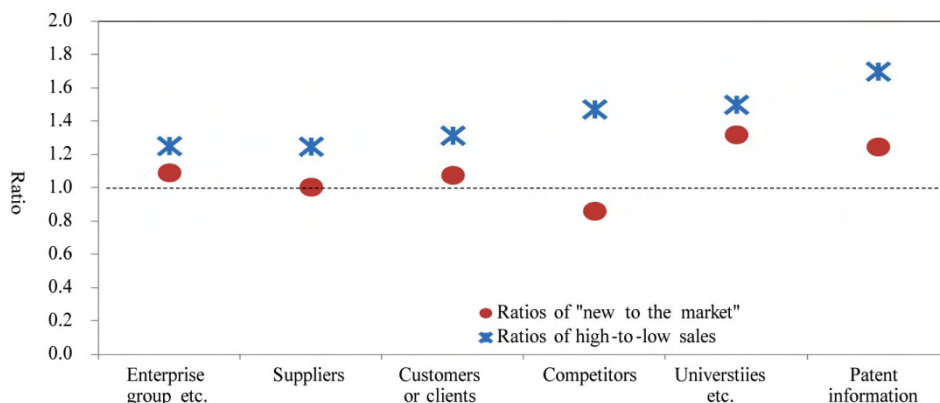

FIGURE 8: INFORMATION SOURCES

---

[11] Monjon and Waelbroeck (2003) suggest that information from universities encourages new-to-firm innovation.

higher-than-median sales of new products. While firms that attain sales at or above the median from product innovation use various information sources, firms with new-to-market product innovation tend to obtain information from universities or patents held by other firms, supporting Hypothesis 6.

2. *Ways of protecting the benefits of innovation*

While it is usually difficult for firms to fully appropriate innovation benefits, they do make partial efforts to protect them through legal processes (e.g., patent protection) or other means, such as the use of trade secrets. In theory, legal means of protection serve to encourage innovation activities by providing firms with a premium for innovation. Among recent empirical studies, Duguet and Lelarge (2006) examined the effectiveness of patent protection for safeguarding firms' potential rewards from product innovation. However, legal means of protection may not always work perfectly (Levin, Klevorick, Nelson, and Winter 1987). As noted in the previous section, there are potential positive spillover from new-to-market product innovation. In view of this, legal means may not effectively protect the profits arising from new-to-market product innovation. As such, we arrive at the following hypothesis:

Hypothesis 7: *Firms with new-to-market product innovation are no more likely than firms with new-to-firm product innovation to use legal protection as opposed to non-legal protection.*

Figure 9 summarizes the ratios of firms used to protect innovation benefits. As before, a circle indicates firms with new-to-market product innovation and an asterisk represents new product sales. While firms with above-median sales from product innovation tend to rely more heavily on legal protection, firms with new-to-market product innovation shows no clear patterns with regard to their use of legal and non-legal means. This finding is consistent with Hypothesis 7, indicating that legal means do not fully protect firms' new-to-market product innovations.
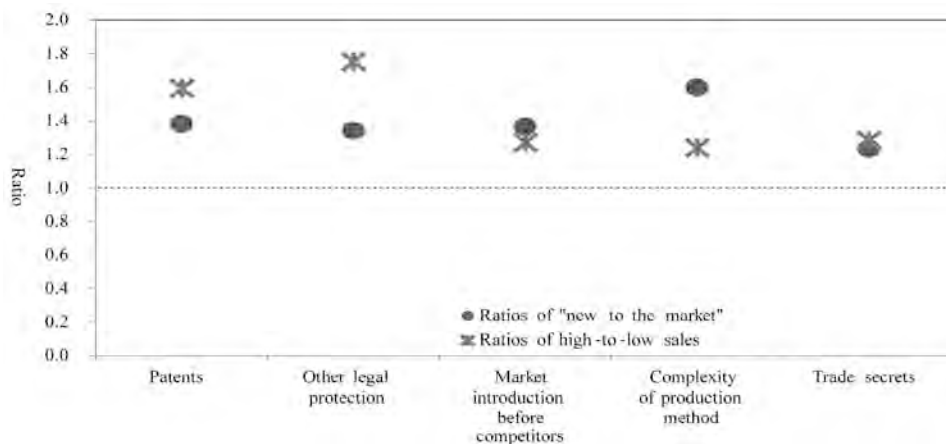

FIGURE 9: Measures for Protecting Innovation Benefits

3. *Public financial support*

Lastly, we examine public financial support for innovation activities. This topic has been well studied in the literature on R&D subsidies and investment. For example, Almus and Czarnitzki (2003) use a matching method to show that R&D subsidies stimulate firms' innovation activities. González, Jaumandreu, and Pazó (2005) also indicate that some firms would not invest in R&D without subsidies and that this does not crowd-out private R&D investment. In addition, other recent studies consider other, non-subsidy forms of public financial support. Finger (2008), for instance, examines the effect of R&D tax credits by considering the interdependence of firms' R&D investments, showing that such tax credits encourage R&D investments by firms in a limited manner.

Meanwhile, among the few studies of the relationship between public financial support and innovation novelty, Mohnen and Hoareau (2003) raise the possibility that interacting with public institutions leads to new-to-market product innovation. If such interaction through channels other than information provision also encourages new-to-market product innovation, public financial support could positively impact innovation height and novelty. Hence, we propose the following hypothesis:

Hypothesis 8: Firms with new-to-market product innovation are more likely than firms with new-to-firm product innovation to receive public financial support.

Figure 10 plots the share of firms with new-to-firm product innovation, indicating whether the firms received public financial support,[12] by firm size.[13]
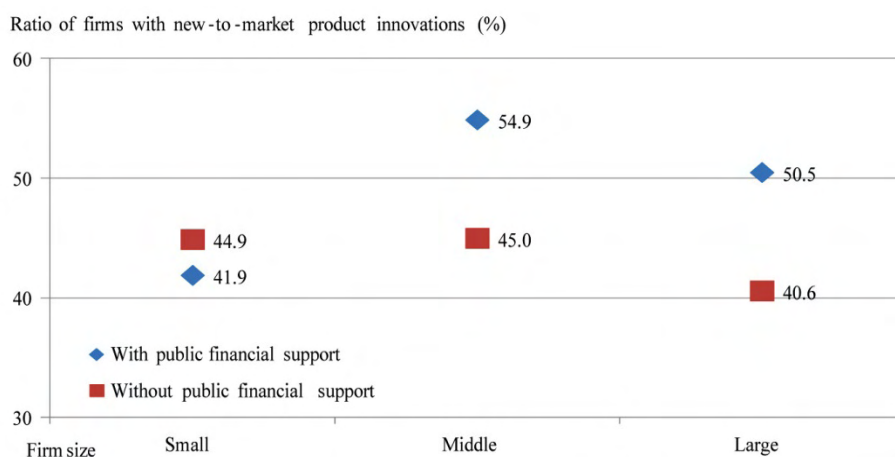

FIGURE 10: Novelty and Public Financial Support, by Firm Size

---

[12]Financial support primarily includes tax credits, subsidies, and loan guarantees.

[13]Small firms have fewer than 50 employees, mid-sized firms have 50–249 employees, and large firms have 250 or more employees.

Among mid- and large-sized firms, a higher share of publicly supported firms produced new-to-market innovations; this is not the case, however, for small-sized firms. Hence, Hypothesis 8 may apply selectively, depending on firm size, perhaps because nonfinancial bottlenecks to new-to-market product innovation exist for smaller firms. For example, small-sized firms are less likely to take advantage of information from universities (Nishikawa, Isogawa, and Ohashi 2010), which may hinder their efforts to conduct new-to-market innovations according to the discussion in Section III.C. In this context, policies that increase interaction between firms and universities may help support innovation among small-sized firms.

IV. Econometric Analysis

The previous section proposed a series of hypotheses on new-to-market product innovation and examined simple statistical correlations in the JNIS data, which were generally consistent with each of the hypotheses. However, drawing conclusions from such casual observations is inadequate owing to omitted variable bias: firm innovation activities and outcomes are affected by numerous factors, many of which are not controlled for in the previous section. Ignoring the endogeneity of some variables of interest could also distort estimation results. To address these challenges, this section first presents an econometric framework (Section IV.A) and subsequently uses it to determine the robustness of our findings presented in the previous section (Section IV.B).

A. *Econometric Model and Estimation*

The model proposed here consists of a system of three sets of equations. The first refers to firm R&D investment. As is well known, R&D expenditures are endogenously determined; any analyses that ignore such endogeneity may suffer from biased estimates. We thus follow the approach taken in the existing literature and add an equation to model R&D expenditures. Among the factors that may affect a firm's R&D expenditures, the consumer demand structure is considered to be a major determinant (e.g., Levin and Reiss 1984). This is sometimes called the demand-pull factor. While CDM base their analysis on the influence of market demand, we control for the market-size effect by using industry dummies as well as a dummy that indicates whether the market size expanded during the survey period.

A second factor that may influence R&D expenditures is technological opportunities (e.g., Rosenberg 1974; Levin and Reiss 1984), or the technology-push factor. To capture this effect, we focus on a firm's technology acquisition by firms (i.e., the inflows of technological spillover, as noted in Section III). Specifically, we create variables reflecting technology acquisitions based on the information available in JNIS; namely, we note which channels a respondent firm used to acquire its technology (shown in the right-hand panel of Figure 7).

We also incorporate information sources into the R&D expenditure equation. Certain past studies, including Belderbos, Carree, and Lokshin (2004), focus on information sources as a means of capturing the inflow of technological spillover.

As shown in Figure 8, JNIS includes information on the information sources relied upon by respondent firms, which we use to create a dummy variable. Besides the demand-pull and technology-push factors, CDM explore what is known as the 'Schumpeterian Hypothesis' by including factors that capture the effects of firm size and market power.[14] Following their approach, we use firm-size dummies, the number of competitors in the domestic market, and a dummy variable that indicates whether the market has undergone product diversification during the survey period. Lastly, we consider public financial support for firms' innovation activities, an issue not addressed in CDM. As described in Section II, a number of studies have sought to identify the effect of public aid on firm innovation. We thus create a dummy variable that indicates whether a firm receives any financial support from local public agencies or the central government.

The second set of equations captures innovation output by firms. As a measure of output, we focus on innovation height or novelty as analyzed by Duguet (2006), and the protection of the innovation benefits for which a proxy is established by CDM, i.e., the number of patent applications. However, for the latter, we do not restrict our attention to patents as firms use various means of protecting their innovation benefits including both legal and non-legal protection, different degrees of the complexity of production methods, and trade secrets—as shown in Figure 9. We therefore construct variables to capture whether a firm uses legal or non-legal means of protection. For the explanatory variables, we use a set of variables similar to that adopted in the first step, adding a firm's R&D expenditures. These are regarded as endogenously determined in the first stage—indeed, many empirical studies, including CDM, consider a firm's R&D investment to be an innovation input. We omit the number of competitors in the domestic market in this stage, just as CDM omit market share from their second stage. In addition to these variables, we use innovation novelty as an explanatory variable for innovation benefit protection (Hypothesis 7).

The third set of equations captures a firm's sales and its technology provision. For the former, we separately consider sales of both new and existing products. This is important in analyses of the economic outcomes of product innovation as such variables can theoretically capture the effects of cannibalization. With regard to the technology provisions by firms, we focus on the channels less likely to be accompanied by monetary compensation by creating a dummy variable that takes the value of one if a firm provides its technology through open sourcing or consortia participation and zero otherwise.

We include three types of explanatory variables in the equations determining product sales and technology provisions. First, we include new-to-market product innovation and the protection of innovation benefits, which are both endogenously determined in the first stage, as mentioned above. Following CDM and Duguet (2006), these innovation outcomes may positively impact firm performance. Second, we use the same explanatory variables identical to those adopted in the second stage as control variables. We thus control for the effects of demand and

---

[14]Much theoretical work has considered whether market concentration encourages firms' innovation activities. The replacement effect (Arrow, 1962) and the efficiency or Schumpeterian effect (Schumpeter, 1943; Gilbert and Newbury, 1982; Reinganum, 1983) are well known. Several empirical studies, including Aghion, Bloom, Blundell, Griffith, and Howitt (2005), have tried to quantify the net impact of these two effects.
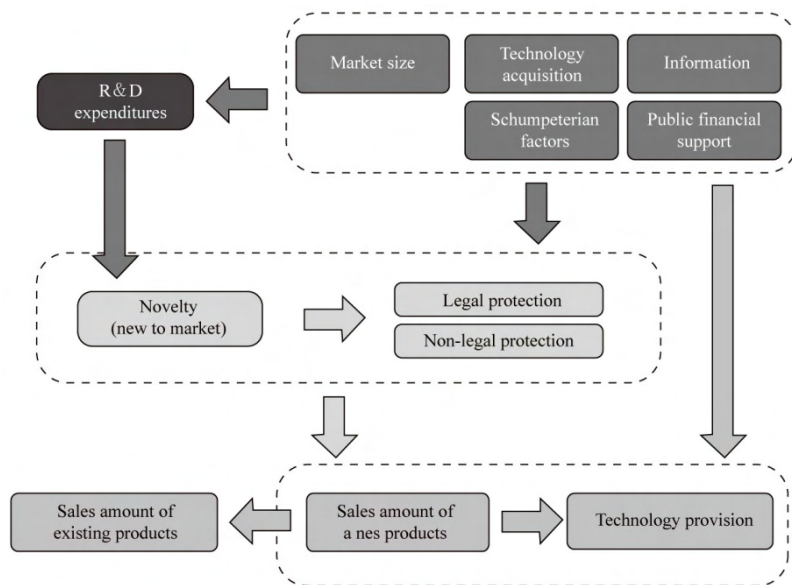
FIGURE 11: OVERVIEW OF THE MODEL

technological conditions, firm size (specifically the number of employees), and product diversification. Third, corresponding to explanatory variables in the third stage of CDM, we consider the acquisition of tangible fixed assets and the number of R&D personnel.[15] In contrast, for the explanatory variables in the equation determining existing products sales, we consider innovation novelty, new product sales, and (as a control variable), the firms' total sales in FY2006. We also include firm-size and industry dummies. With this equation, we aim to quantify the degree of cannibalization and the extent to which innovation novelty affects this. Figure 11 summarizes the structure of the model described above and used to test the hypotheses developed in Section III.

1. *Comparison with the CDM model*

Although our model is based on that of CDM, there are four significant differences. First, we incorporate innovation height, or novelty, into the model. As argued in Section I, such an inclusion is important because new-to-market product innovation is likely to affect firm performance, leading to technological spillover. Second, we consider both legal and non-legal means of protecting innovation benefits. Earlier work, while recognizing that patents do not represent a sufficient means of protecting knowledge (Levin, Klevorick, Nelson, and Winter 1987), has not systematically examined non-legal means. Third, we separately consider firm sales of new and existing products as measures of firm performance. While CDM consider in their second stage the share of a firm's sales that is innovation-related (equivalent to the sum of the firms' sales of new and existing products), such an

---

[15]CDM include physical capital and the portion of employees who are engineers or administrators.

approach may not be adequate to capture cannibalization. Fourth, we consider both the inflow and outflow of technology by using information on the firm's acquisitions and provisions of technology. Most studies, including CDM, do not include outflow in their analytical framework.

2. Estimating equations

Based on the theoretical framework detailed above, we estimate a set of equations for firm i. Equation (1) corresponds to the first part of the model, determining firm's R&D expenditures. Because there are many firms with zero R&D expenditures, we choose to use a Tobit model:

$$R\&D_i^* = x_{1,i}\beta_1 + u_{1,i},$$

$$(1) \qquad R\&D_i = \begin{cases} R\&D_i^* & \text{if } R\&D_i^* > 0, \\ 0 & \text{otherwise,} \end{cases}$$

where $R\&D_i$ represents the firm's R&D expenditures and $x_{1,i}$ includes the dummy variables that capture, respectively, the factors of industry, market expansion, technology acquisition, information sourcing, firm size, product differentiation, and public financial support, along with the number of competitors in the domestic market.

Equations (2), (3), and (4) correspond to the second part of the model. Since the dependent variables are all binary, we choose the following probit models:

$$Novelty_i = \alpha_2 R\&D_i + x_{2,i}\beta 2 + u_{2,i},$$

$$(2) \qquad where\ u_{2,i} \sim N(0,1) \quad and \quad Novelty_i = \begin{cases} 1 & \text{if } Novelty_i^* > 0, \\ 0 & \text{otherwise.} \end{cases}$$

$$Legal_i = \gamma_3 Novelty_i + x_{2,i}\beta_3 + u_{3,i},$$

$$(3) \qquad where\ u_{3,i} \sim N(0,1) \quad and \quad Legal_i = \begin{cases} 1 & \text{if } Legal_i^* > 0, \\ 0 & \text{otherwise.} \end{cases}$$

$$Non\text{-}legal_i = \gamma_4 Novelty_i + x_{2,i}\beta_4 + u_{4,i},$$

$$(4) \qquad where\ u_{4,i} \sim N(0,1) \quad and \quad Non\text{-}legal_i = \begin{cases} 1 & \text{if } Non\text{-}legal_i^* > 0, \\ 0 & \text{otherwise.} \end{cases}$$

in which $Novelty_i$ is equal to one if the product innovation is new to market (and zero otherwise), $legal_i$ is the legal protection dummy, $Non\text{-}legal_i$ is the non-legal protection dummy, and $x_{2,i}$ is similar to $x_{1,i}$ except that it does not include the number of domestic market competitors.[16]

Equations (5) to (7) correspond to the third part of the analytical framework. For the technology provision equation, we estimate the following probit models:

---

[16]We omit the firm's R&D expenditures from Equations (3) and (4) to avoid problems of numerical convergence.

(5) $log(Newsales_i) = \alpha_5 R\&D_i + [Novelty_i, Legal_i, Non\text{-}legal_i]\eta_5 + x_{5,i}\beta_5 + u_{5,i}$

(6) $log(Existingsales_i) = [Novelty_i, Newsales_i, Novelty_i * Newsales_i]\rho_6 + x_{6,i}\beta_5 + u_{6,i}$

(7) $Provision_i^* = \alpha_7 R\&D_i + [Novelty_i, Legal_i, Non\text{-}legal_i]\eta_7 + x_{5,i}\beta_7 + u_{7,i}$

$$where\ u_{7,i} \sim N(0,1)\quad and\quad Provision_i = \begin{cases} 1 & if\ \ Provision_i^* > 0, \\ 0 & otherwise, \end{cases}$$

Here, the variable $Newsales_i$ and $Existingsales_i$ represent the sales of a new product and of existing products, respectively; $Provision_i$ is a dummy capturing technology provision through open sourcing or consortia participation; $x_{5,i}$ includes $x_{2,I}$ plus purchased tangible fixed assets and the number of workers in R&D; and $x_{6,i}$ includes the logarithm of the firm's total sales and the firm size and industry dummies.

3. *Methodology and summary statistics*

We estimate the parameters of this system of equations via maximum likelihood estimation. Estimation samples are restricted to firms that conduct innovation activities and achieve product innovation, which reflects our interest in innovation output, including the height (i.e., novelty) of product innovation. This restriction causes few problems as long as we focus on the economic impact of product innovation conditional on a firm conducting innovation activities and achieving product innovation. Note that CDM also examine only firms achieving innovation.

We omit observations with missing values for any of the models' variables; the characteristics of the omitted firms are similar to those without missing values.[17] The resulting sample size is 539.[18] Table 1 presents summary statistics for the models' variables.

TABLE 1—SUMMARY STATISTICS

		Mean	Std. Dev.
Novelty		47.40%	50.00%
Sales of a new product	(million JPY)	5148.1	53945.3
Sales of existing products	(million JPY)	42354.8	188152.8
R&D expenditure	(million JPY)	4508	41395.2
Firm size			
	Mid-sized	24.90%	43.30%
	Large	62.80%	48.40%
Number of competitors		10.2	7.64
Product differentiation		61.97%	48.57%
Acquisition of tangible fixed assets	(million JPY)	7179.3	47235.0
No. of workers in R&D		202.2	1374.6

(Continued)

---

[17]There is little difference in the average size, age, and industry of the sampled firms. However, our obtained t-test results do not allow us to reject the hypothesis that there is a difference in average sales and firm age between the two subsamples. We also cannot reject the hypothesis of a correlation between the existence of missing values and the firm's industry classification, based on Pearson chi-squared test.

[18]The original sample size was 1,224 before we omitted these observations.

TABLE 1—SUMMARY STATISTICS *(Continued)*

		Mean	Std. Dev.
Information			
	Enterprise group, etc.	77.50%	41.80%
	Suppliers	57.90%	49.40%
	Customers or clients	68.50%	46.50%
	Competitors	36.40%	48.20%
	Private research institutes, etc.	24.20%	42.90%
	Universities, etc.	34.20%	47.50%
	Public research institutes	28.60%	45.20%
	Academic conference, etc.	36.40%	48.20%
	Professional publications, etc.	43.20%	49.60%
	Exhibitions, etc.	53.70%	49.90%
	Patent information	37.50%	48.50%
Technology acquisition			
	Buyout	9.70%	29.60%
	R&D outsourcing	37.00%	48.30%
	Purchase of equipment, etc.	51.30%	50.00%
	Company split-up	5.30%	22.40%
	Licensing contract	20.50%	40.40%
	Open sourcing	13.40%	34.10%
	Consortium	11.70%	32.20%
	Alliance	16.30%	37.00%
	Accepting researchers, etc.	16.30%	37.00%
Technology provision			
	Open sourcing or consortia	11.70%	32.20%
Public financial support		26.20%	44.00%
Protection			
	Legal means	53.80%	49.90%
	Non-legal means	72.00%	45.00%
Observations		539	

We attempt to correct for possible sampling bias via the following method. First, for all firms included in JNIS, we regress a dummy variable indicating whether a given firm is included in our estimation sample on a set of control variables, including the firm's total sales, sales cost, total wages, and firm-size and industry dummies. Then, we calculate the residual for each firm and include these values in Equations (1) to (7) as an additional explanatory variable. The estimation results differ little from the results as reported in the next section.

B. *Estimation Results*

Table 2 shows the results of estimating Equation (1). Specification (1-a) includes all the explanatory variables discussed in Section IV.A. Considering the demand side, market expansion is estimated to be statistically significant, whereas the estimated coefficients on the dummy variables for technology-push factors are mostly insignificant. Two exceptions are technology acquisition through corporate reorganization (e.g., a buyout or split) and open sourcing, both of which positively affect a firm's R&D investment. Schumpeterian factors are estimated to have little effect on a firm's R&D investment, implying that they do not directly determine a firm's innovation activities once both demand-pull and technology-push factors are controlled for. The coefficient on public financial support is significant and positive.

TABLE 2—ESTIMATION RESULTS, EQUATION (1)

		Tobit model Dependent variable: R&D expenditures (million JPY)		
		(1-a)	(1-b)	(1-c)
Market expansion		8275.22**	8124.01**	8135.44**
	(s.e.)	(4020.59)	(4012.51)	(3965.68)
Technology acquisition	Buyout	15914.05**	16204.31**	19139.71***
	(s.e.)	(7053.88)	(6984.60)	(6625.08)
	R&D outsourcing	-2149.15	-2395.67	
	(s.e.)	(4546.19)	(4529.89)	
	Purchase of equipment, etc.	-2119.86	-1931.71	
	(s.e.)	(4211.06)	(4182.13)	
	Company split-up	39097.56***	39021.40***	40387.06***
	(s.e.)	(9164.63)	(9152.60)	(8811.41)
	Licensing contract	828.84	848.65	
	(s.e.)	(5234.19)	(5219.32)	
	Open sourcing	13447.71**	13000.43**	14746.31***
	(s.e.)	(5648.86)	(5619.70)	(5167.44)
	Consortium	5190.82	5197.15	
	(s.e.)	(6238.81)	(6204.72)	
	Alliance	7539.55	7107.43	
	(s.e.)	(5582.68)	(5529.69)	
	Accepting researchers, etc.	2857.23	2606.04	
	(s.e.)	(5195.53)	(5184.03)	
Information	Enterprise group, etc.	-185.12	-609.43	
	(s.e.)	(4735.60)	(4720.39)	
	Suppliers	-2704.37	-3352.89	
	(s.e.)	(4016.86)	(3949.60)	
	Consumers or clients	2703.18	3474.55	
	(s.e.)	(4467.36)	(4417.88)	
	Competitors	1218.17	1059.49	
	(s.e.)	(4205.58)	(4188.76)	
	Private research institutes, etc.	1655.63	1186.53	
	(s.e.)	(4536.11)	(4480.14)	
	Universities, etc.	1234.78	1885.10	
	(s.e.)	(5068.91)	(5022.86)	
	Public research institutes	3732.63	3876.83	
	(s.e.)	(5142.44)	(5120.27)	
	Academic conference, etc.	-5991.11	-5729.08	
	(s.e.)	(5087.50)	(5045.53)	
	Professional publications, etc.	2075.06	1701.04	
	(s.e.)	(4976.04)	(4932.46)	
	Exhibitions, etc.	-5902.77	-5369.79	
	(s.e.)	(4606.41)	(4568.37)	
	Patent information	5822.03	6718.57	
	(s.e.)	(4691.64)	(4613.64)	
Firm size	Mid-sized	5153.42	6686.65	5862.78
	(s.e.)	(7529.56)	(7370.43)	(7303.05)
	Large	9945.24	11271.57*	12464.83*
	(s.e.)	(6957.73)	(6783.30)	(6600.65)
Number of competitors		179.30	123.38	116.50
	(s.e.)	(248.80)	(243.08)	(241.18)
Product differentiation		-1118.27	-1771.30	-2960.48
	(s.e.)	(4078.83)	(4049.63)	(3957.21)
Public financial support		7638.40*	7543.09*	9736.94**
	(s.e.)	(4554.47)	(4488.56)	
Industry dummies		Yes	No	No

Notes: ***, **, and * indicate that the estimate is significant at the 1%, 5%, and 10% level, respectively. "s.e." refers to the standard error.

Specifications (1-b) and (1-c) omit the industry dummies and technological factors with insignificant estimated coefficients in specification (1-a). These results are similar to those of (1-a) except that the coefficient on the large-firm dummy is estimated to be significantly positive. Our results are consistent with the findings of Cohen and Klepper (1996) and Klepper (1996) who argue that firm size has positive impacts on innovation activities.

Table 3 presents the results of estimating Equation (2). Specification (2-a) includes all explanatory variables discussed in Section IV.A. Interestingly, R&D expenditures show no significant impact on the success of new-to-market product innovation, in contrast to the result of Duguet (2006) that there is a positive impact of a firm's formal R&D activities on the degree of innovation novelty. One reason for the difference in results is that Duguet (2006) does not fully control for the effect of demand and technological opportunity, whereas we attempt to do so in the present analysis. While we find no positive impact of market expansion on innovation novelty, some of the coefficients on the technology acquisition and information source indicators are significant. In particular, the indicator for acquiring technology by accepting new researchers and that for doing so via sourcing information from universities both have positive effects on innovation novelty; the latter effect is consistent with Hypothesis 6. Similar to the results of previous studies, universities appear to be influential sources of information for new-to-market innovations.

TABLE 3—ESTIMATION RESULTS, EQUATION (2)

		Probit model Dependent variable: Innovation novelty		
		(2-a)	(2-b)	(2-c)
R&D expenditures		5.04E-06	5.46E-06	8.07E-06
	(s.e.)	(5.24E-06)	(5.19E-06)	(4.97E-06)
Market expansion		0.01	-0.02	0.03
	(s.e.)	(0.13)	(0.13)	(0.12)
Technology acquisition	Buyout	0.390	0.37	
	(s.e.)	(0.24)	(0.24)	
	R&D outsourcing	0.13	0.12	
	(s.e.)	(0.14)	(0.14)	
	Purchase of equipment, etc.	-0.05	-0.07	
	(s.e.)	(0.13)	(0.13)	
	Company split-up	-0.46	-0.49	
	(s.e.)	(0.34)	(0.34)	
	Licensing contract	0.19	0.17	
	(s.e.)	(0.17)	(0.16)	
	Open sourcing	0.06	0.07	
	(s.e.)	(0.19)	(0.19)	
	Consortium	0.28	0.25	
	(s.e.)	(0.20)	(0.20)	
	Alliance	0.18	0.14	
	(s.e.)	(0.18)	(0.18)	
	Accepting researchers, etc.	0.29*	0.28*	0.33**
	(s.e.)	(0.17)	(0.16)	(0.16)

(Continued)

TABLE 3—ESTIMATION RESULTS, EQUATION (2) *(Continued)*

| | | Probit model | | |
| | | Dependent variable: Innovation novelty | | |
		(2-a)	(2-b)	(2-c)
Information	Enterprise group, etc.	0.24	0.21	
	(s.e.)	(0.15)	(0.15)	
	Suppliers	-0.11	-0.07	
	(s.e.)	(0.13)	(0.12)	
	Consumers or clients	0.12	0.09	
	(s.e.)	(0.14)	(0.14)	
	Competitors	-0.16	-0.17	
	(s.e.)	(0.13)	(0.13)	
	Private research institutes, etc.	-0.09	-0.15	
	(s.e.)	(0.15)	(0.14)	
	Universities, etc.	0.39**	0.34**	0.32**
	(s.e.)	(0.16)	(0.16)	(0.15)
	Public research institutes	-0.40**	-0.34**	-0.33**
	(s.e.)	(0.16)	(0.16)	(0.15)
	Academic conference, etc.	-0.15	-0.11	
	(s.e.)	(0.16)	(0.16)	
	Professional publications, etc.	-0.25	-0.26*	-0.26*
	(s.e.)	(0.16)	(0.16)	(0.14)
	Exhibitions, etc.	0.02	0.02	
	(s.e.)	(0.15)	(0.14)	
	Patent information	0.28*	0.30**	0.29**
	(s.e.)	(0.15)	(0.15)	(0.14)
Firm size	Mid-sized	-0.08	-0.02	-0.02
	(s.e.)	(0.23)	(0.23)	(0.22)
	Large	-0.35	-0.25	-0.19
	(s.e.)	(0.22)	(0.21)	(0.20)
Product differentiation		0.18	0.14	0.13
	(s.e.)	(0.13)	(0.13)	(0.12)
Public financial support		-0.11	-0.02	0.00
	(s.e.)	(0.15)	(0.14)	(0.14)
Industry dummies		Yes	No	No
Exogeneity test	(Wald)	0.01	0.02	0.29

Notes: ***, **, and * indicate that the estimate is significant at the 1%, 5%, and 10% level, respectively. "s.e." refers to the standard error.

Lastly, public financial support has no significant impact on new-to-market innovators, leading us to reject Hypothesis 8. This finding might arise partly because nonfinancial factors, including the utilization of information from universities, are essential for fostering new-to-market innovation, as noted in Section III.C.3. Specifications (2-b) and (2-c) omit the industry dummies and technological factors with insignificant coefficients in (2-a); the results are essentially the same for (2-a).

Table 4 reports the estimated coefficients for Equations (3) and (4). [19] Specifications (3-a) and (4-a) include all of the explanatory variables discussed in

---

[19]Unfortunately, the effectiveness of the instruments is rejected for specifications (3-a), (3-b), and (4-b), an issue we leave for future research.

Section IV.A except for the firm's R&D expenditures and industry dummies[20] whereas specifications (3-b) and (4-b) also omit the technological factors with insignificant estimated coefficients. The results indicate that innovation novelty has a significant positive impact on the likelihood of seeking each type of protection (legal and non-legal). The estimated coefficients, however, do suggest that firms with new-to-market product innovation are no more likely than other firms to use legal protection as opposed to non-legal means. Hence, we cannot reject Hypothesis 7.

TABLE 4—ESTIMATION RESULTS, EQUATIONS (3) AND (4)

		Probit model			
Dependent variable:		Legal protection		Non-legal protection	
		(3-a)	(3-b)	(4-a)	(4-b)
Innovation novelty		2.10***	2.07***	2.11***	2.09***
	(s.e.)	(0.07)	(0.07)	(0.09)	(0.08)
Market expansion		0.00	-0.03	0.00	0.01
	(s.e.)	(0.10)	(0.10)	(0.10)	(0.11)
Technology acquisition	Buyout	-0.29		-0.30*	-0.20
	(s.e.)	(0.17)		(0.18)	(0.20)
	R&D outsourcing	-0.09		-0.09	
	(s.e.)	(0.11)		(0.11)	
	Purchase of equipment, etc.	0.05		0.08	
	(s.e.)	(0.10)		(0.11)	
	Company split-up	0.28		0.34	
	(s.e.)	(0.23)		(0.24)	
	Licensing contract	-0.11		-0.11	
	(s.e.)	(0.13)		(0.15)	
	Open sourcing	-0.10		-0.08	
	(s.e.)	(0.14)		(0.14)	
	Consortium	-0.18		-0.21	
	(s.e.)	(0.15)		(0.16)	
	Alliance	-0.09		-0.07	
	(s.e.)	(0.14)		(0.20)	
	Accepting researchers, etc.	-0.18		-0.22*	-0.20
	(s.e.)	(0.14)		(0.13)	(0.14)
Information	Enterprise group, etc.	-0.17		-0.13	
	(s.e.)	(0.12)		(0.14)	
	Suppliers	0.05		0.04	
	(s.e.)	(0.10)		(0.10)	
	Consumers or clients	-0.05		-0.04	
	(s.e.)	(0.11)		(0.14)	
	Competitors	0.11		0.09	
	(s.e.)	(0.10)		(0.13)	
	Private research institutes, etc.	0.09		0.10	
	(s.e.)	(0.11)		(0.12)	
	Universities, etc.	-0.20		-0.24	
	(s.e.)	(0.14)		(0.15)	
	Public research institutes	0.26**	0.17	0.31*	0.29*
	(s.e.)	(0.13)	(0.12)	(0.17)	(0.15)

(Continued)

---

[20]We omit these variables in order to avoid a numerical convergence problem.

TABLE 4—ESTIMATION RESULTS, EQUATIONS (3) AND (4) *(Continued)*

	Dependent variable:	Probit model			
		Legal protection		Non-legal protection	
		(3-a)	(3-b)	(4-a)	(4-b)
Information	Academic conference, etc.	0.12		0.10	
	(s.e.)	(0.12)		(0.12)	
	Professional publications, etc.	0.22*	0.15	0.22*	0.18
	(s.e.)	(0.12)	(0.11)	(0.13)	(0.12)
	Exhibitions, etc.	0.01		0.01	
	(s.e.)	(0.11)		(0.11)	
	Patent information	-0.16		-0.22	
	(s.e.)	(0.14)		(0.13)	
Firm size	Mid-sized	0.10	0.16	0.01	-0.03
	(s.e.)	(0.20)	(0.19)	(0.18)	(0.18)
	Large	0.30	0.33*	0.19	0.13
	(s.e.)	(0.20)	(0.20)	(0.16)	(0.17)
Product differentiation		-0.11	-0.11	-0.10	-0.04
	(s.e.)	(0.10)	(0.10)	(0.10)	(0.11)
Public financial support		0.01	-0.03	0.01	-0.03
	(s.e.)	(0.11)	(0.11)	(0.11)	(0.11)
Industry dummies		No	No	No	No
Exogeneity test	(Wald)	8.54***	31.34***	1.58	9.17***

Notes: ***, **, and * indicate that the estimate is significant at the 1%, 5%, and 10% level, respectively. "s.e." refers to the standard error.

Table 5 reports the results of estimating Equation (5). We omit the technological variables from these specifications because otherwise all estimated coefficients become insignificant.[21] Specifications (5-a) and (5-b) include the logarithms of the value of tangible fixed assets acquired and of the number of workers in R&D with and without industry dummies, respectively, whereas specifications (5-c) and (5-d) do not.

The results of estimating specification (5-a) indicate that new-to-market product innovation has a significant positive effect on new product sales, which is consistent with Hypothesis 1. This implies that new-to-market product innovation could help firms stave off severe competition. In contrast, the coefficient on legal protection is estimated to be negative: legal means of protecting the benefits of innovation are not shown to affect firm performance in terms of innovation-related sales in this case. The other estimates show that firms with many employees, larger numbers of R&D workers, and higher values of tangible fixed assets tend to have greater sales from product innovation for those innovations that meet or surpass the median sales distribution.

The results for specification (5-b) are similar to those of (5-a) except that the coefficient on public financial support is estimated to be significantly negative. However, it is likely that this is capturing the difference in the market environment, as specification (5-b) omits the industry dummies.

---

[21]Hence, Hypothesis 5 would not be supported here, in that we find little evidence that technology acquired through consortia directly affects the sales of a new product.

TABLE 5—ESTIMATION RESULTS, EQUATION (5)

		Linear model Dependent variable: Sales of a new product (logarithm)			
		(5-a)	(5-b)	(5-c)	(5-d)
Innovation novelty		1.26*	1.26	0.95	0.94
	(s.e.)	(0.73)	(0.78)	(0.72)	(0.77)
Legal protection		-2.13***	-2.19***	-0.28	-0.28
	(s.e.)	(0.82)	(0.83)	(0.74)	(0.73)
Non-legal protection		1.10	1.47	1.49	1.78*
	(s.e.)	(0.95)	(1.01)	(0.92)	(0.98)
Market expansion		0.21	0.210	0.53***	0.54***
	(s.e.)	(0.19)	(0.19)	(0.18)	(0.18)
Firm size	Mid-sized	1.20***	1.13***	1.73***	1.71***
	(s.e.)	(0.38)	(0.38)	(0.37)	(0.38)
	Large	2.04***	2.00***	3.47***	3.45***
	(s.e.)	(0.42)	(0.41)	(0.40)	(0.40)
Product differentiation		0.04	0.06	-0.08	-0.09
	(s.e.)	(0.19)	(0.19)	(0.18)	(0.19)
Public financial support		-0.22	-0.34*	-0.33*	-0.44**
	(s.e.)	(0.20)	(0.20)	(0.20)	(0.20)
Acquisition of tangible fixed assets	[logarithm]	0.28***	0.31***		
	(s.e.)	(0.06)	(0.06)		
				1.07E-05***	1.09E-05***
	(s.e.)			(2.78E-06)	(2.83E-06)
No. of workers in R&D	[logarithm]	0.58***	0.55***		
	(s.e.)	(0.09)	(0.09)		
				1.14E-04*	1.12E-04
	(s.e.)			(6.75E-05)	(6.95E-05)
Industry dummies		Yes	No	Yes	No
Exogeneity test	(Sargan)	26.04	24.32	35.80**	32.16**

Notes: ***, **, and * indicate that the estimate is significant at the 1%, 5%, and 10% level, respectively. "s.e." refers to the standard error.

Table 6 shows the results of estimating Equation (6). Specifications (6-a) and (6-b) adopt the specification described in Section IV.A.2 with and without industry dummies, respectively, while specifications (6-c) and (6-d) include the logarithm of the sales of a new product.

The results of specification (6-a) indicate that new product sales have a significant negative effect on those of existing products. This is consistent with the view that a new product cannibalizes a part of the sales of a firm's existing products, consistent with Hypothesis 2. In contrast, the coefficient on the interaction term for innovation novelty and new product sales is significant and positive, nearly cancelling out the cannibalization term. Hence, we can interpret this finding as indicating that the cannibalization effect is attenuated by innovation novelty, which is consistent with Hypothesis 3.

The results of specification (6-b) are similar to those of (6-a). In specifications (6-c) and (6-d), the coefficients on new product sales and the interaction term are estimated as insignificant, although their signs are the same as in (6-a).

TABLE 6—ESTIMATION RESULTS, EQUATION (6)

		Linear model Dependent variable: Sales of existing products (logarithm)			
		(6-a)	(6-b)	(6-c)	(6-d)
Innovation novelty		-0.03	-0.05	-0.09	-0.11
	(s.e.)	(0.09)	(0.09)	(0.35)	(0.36)
Sales of a new product		-1.12E-05**	-1.21E-05**		
	(s.e.)	(5.55E-06)	(5.72E-06)		
	[logarithm]			-0.07	-0.08
	(s.e.)			(0.05)	(0.05)
Innovation novelty * sales of a new product		1.14E-05**	1.23E-05**		
	(s.e.)	(5.74E-06)	(5.94E-06)		
	[logarithm]			0.02	00.02
	(s.e.)			(0.06)	(0.06)
Total sales	[logarithm]	0.99***	1.00***	1.02***	1.03***
	(s.e.)	(0.02)	(0.02)	(0.03)	(0.03)
Firm size	Mid-sized	0.04	0.03	0.07	00.07
	(s.e.)	(0.06)	(0.06)	(0.06)	(0.06)
	Large	0.03	0.02	0.10	00.090
	(s.e.)	(0.08)	(0.08)	(0.07)	(0.07)
Industry dummies		Yes	No	Yes	No
Exogeneity test	(Sargan)	24.38	22.17	29.51	27.09

Notes: ***, **, and * indicate that the estimate is significant at the 1%, 5%, and 10% level, respectively. "s.e." refers to the standard error.

TABLE 7—ESTIMATION RESULTS, EQUATION (7)

		Linear model Dependent variable: Technology provision through open sourcing or consortia			
		(7-a)	(7-b)	(7-c)	(7-d)
Innovation novelty		2.29**	2.09**	2.52**	2.25**
	(s.e.)	(0.93)	(0.82)	(1.23)	(1.04)
Legal protection		-1.11	-1.01	-1.17	-1.05
	(s.e.)	(1.06)	(0.97)	(1.12)	(1.00)
Non-legal protection		0.28	0.58	0.28	0.63
	(s.e.)	(0.98)	(0.98)	(1.07)	(1.08)
Market expansion		-0.04	-0.03	-0.03	-0.02
	(s.e.)	(0.12)	(0.11)	(0.13)	(0.12)
Firm size	Mid-sized	0.19	0.13	0.20	0.16
	(s.e.)	(0.30)	(0.27)	(0.35)	(0.33)
	Large	0.53	0.41	0.60	0.48
	(s.e.)	(0.38)	(0.31)	(0.50)	(0.43)
Product differentiation		-0.10	-0.09	-0.12	-0.10
	(s.e.)	(0.12)	(0.12)	(0.14)	(0.13)
Public financial support		0.17	0.08	0.19	0.09
	(s.e.)	(0.15)	(0.12)	(0.17)	(0.14)
Acquisition of tangible fixed assets	[logarithm]	-0.02	0.00		
	(s.e.)	(0.04)	(0.04)		
				-8.14E-07	-2.77E-07
	(s.e.)			(2.16E-06)	(1.91E-06)
No. of workers in R&D	[logarithm]	0.05	0.02		
	(s.e.)	(0.08)	(0.08)		
				6.20E-06	2.59E-07
	(s.e.)			(4.74E-05)	(4.40E-05)
Industry dummies		Yes	No	Yes	No
Exogeneity test	(Sargan)	7.65	9.20	6.30	8.06

Notes: ***, **, and * indicate that the estimate is significant at the 1%, 5%, and 10% level, respectively. "s.e." refers to the standard error.

Finally, Table 7 includes the estimates for Equation (7). We omit the technological variables from these specifications because they are all estimated to be insignificant. Specifications (7-a) and (7-b) include the logarithms of the value of tangible fixed assets acquired and of the number of workers in R&D with and without industry dummies, respectively, while specifications (7-c) and (7-d) do not include these variables. For all specifications, the coefficient on innovation novelty is estimated as significant and positive. This implies that a firm with new-to-market product innovations are more likely to provide their technology through open sourcing and/or consortia, which is consistent with Hypothesis 4. Hence, the technological spillover arising from novel product innovation are more likely to occur through channels that seldom entail monetary compensation.

V. Conclusion

This study has focused on the degree to which new-to-market product innovation influences firm performance (i.e., sales of new and existing products), technological spillover, and other related characteristics. We proposed eight hypotheses and tested them through empirical analysis of JNIS data from April 2006 to March 2009. Our results are generally consistent with the hypotheses. We found that innovators tend to achieve higher sales from new-to-market product innovations and are less likely to suffer from cannibalization of existing sales. Moreover, new-to-market product innovation tends to result in knowledge spillover to other firms through channels that do not normally assume monetary compensation—i.e., consortia and open sourcing. As is always the case with any empirical research, these empirical results of the paper should be taken cautiously; in particular, because the paper's estimates could be subject to weak instruments. Further studies on this line warrants fruitful research.

Considering the policy implications of our findings, the result that new-to-market product innovation significantly improves firm performance and is associated with technological spillover suggests that policy interventions promoting such innovation may be beneficial to society. Our empirical results show that firms with new-to-market product innovation are more likely to use information from universities, and less likely to rely on legal protection. However, we also note that public financial support may not always stimulate new-to-market product innovation, especially for small-sized firms. How to better support small-sized firms to work with universities may be an important policy challenge, which, if solved, would encourage more widespread innovation.

This paper has focused on the Japanese experience owing to information availability. While our findings are generally comparable to the French experience, as analyzed in Duguet (2010), it would be interesting to compare these results to the South Korean experience, where product innovation is much more active than in either Japan or France, as shown in Figures 1 and 2. Collaboration between Korean and Japanese researchers to match the Korean National Innovation Survey with the JNIS might yield research and policy insights useful to not only these two countries but also other Asian economies.

REFERENCES

Aghion, P. and P. Howitt. 1992. "A Model of Growth through Creative Destruction." *Econometrica* 60: 323–351.

Aghion, P., N. Bloom, R. Blundell, R. Griffith and P. Howitt. 2005. "Competition and Innovation: An Inverted-U Relationship." *Quarterly Journal of Economics* 120: 701–728.

Almus, M. and D. Czarnitzki. 2003. "The Effects of Public R&D Subsidies on Firms' Innovation Activities: The Case of Eastern Germany." *Journal of Business & Economic Statistics* 21: 226–36.

Arrow, K. 1962. "Economic Welfare and the Allocation of Resources for Invention." In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, edited by Universities-National Bureau, UMI, Princeton.

Arundel, A., C. Bordoy and M. Kanerva. 2008. "Neglected Innovators: How Do Innovative Firms that Do Not Perform R&D Innovate?" INNO-Metrics Thematic Paper.

Arundel, A. and H. Hollanders. 2005. "EXIS: An Exploratory Approach to Innovation Scoreboards." Brussels, European Commission, DG Enterprise.

Barlet, C., E. Duguet, D. Encaoua and J. Pradel. 1998. "The Commercial Success of Innovation: an Econometric Analysis at the Firm Level in French Manufacturing." *Annales d'Economie et de Statistique* 49–50: 457–78

Belderbos, R., M. Carree and B. Lokshin. 2004. "Cooperative R&D and Firm Performance." Research Policy 33: 1477–1492.

Bloom, N., M. Schankerman and J. V. Reenen. 2013. "Identifying Technology Spillovers and Product Market Rivalry." *Econometrica* 81 (4): 1347–1393.

Branstetter, L. G. and M. Sakakibara. 2002. "When Do Research Consortia Work Well and Why? Evidence from Japanese Panel Data." *American Economic Review* 92: 143–159.

Chudnovsky, D., A. López and G. Pupato. 2006. "Innovation and Productivity in Developing Countries: A Study of Argentine Manufacturing Firms' Behavior (1992-2001)." Research Policy 35: 266–288.

Cohen, W. M. and S. Klepper. 1996. "Firm Size and the Nature of Innovation within Industries: The Case of Process and Product R&D." *Review of Economics and Statistics* 78: 232–243.

Crépon, B., E. Duguet and J. Mairesse. 1998. "Research, Innovation and Productivity: An Econometric Analysis at the Firm Level." *Economics of Innovation and New Technology* 7: 115–158.

De Loecker, J. 2011. "Product Differentiation, Multiproduct Firms, and Estimating the Impact of Trade Liberalization on Productivity." *Econometrica* 79: 1407–1451.

Duguet, E. 2006, "Innovation Height, Spillovers and TFP Growth at the Firm Level: Evidence from French Manufacturing." *Economics of Innovation and New Technology* 15: 415–442.

Duguet, E. and C. Lelarge. 2006. "Does Patenting Increase the Private Incentives to Innovate? A Microeconometric Analysis." Working Papers 2006-09, Centre de Recherche en Economie et Statistique.

Finger, S. R. 2008. *An Empirical Analysis of R&D Competition in the Chemicals Industry*, University of South Carolina.

Gilbert, R. and D. Newbery. 1982. "Preemptive Patenting and the Persistence of Monopoly." *American Economic Review* 72: 514–526.

González, X., J. Jaumandreu and C. Pazó. 2005. "Barriers to Innovation and Subsidy Effectiveness." *Rand Journal of Economics* 36: 930–950.

Griffith, R., E. Huergo, J. Mairesse and B. Peters. 2006. "Innovation and Productivity across Four European Countries." Oxford Review of Economic Policy 22: 483–498.

Griliches, Z. 1992. "The Search for R&D Spillovers." *Scandinavian Journal of Economics* 94: 29–47.

Grossman, G. M. and E. Helpman. 1991. "Quality Ladders in the Theory of Growth." *Review of Economic Studies* 58: 43–61.

Isogawa, D. and K. Nishikawa, and H. Ohashi. 2012. "New-to-Market Product Innovation and Firm Performance: Evidence from a Firm-level Innovation Survey in Japan." 12-E-077,

RIETI.

Jefferson, G. H., B. Huamao, G. Xiaojing and Y. Xiaoyun. 2006. "R&D Performance in Chinese Industry." *Economics of Innovation and New Technology* 15: 345–366.

Kaiser, U. 2002. "An Empirical Test of Models Explaining Research Expenditures and Research Cooperation: Evidence for the German Service Sector." *International Journal of Industrial Organization* 20: 747–774.

Katz, M. L. 1986. "An Analysis of Cooperative Research and Development." *RAND Journal of Economics* 17: 527-43

Klepper, S. 1996. "Entry, Exit, Growth, and Innovation over the Product Life Cycle." *American Economic Review* 86: 562–583.

Klette, T. J. and S. Kortum. 2004. "Innovating Firms and Aggregate Innovation." *Journal of Political Economy* 112: 986–1018.

Levin, R. C., A. K. Klevorick, R. R. Nelson and S. G. Winter. 1987. "Appropriating the Returns from Industrial Research and Development." *Brookings Papers on Economic Activity* 18: 783–832.

Levin, R and P. C. Reiss. 1984. "Tests of a Schumpeterian Model of R&D and Market Structure," In *R&D, Patents and Productivity*, edited by Z. Griliches, Cicago: Cicago University Press.

Mairesse, J. and P. Mohnen. 2010. "Using innovations surveys for econometric analysis." In *Handbook of the Economics and Innovation*, Vol 2, edited by B. H. Hall and N. Rosenberg, Elsevier, Amsterdam and New York.

Mohnen, P. and C. Hoareau. 2003. "What Type of Enterprise Forges Close Links with Universities and Government Labs? Evidence from CIS 2." *Managerial and Decision Economics* 24: 133–145.

Monjon, S. and P. Waelbroeck. 2003. "Assessing Spillovers from Universities to Firms: Evidence from French Firm-Level Data." *International Journal of Industrial Organization* 21: 1255–1270.

Nishikawa, K., D. Isogawa and H. Ohashi. 2010. "The Second Japanese National Innovation Survey: Results and Implications." NISTEP DISCUSSION PAPER 70, NISTEP.

NISTEP. 2010. Report on Japanese National Innovation Survey 2009, NISTEP REPORT 144, NISTEP.

OECD. 1992. *Oslo Manual*, 1st editions, Paris, Frnace: OECD.

OECD. 1996. *Oslo Manual*, 2nd editions, Paris, Frnace: OECD.

OECD. 2005. *Oslo Manual*, 3rd editions, Paris, Frnace: OECD.

OECD. 2009. *Innovation in Firms*, OECD Publishing.

Pakes, A. 1986. "Patents as Options: Some Estimates of the Value of Holding European Patent Stocks." *Econometrica* 54: 755–784.

Petrin, A. 2002. "Quantifying the Benefits of New Products: The Case of the Minivan." *Journal of Political Economy* 110: 705–729.

Reinganum, J. 1983. "Uncertain Innovation and the Persistence of Monopoly" *American Economic Review* 73: 61–66.

Rosenberg, N. 1974. "Science, Invention and Economic Growth." *Economic Journal* 84: 90–108.

Schumpeter, J. 1943. *Capitalism, Socialism and Democracy*, London: Allen Unwin.

Smith, K. 2005. "Measuring Innovation." In *The Oxford Handbook of Innovation*, edited by Fagerberg, J., D. C. Mowery, and R. R. Nelson, Oxford University Press, New York.

Spence, M. 1984. "Cost Reduction, Competition, and Industry Performance." Econometrica 52: 101–122.

Trajtenberg, M. 1989. "The Welfare Analysis of Product Innovation, with an Application to Computed Tomography Scanners." Journal of Political Economy 97: 444–479.

Van Leeuwen, G. and L. Klomp. 2006. "On the Contribution of Innovation to Multi-Factor Productivity Growth." *Economics of Innovation and New Technology* 15: 367–390.

Xu, Y. 2006. "Structural Empirical Model of R&D, Firm Heterogeneity, and Industry Evolution." Working Paper, Pennsylvania State University.

R&D, Innovation and Productivity:
The Role of Public Support[†]

By AMANI ELNASRI, KEVIN J. FOX[*]

Research and innovation are widely agreed to be major driving forces behind long-term productivity and economic growth. However, the relationships have proven to be difficult to quantify. We make reference to the international literature and draw on recent research for Australia to advance our understanding of these relationships. Particular focus is on assessing the impact of publically financed R&D on productivity. The conclusions have implications for government innovation policies, providing insight into possible productivity gains from funding reallocations. Specifically, the findings suggest that government research agencies and higher education are areas in which investment leads to more potential productivity gains.

The role of government funding in supporting R&D and innovation has been a topic of persistent interest in both academic and policy circles. Much of this interest derives from the perceived, yet often unreliably quantified, relationship between R&D, innovation and productivity growth, which in turn is a significant contributor to long-term economic growth and well-being.

Productivity growth, as per the standard statistical agency definition, is the ratio of output growth to input growth, that is, the amount of growth in output that cannot be explained by the growth in measured inputs. Labour productivity is

based solely on labour inputs (e.g., hours worked to produce the outputs), whereas multifactor productivity (MFP) takes into account the multiple inputs used in production (e.g., labour, capital and land).[1]

The contribution to economic growth through resources utilisation is limited by the finite nature of resources; hence, sustained economic growth in the long term has to come from productivity enhancements. Many possible sources of productivity growth have been proposed and examined extensively in the literature; see, e.g., Rosenberg (1963, 1981), Schmookler (1966), Griliches (1998), Diewert (2001), Isaksson (2007), Wong *et al.* (2007), Hall and Rosenberg (2010), Soames *et al.* (2011) and Syverson (2011). The literature regards investments in research and innovation (such as information and communication technology (ICT), R&D, skills development, design and organisational improvements and other types of intangible assets) as central drivers of productivity; they create more efficient services and production processes, more effective workplace organisation and open up new markets (Hall 2011, Aghion *et al.* 2009, Gorodnichenko *et al.* 2010, Yaşar and Morrison Paul 2012).

Over the last few decades, productivity growth has played a key part in the growth of the Australian economy, with a particularly notable and well-documented role during the mid-1990s. This is generally attributed to microeconomic reform and the uptake of information and communications technology (ICT). However, there has been recent concern in Australia and other developed economies about the apparent slowdown in innovation and productivity growth; see, e.g., Parham (2012) and Connolly and Gustafsson (2013) for Australia, and Gordon (2012) and Phelps (2013) for the U.S. To illustrate the source of this concern, Figure 1 plots labour productivity for OECD countries, along with the OECD average, over the periods 1995-2004 and 2005-2012.[2]
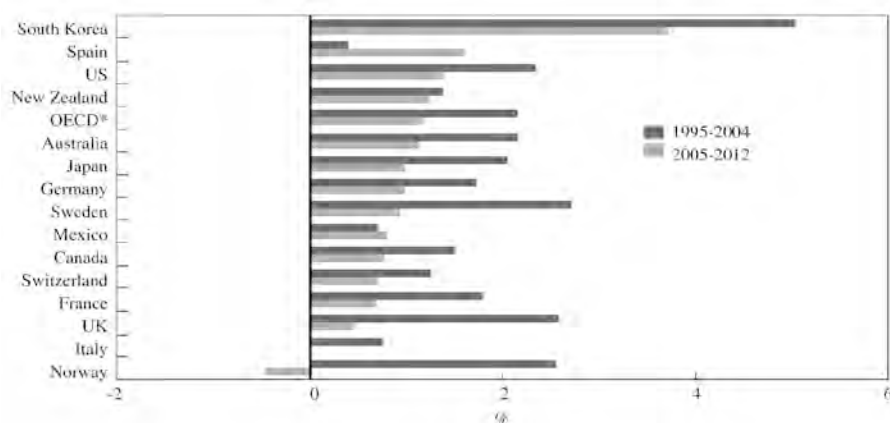

FIGURE 1. LABOUR PRODUCTIVITY GROWTH, REAL GDP PER HOUR WORKED, ANNUAL AVERAGE

---

[1] MFP is sometime called total factor productivity (TFP). Many statistical agencies prefer the MFP terminology, as "total" factor productivity could be inaccurately interpreted as implying that all factors (i.e. inputs) related to production have been accounted for in the analysis.

[2] From a speech by Dr. Phillip Lowe, Deputy Governor, Reserve Bank of Australia: "Demographics, Productivity and Innovation," the Sydney Institute, Sydney, 12 March 2014. http://www.rba.gov.au/speeches/2014/sp-dg-120314.html

Real gross domestic product (GDP) as a ratio to hours worked is a rough but standard measure of labour productivity growth.[3] As labour productivity is a key determinant of wages, this pattern of generally lower productivity in the more recent period raises the question of whether or not this is driven simply by macroeconomic conditions, or if there are microeconomic policy responses which may encourage innovation and entrepreneurial effort to again achieve the productivity performance of the past.[4]

This paper reviews the productivity performance of Australia, and examines the role that public support may have in fostering higher future productivity growth through funding support for R&D and innovation.

I. Productivity Performance: The Australian Experience

For a better understanding of the productivity performance of Australia, it is useful to refer to the detailed Estimates of Industry Multifactor Productivity produced by the Australian Bureau of Statistics (ABS). These take into account additional inputs, in particular, capital and land, and adjust labour for compositional changes; see ABS (2007, 2013). These accounts report annual results for sixteen "market" (i.e. non-government) sectors of the economy. Here, the focus will be on the original twelve industries (ABS 2007) for which the longest time series is available.
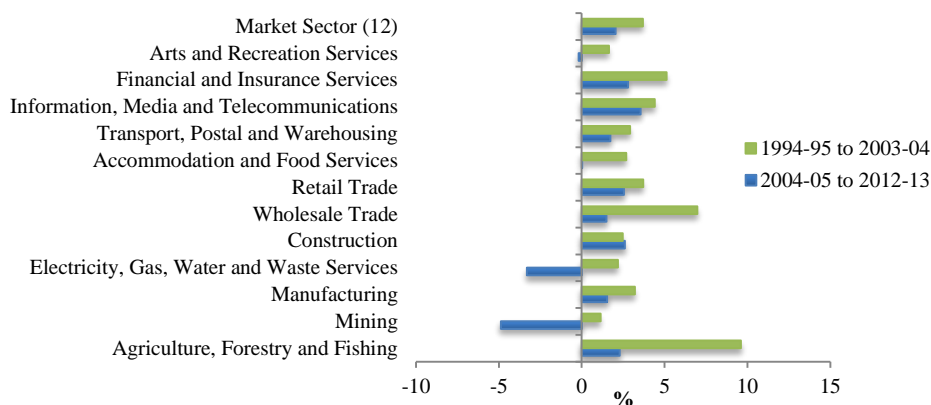

FIGURE 2. LABOUR PRODUCTIVITY GROWTH SLOWDOWN

Notes: Annual average growth between 1994–95 to 2003–04 and 2004–05 to 2011–13. Derived from ABS Cat. No. 5260.0.55.002 - Estimates of Industry Multifactor Productivity, 2012-13, Table 6. Labour productivity indexes, Gross value added per hour worked.

---

[3]Note that by using hours worked as the labour measure, there is no adjustment for variations in work intensity or changes in the composition of the labour force due to education and training; such adjustments to labour input may be of interest for an analysis of productivity, but they require additional assumptions and more data, posing problems for the internationally comparability of results.

[4]While Gordon (2012) and Phelps (2013) have been pessimistic in their assessment of the future of innovation and productivity, it is worth noting the following from Griliches (1988), commenting on an earlier productivity slowdown: "But what about the evidence of a decline in "inventiveness" ....?" "I interpret most of the proffered evidence as reflecting the impact of reduced aggregate demand and less favourable economic prospects for inventive activity in the late 1970s, rather than as the result of technological springs running dry."

First, using the labour productivity series from these accounts, it is possible to see the productivity decline by sector by comparing the average productivity growth from 1994-95 to 2003-04 to that from 2004-05 to 2012-13, as plotted in Figure 2.

It is clear that there was a significant slowdown in productivity growth for all sectors except for the construction sector.

From the multifactor productivity statistics from the ABS accounts for these industries over the period of 2003-04 to 2012-13, the level of market-sector multifactor productivity declined by around 5 percent. Given the importance of both labour and multifactor productivity in determining living standards in the long run, such periods of declining productivity are of significant public policy concern.

To provide further insight, Figure 3 plots the multifactor productivity performance for each of the twelve core market-sector industries, as well as for the aggregate of the twelve market sectors, "market-sector" (12), over the period of 1989-90 to 2012-13. Although market-sector productivity grew by 16 percent over this period, there have been significantly different experiences over time and across industries; mining is 35 percent less productive in 2012-13 than in 1989-90, while agriculture, forestry and fishing were 72 percent more productive, with most of the productivity gains coming before 2004-05.
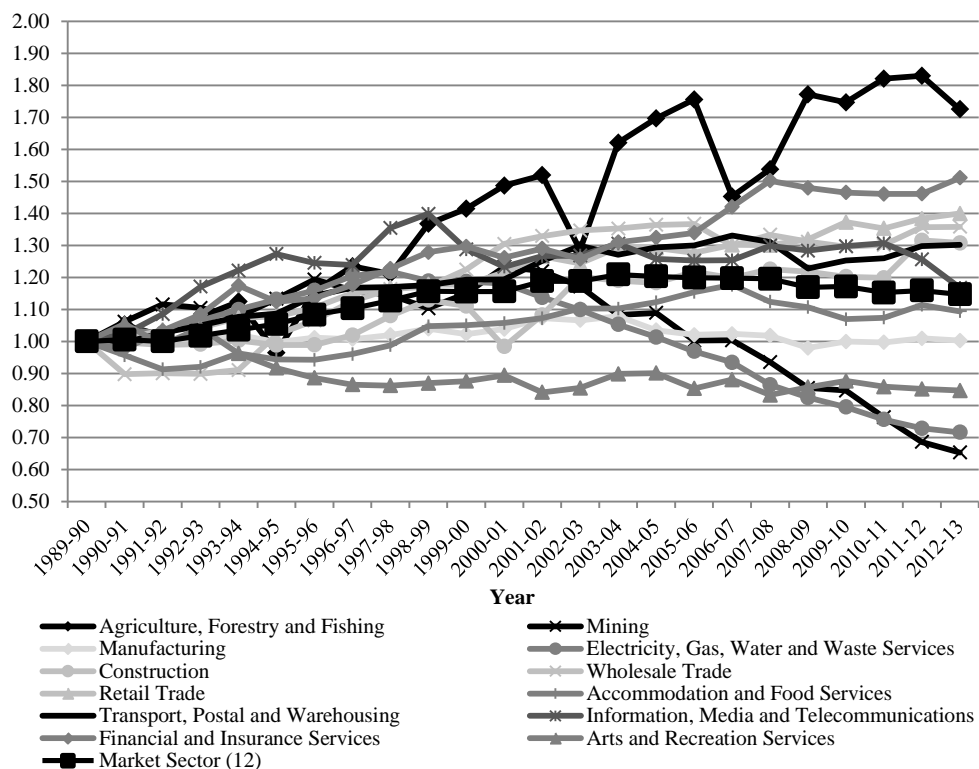

FIGURE 3. MARKET-SECTOR PRODUCTIVITY INDEXES

Source: ABS Cat. No. 5260.0.55.002 - Estimates of Industry Multifactor Productivity, 2012-13, Table 1. Gross value added based multifactor productivity indexes, quality-adjusted hours worked basis.

Much of this dispersion in productivity performance can be explained. For example, the mining industry has made long-term investments in infrastructure, which take years to complete, and more time must elapse before they result in higher levels of output. The electricity, gas, water and waste services industry also experienced a significant decline in productivity over the period (28 percent). This can be partially explained by the electricity sector making catch-up investments in infrastructure following privatisation, without corresponding increases in outputs; some commentators have suggested that this was "gold plating" on the part of the networks. Such investments do not immediately result in increased production and therefore have a downward impact on annual productivity figures. As might be expected from these examples, labour productivity growth (on an hours-worked basis) generally paints a more positive picture, with 76 percent growth over the same period for the market sector (12), although labour productivity in mining has fallen by almost 100 percent since the peak in 2001-02, reflecting the large increase in employment in this sector without, however, a corresponding increase in output.

Other factors may have also contributed to the mixed productivity performance over time and over sectors. Reducing trade barriers, increasing competition and privatising large public-sector organisations may have had productivity impacts on some sectors more than others. In addition, improvements in public infrastructure, changes in public support for R&D, unmeasured quality changes in outputs, workplace relations, new regulation and legislation, and a possible slide in Australia's take-up of productivity-enhancing technologies all may have had differential effects on sectors. See Connolly and Gustafsson (2013)[5] and Parham (2012),[6] two recent studies that assessed some possible explanations of the recent productivity performance.

With such potentially diverse contributing factors, there are obvious complexities in disentangling the influences on productivity at this level, which in turn impedes an analysis of the fundamental drivers of productivity. A better understanding of the transmission of public policy and innovation through to measured productivity growth is thus important for informing effective innovation policy.

II. Innovation and Productivity

While there are many possible influences on productivity, innovation is recognised as being key to increasing productivity in the economy. Productivity has been shown to be positively correlated with innovation performance.[7] The OECD

---

[5]"The current labour-intensive mining investment phase is beginning to wind down and is expected to be followed over the period ahead by a substantial pick-up in mining output, which should boost measured productivity in the mining industry and the economy more generally." "Looking ahead, there is reason to believe that productivity growth will return to being the main driver of improved living standards." Connolly and Gustafsson (2013).

[6]Parham (2012) considers volatility and cyclical effects, compositional shifts, adjustment pressures, and measurement error as sources of the productivity slump. He concludes as follows: "The key point is that, to the extent that such explanations are at work, a drop in measured productivity growth does not represent a prosperity-sapping misallocation of resources or loss of knowledge or efficiency."

[7]See, for example, Hall (2011), Crepon *et al.* (1998), Janz *et al.* (2003), Mairesse and Robin (2010), Siedschlag, Zhang and Cahill (2010), Criscuolo and Haskel (2003) and Loof and Heshmati (2006).

(2005) defines innovation as follows:

> *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.*

It is important to understand that R&D is just one input to innovation. Not all science, research and technology contribute to productivity growth, and not all innovations arise from R&D. Innovations contribute to productivity growth either by lowering the cost of production or by improving the quality of goods and services. Some innovations, such as those that lead to improvements in quality of goods and services, may make only a small contribution to improving measured productivity. However, some of these lead to improved well-being and quality of life, such as technological improvements in aged care. Increasing the stock of knowledge may, at times, make large and unexpected contributions to productivity.

Sometimes productivity gains are captured by innovating firms, but often the benefits of innovation also flow to firms copying the ideas or using new products that have been developed by others. Put another way, the rationale for governmental intervention in the area of research and innovation is the existence of market failure associated with research and innovation. This type of market failure is typically due to the diffusion of knowledge beyond the control of the inventor, which implies that the private rate of return to research and innovation is lower than its social return. Additionally, the high risks involved in innovation discourage firms from engaging in such activities. For both reasons, the amount invested by firms in research activities in a competitive framework is likely to be below the socially optimal level. Thus, there is a potential role for governments to intervene to eliminate this gap between private and social returns.

Information and communications technology (ICT) has been shown to be a major factor in productivity gains experienced towards the end of the 20th century; see, e.g., Oliner, Sichel and Stiroh (2007) and Connolly and Fox (2006). These gains have been described as spectacular in ICT-producing industries and more modest in ICT-using industries (Syverson 2011). Like most countries, Australia has only a small ICT-producing industry, and most of the productivity gains from ICT are via the use of ICT. For example, Australia's banking sector now operates with fewer tellers and relies extensively on Internet transactions.

III. Knowledge and Other Intangibles

In general, economic growth can be decomposed into two components: the growth of factor inputs (such as capital, labour and land) and the growth of productivity. Productivity is a measure of how efficiently an economy utilises finite resources to produce goods and services. There are several ways to improve productivity, but knowledge capital (through new technology, skills, R&D and efficient services and production processes) is a significant factor. New technology enables the same level of output to be produced with fewer inputs.

The effect of knowledge capital on productivity may work through various

channels depending on the source of the knowledge. For example, R&D, a major component of knowledge capital, can be performed either by the business sector, the public sector or beyond the borders of a country. Each of these types of R&D performers can be a source of significant domestic technological change. R&D performed by the business sector results in new goods and services, a higher quality of output, and new production processes. These are sources of productivity growth at the firm and national levels.

Many empirical studies confirm the positive impact of business R&D on productivity; see, e.g., Griliches (1998), and Nadiri (1993). Business-performed R&D may be funded by business itself or by the government. Accordingly, business R&D may have a different effect on productivity, depending on its source of funding (which affects the research agenda and the incentive structure). For example, Lichtenberg (1993) tests whether government-funded R&D performed by firms had a different impact than business-funded R&D. The author's evidence suggests that while privately funded R&D investment has a significant positive effect on productivity, government support for business R&D has a negative impact.

Besides their support for business R&D, governments are major R&D performers through their funding of government research agencies and higher education R&D. Research agencies and university R&D have been shown to have a strong effect on scientific and basic knowledge and on public missions. Basic research performed by universities enhances the stock of knowledge available to society (Mowery and Sampat, 2010). It may open new opportunities for business research, which in turn may improve productivity. Nevertheless, there have been few attempts to measure the impact of public R&D on productivity. In a group of studies, only some components of public research have been used in empirical frameworks. For example, Adams (1990) examines the contribution of fundamental stocks of knowledge, proxied by accumulated academic scientific papers, and finds significant contributions to productivity growth in manufacturing industries in the U.S. Another example is Poole and Bernard (1992), who examine military innovations and find a negative impact on total factor productivity in Canada.

The knowledge originating from abroad is a third source of new technology for any national economy. Evidence demonstrates many avenues through which knowledge can cross the borders of a given country and, depending on the absorptive capacity, how it can improve productivity in other countries (Mohnen 2001).

The Australian literature has a limited number of studies that have quantitatively examined Australia's innovation system and its impact. Most of these studies focused on the link between productivity and R&D, ignoring other types of innovation, such as management and organisational arrangements. The R&D measures employed by these studies largely relate to business R&D (e.g., Shanks and Zheng 2006 and Louca 2003). Moreover, the empirical evidence obtained by these studies was mixed or generally not supportive of the productive role of business R&D. For example, Shanks and Zheng (2006) find that despite the advances in data collection and methods used, they were unable to find a consistently robust result with regard to the impact of R&D on productivity:

"At this point in time, there remains no precise, robust estimate of the effect of increases in domestic business R&D on Australia's productivity performance.

Standard models and estimation methods, grounded in theory, tended to generate unreliable results, as well as estimates that were sensitive to seemingly modest changes in specification. A comprehensive investigation of alternative specifications and estimation techniques brought new insights, but proved unable to arrive at any definitive estimate." (Shanks and Zheng 2006, p. XLI)[8]

There are a small number of cases in which the role of higher education R&D is assessed. One example is a study by Burgio-Ficca (2004), who finds evidence of a positive relationship between higher education R&D and gross state product. With the exception of the Productivity Commission study (2007), there is no study which has explicitly scrutinised the effects of publicly funded R&D for Australia.[9] Although the results suggest significant aggregate economic, social and environmental benefits from publicly supported science and innovation, the Productivity Commission (2007) study finds that the quantitative estimates are statistically unreliable.

Despite its importance, R&D is not the only source of new technology. Innovation can result from the contributions made by other types of intangible capital, and extends beyond physical capital accumulation. We now consider this broader class of intangibles.

Despite the increase in their prominence, in many countries research and innovation, among a large set of intangible assets, are largely ignored in National Accounts and corporate financial reports because they are difficult to understand and measure. Two recent studies by Corrado, Hulten and Sichel (2005, 2006), henceforth collectively referred to as CHS, have drawn attention to the importance of measuring and capitalising intangibles. Using U.S. data, CHS developed a methodology with which to capitalise a broad range of intangibles and, by applying a growth accounting framework, demonstrated how the conventional growth rates of inputs, output and productivity measures changed as a consequence; see Table 1 for the CHS classification of intangibles assets, and the corresponding summary statistics for estimates for Australia from Elnasri and Fox (2014). Following CHS, researchers in a number of other advanced countries (e.g., the United Kingdom, Japan, Netherlands, Canada and Australia) have conducted similar studies, finding results similar to those of CHS.[10]

Following the recommendations of the System of National Accounts (SNA) 1993, Australia was one of the first countries to capitalise computer software, artistic originals and mineral exploration in 1993, rather than treating them as intermediate inputs. In addition, as part of the revisions to implement the recommendations contained in SNA 2008, Australia started to capitalise scientific R&D from 2009. However, as shown in Table 1, intangible assets are not restricted

---

[8]For a concise summary and discussion of this and related work, see Parham (2006).

[9]A small number of studies have partially addressed this question with data on the gross expenditures on R&D: Gross Expenditure on R&D (GERD), an aggregate measure of business, government and higher education R&D. However, using GERD as a measure will not isolate the effects of government or higher education R&D. Thompson (2009) uses firm-level data to examine the effectiveness of the R&D tax concessions as an effective policy tool, but does not consider other types of support for R&D.

[10]While this approach is becoming widely accepted, there are alternatives to the CHS approach to capitalising intangibles; see, e.g., Griliches (1981), Webster and Jensen (2006) and Diewert and Huang (2011).

TABLE 1—ESTIMATES OF NOMINAL INTANGIBLE INVESTMENTS IN THE AUSTRALIAN MARKET SECTOR

Categories	1974-1975	1984-1985	1994-1995	2004-2005	2012-2013
					millions of dollars
Computerised information	26	627	3,512	7,262	9,948
Innovative property	917	3,857	9,342	19,414	38,624
Scientific R&D; Social sciences R&D (Business R&D)	199	614	2,782	7,010	14,483
Mineral exploration	203	1,271	1,567	2,074	7,849
Copyright and licence costs (Artistic originals)	35	172	256	1045	2,450
Other product development, design and research	480	1,800	4,737	9,286	13,841
New product development in financial industry	342	1,310	3,133	5,311	8,338
New architectural and engineering designs	137	490	1,604	3,975	5,504
Economic competencies	1,259	4,926	11,276	23,374	33,428
Brand equity	653	2,830	4,679	8,365	10,362
Advertising	648	2,774	4,420	7,391	9,463
Market research	5	56	260	974	899
Firm-specific human capital	301	1,024	2,669	3,870	5,791
Organisational capital	306	1,073	3,927	11,138	17,276
Purchased	21	232	1,944	7,058	9,143
Own account	284	840	1,983	4,081	8,133
Total intangibles investment	2,202	9,410	24,130	50,050	82,000
New intangibles	1,739	6,726	16,013	32,659	47,270
National Accounts intangibles	463	2,684	8,118	17,391	34,730
Tangibles	9,251	32,333	54,984	10,6195	227,751
Total investment	11,453	41,743	79,114	156,245	309,751
Share of computerised information %	1	7	15	15	12
Share of innovative property %	42	41	39	39	47
Share of economic competencies %	57	52	47	47	41
Share of intangible investment%	19	23	31	32	26
Share of tangible investment%	81	77	69	68	74
Ratio intangible to tangible investment	0.24	0.29	0.44	0.47	0.36

Notes: The share of tangible (intangible) investment is the ratio of tangibles (intangibles) to total investment. The shares of computerised information, innovative property, and economic competencies are calculated relative to all intangibles.

to these four elements, with firms also investing in other types of intangible assets which may represent a source of economic growth; these investments are still treated in the National Accounts as current expenses. Excluding investment in intangibles underestimates total investment, which in turn may misrepresent the measures of output, capital services, factor income shares and consequently productivity.

For Australia, Elnasri and Fox (2014) extend the work of Barnes and McClure (2009) and de Rassenfosse (2012) in applying the methodology of CHS to measure and classify a range of 'new' intangibles. However, as they state, "Given the experimental nature of the methodology, the assumptions required, measurement challenges and data limitations, the estimates should be interpreted as only indicative" (Barnes and McClure 2009, p. XIII).[11]

From Table 1, we see that investment in intangibles has increased over time,

---

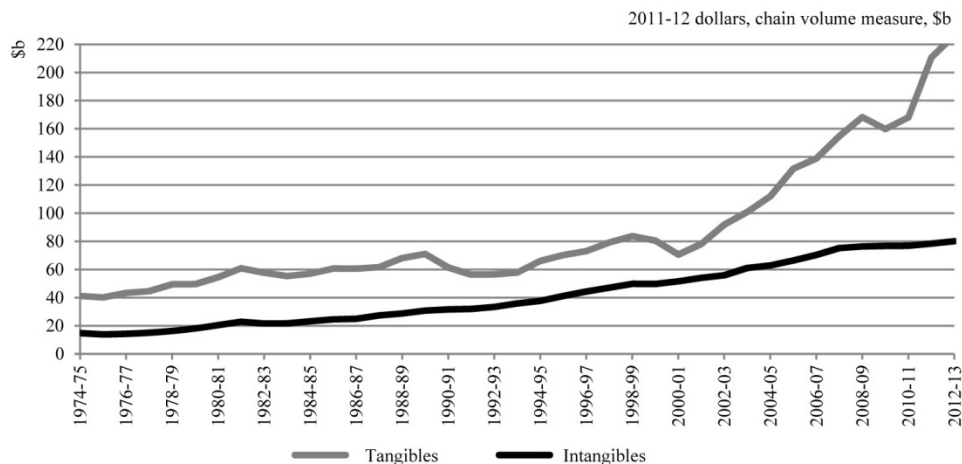[11]The following results are drawn from Elnasri and Fox (2014).

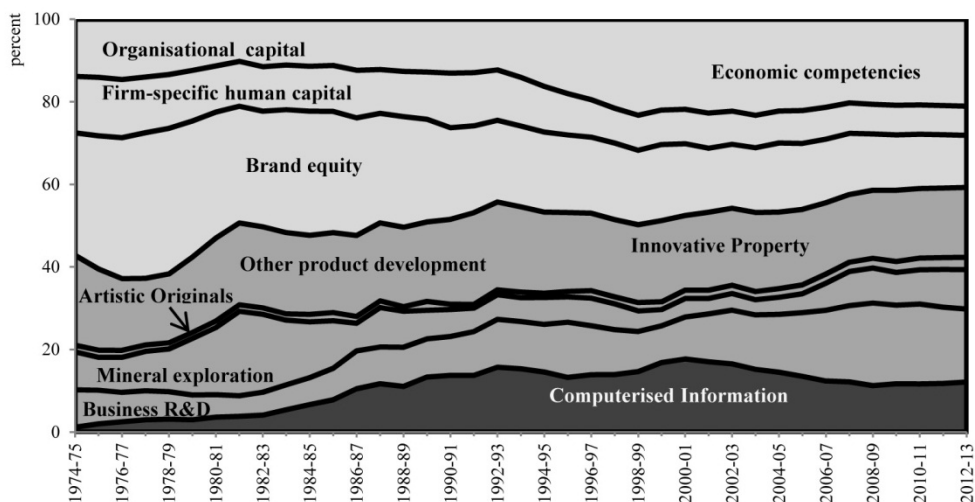FIGURE 4. MARKET-SECTOR REAL TANGIBLE AND INTANGIBLE INVESTMENTS (1974-75 TO 2012-13)

FIGURE 5. SHARES OF NOMINAL TOTAL INTANGIBLE INVESTMENT, BY ASSET TYPE PERCENT

reaching $82 billion in 2012-13 and constituting around 26 percent of all investment in the market sector for that year. With the exception of the last few years, total investment in intangibles grew more rapidly than investment in tangibles, as shown in Figure 4. The ratio of intangibles to tangibles increased continuously from 0.24 in 1974-75 to 0.47 in 2004-05; however, it decreased to 0.36 by 2012-13. Only computer software, artistic originals, mineral exploration and R&D have been capitalised in the Australian System of National Accounts, and these constitute less than half of the total amount of intangible investment. In 2012-13, National Accounts intangibles accounted for 42 percent of the total amount of intangible investment, while new intangibles accounted for 58 percent.

Table 1 and Figure 5 show that the composition of intangible investments has changed considerably over the last three and a half decades. For the first four years

presented in Table 1, the component of economic competencies is the largest component of intangible investment, with an average share of 51 percent. The second largest component was innovative property, with an average share of 40 percent. However, by 2012-13, these two categories of intangibles had reversed their contribution ranking; economic competencies decreased to 41 percent while the share of innovative property increased to 47 percent. Investment in computerised information has dramatically increased over time, although remaining the smallest component of intangibles. Figure 5 illustrates the extent of the shift towards investment in computerised information and organisational capital over time. The share of organisational capital has increased, while that of economic competencies as a group has decreased, influenced by the decrease in brand equity and firm-specific human capital. The share of innovative property decreased slightly but started to recover by the end of the period, as the involvement of firms in business R&D has increased noticeably in recent years.

Elnasri and Fox (2014) use the CHS methodology to capitalise the new, broader class of intangibles, and compare the impact on multifactor productivity (MFP) growth for the market sector from different treatments of intangibles investment. Figure 6 shows that capitalising expenditures on intangibles changes the rate of MFP growth. In particular, the figure indicates that MFP growth decreases as more knowledge, innovation and other intangible assets are accounted for. This can be explained by the fact that the inclusion of intangibles has raised output growth by a lower rate than it has raised the growth in inputs. Although the rate of MFP growth has decreased across the period, the pattern of the growth remains unchanged. Specifically, the improvement in productivity during the productivity growth cycle of 1998-99 to 2003-04 and the overall decline during the recent productivity growth cycle is still present after capitalising intangibles. Hence, enhanced measurement by capitalising intangibles in this way does not resolve the recent productivity decline.
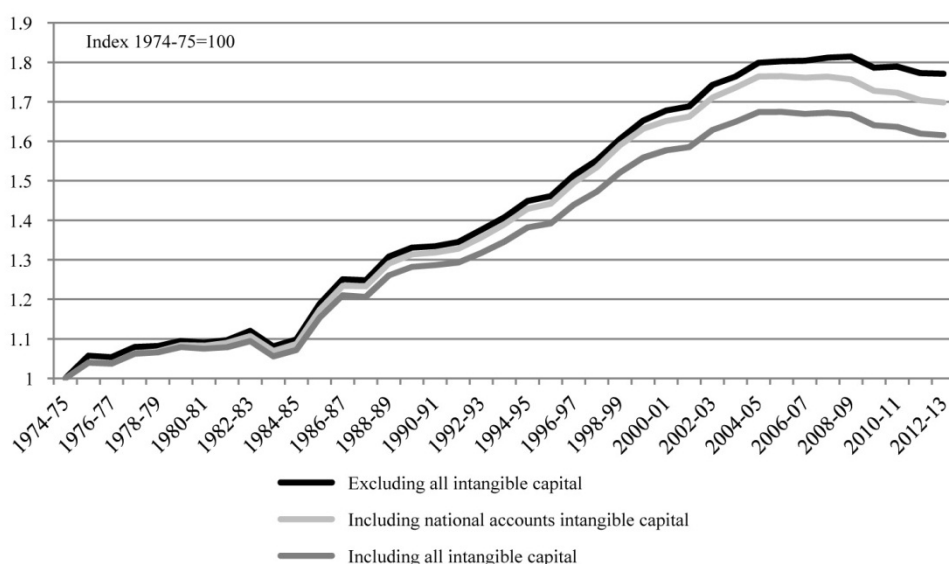

FIGURE 6. MULTIFACTOR PRODUCTIVITY, MARKET SECTOR, 1974-75 TO 2012-13

IV. Public Funding

Besides fulfilling public needs (such as improving the products and services offered or better delivery of functions), the economic rationale for governmental involvement in the area of research and innovation is the existence of market failure associated with research and innovation. This type of market failure is typically due to the diffusion of knowledge beyond the control of the innovator, which implies that the private rate of return to research and innovation is lower than its social return. Thus, governments intervene to eliminate this gap between private and social returns.

Another reason for the provision of public support is that governments want to stimulate research and innovation performed by the business sector. This is likely to be below the socially optimal level, as firms are often discouraged from engaging in research activities by the inherently high risk of research (Arrow 1962). Therefore, governments intervene to assist firms either by mitigating their private costs or by raising awareness of the technological opportunities that are available to reduce both the cost and uncertainty of research and innovation.

There are two main sources of data on public support for R&D and innovation in Australia: the Science, Research and Innovation Budget Tables (SRIBTs) and the ABS survey on R&D. With each federal budget, the Australian government publishes SRIBTs, which provide an overview of government support for science, research and innovation over a period of ten years. The SRIBTs summarise the total amount of Australian government support by sector of performance while also breaking down total expenditures by program and socioeconomic objectives. The ABS survey on public spending on R&D captures R&D expenditures when the R&D is performed.

The SRIBTs classify government support for research and innovation into four sectors of performance: Commonwealth research agencies, the higher education sector, the business enterprise sector, and a "multisector" category. Figure 7 presents public spending as estimated for the year 2012-13. The higher education sector is the recipient of the largest share of science and innovation funding from the Australian government, receiving around 32 percent of all public support, followed by the business enterprise sector and those in the multisector category, which respectively received 25 percent and 23 percent of all support. The research agency sector has received the smallest portion of support, equivalent to 20 percent of the total support.

The public funding devoted to each of these sectors is allocated to different areas. An analysis of the $8.9 billion outlay by the Australian government for R&D and innovation in 2012-13 shows the following:

Higher Education Research: Performance-based block funding (PBBF) accounts for 67 percent of the total funding to the higher education sector. PBBF is provided through a number of 'performance-based' arrangements, such as the Research Training Scheme (RTS), the Institutional Grants Scheme (IGS), the Research Infrastructure Block Grants scheme (RIBG), and the Australian Postgraduate
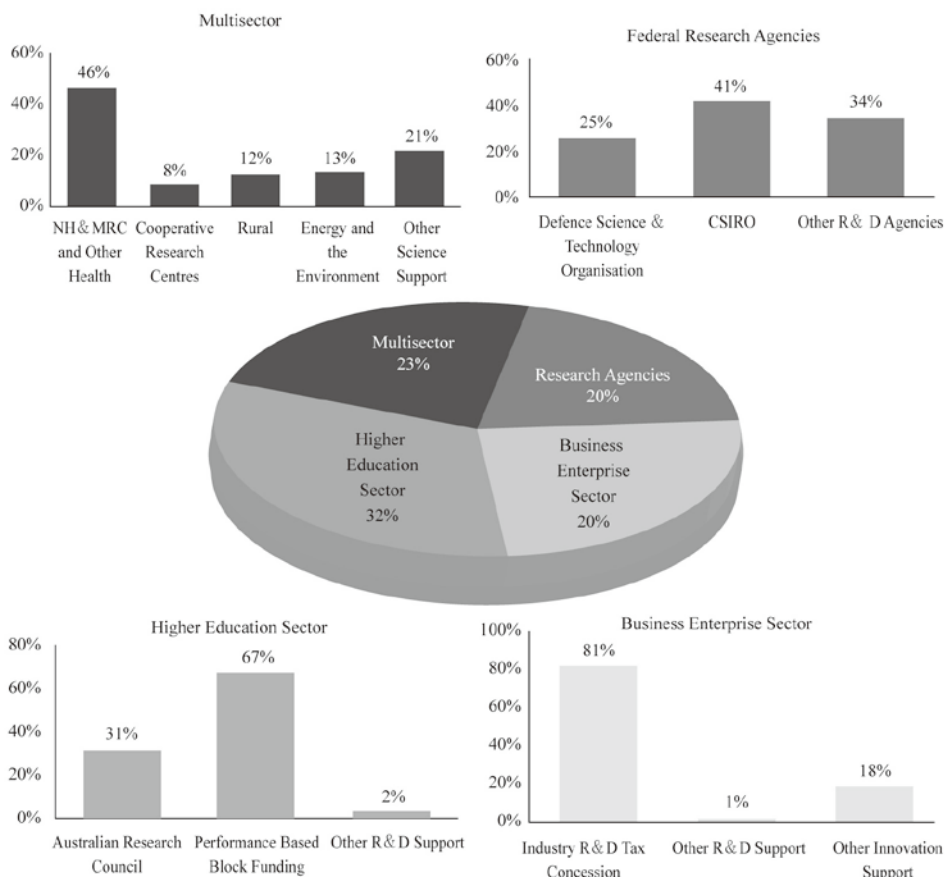
FIGURE 7. AUSTRALIAN GOVERNMENT SPENDING ON SCIENCE AND INNOVATION, 2012-13

Awards scheme (APA).[13] Australian Research Council (ARC) funding accounts for 31 percent of all funding to higher education. Other R&D support accounts for 2 percent.

Business Enterprise Sector: Government support for business sector science and innovation activities is delivered through a range of programs. The main program is the R&D Tax Concession, which accounts for approximately 81 percent of the total amount of business support in 2012-13. The categories of Other Innovation Support and Other R&D Support account for 18 percent and 1 percent, respectively.

Research Agencies: Two main organisations – the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Defence Science and Technology Organisation (DSTO) – dominate the research funding allocated to public-sector research agencies. In 2012-13, the CSIRO accounted for 41 percent

---

[13]These arrangements are known as "performance-based" because allocations to each institution depend on its past performance as assessed by various formulae administered through the Department of Education, Employment and Workplace Relations.

of all public-sector research agency funding, while the DSTO accounted for 25 percent. Other public R&D agencies accounted for 34 percent.[14]

Multisector: Nearly 46 percent of multisector funding is devoted to the National Health and Medical Research Council (NHMRC) and to other health grants, which predominantly go to universities and private non-profit medical research institutes (MRIs). The Cooperative Research Centres (CRCs) and Rural Funds also have strong university components; they constitute around 8 percent and 12 percent of multisector outlays, respectively. The category entitled Energy and the Environment has a share of 13 percent, and Other Science Support is at 21 percent.
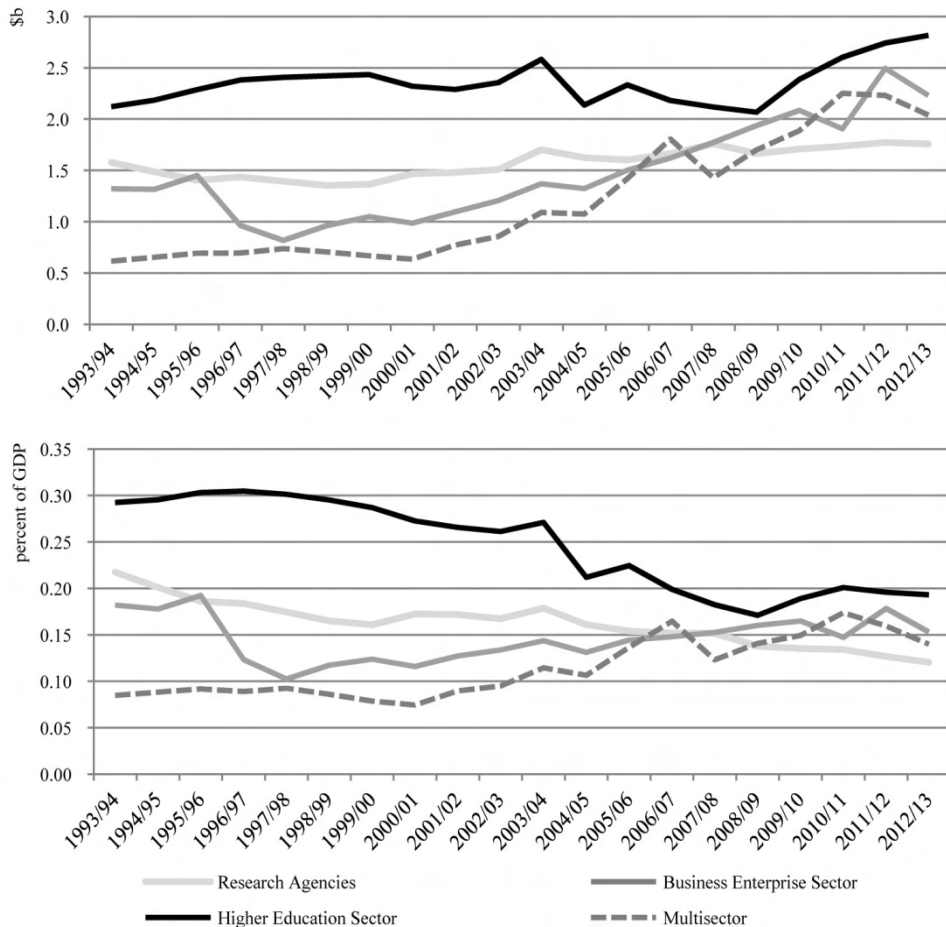
FIGURE 8. AUSTRALIAN GOVERNMENT SUPPORT FOR RESEARCH AND INNOVATION,
1993-94 TO 2012-13

---

[14]Other public R&D agencies include the Australian Nuclear Science and Technology Organisation (ANSTO), Geoscience Australia, Antarctic Division, Australian Institute of Marine Science (AIMS), Bureau of Meteorology Research Centre, Environmental Research Institute of the Supervising Scientist, Australian Animal Health Laboratory, Great Barrier Reef Marine Park Authority, and the Anglo-Australian Telescope.

Figure 8 plots the support for research and innovation and its components over time. From the top panel of the figure, total support has increased in real terms over the past two decades. However, as shown in the lower panel, it has fallen as a share of GDP. There have been noticeable changes in the role of the government support across its four components of funding. In particular, indirect public support for the business enterprise sector and for the multisector category has also grown in real terms during the past two decades. However, support to higher education and direct support to research agencies has barely grown. This has meant that the share of public support to the multisector category has roughly doubled between 1993-94 and 2012-13, while support to higher education has halved. A number of factors can account for this changing pattern in government investment, including an increased focus on collaboration in the multisector category and progressive increases in claims on the R&D tax concessions in the business enterprise sector.

ABS survey data can be used to explore how public R&D resources are allocated according to the intended purpose or outcome of the research. Figure 9 presents a comparison between 1992-93 and 2011-12, breaking down expenditures on R&D by the associated socioeconomic objective. As shown in the figure, the largest share of government R&D expenditure was directed towards economic activities, followed by defence and environment activities. However, social activities such as education and training and social development and community activities receive a small share of government R&D expenditure.
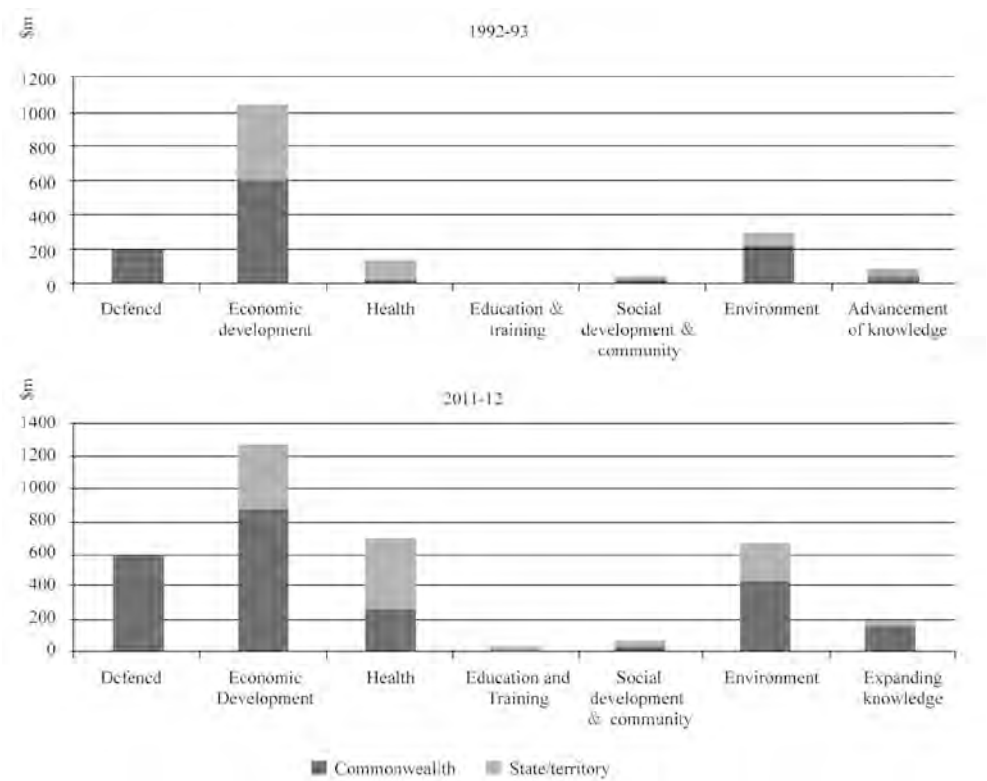

FIGURE 9. BREAKDOWN OF UNDERPINNING RESEARCH FUNDED BY THE COMMONWEALTH AND STATE/TERRITORY BY SOCIOECONOMIC OBJECTIVE, 1992-93 AND 2011-12
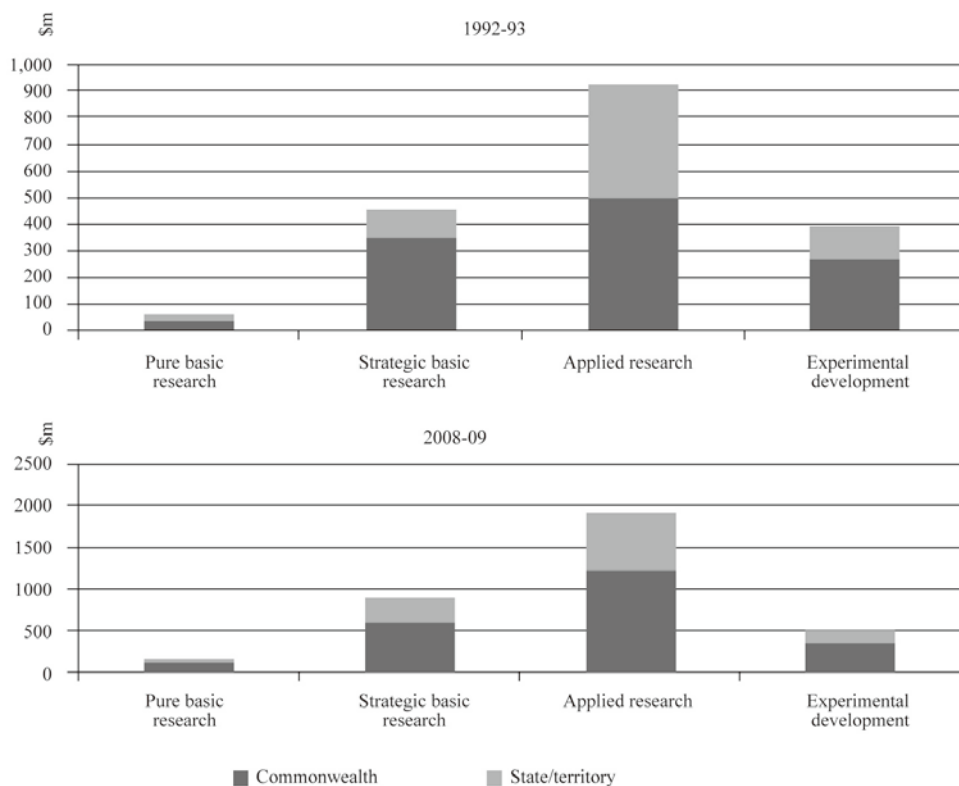
FIGURE 10. COMMONWEALTH SUPPORT FOR R&D, BY TYPE OF ACTIVITY, 1992-93 AND 2008-09

The ABS data also breaks down Commonwealth expenditures on R&D according to the types of activities, with the categories being basic research, applied research and experimental development. Basic research is broken down further into the two types of pure and strategic basic research. Applied research is a critical input to the innovation system and is often seen to be more immediately relevant and applicable for end users, specifically industry, than basic research. In Figure 10 it is shown that the Commonwealth and State governments focus more on applied research and strategic basic research at the expense of pure basic and experimental development research.

V. Public R&D Capital and Productivity Growth

Most of the literature that examined the relationship between R&D and economic or productivity growth have avoided the problem of obtaining an estimate of R&D capital stock by employing a measure of R&D intensity (i.e., a ratio of R&D expenditures to the value of production); see, e.g., Griliches (1998) and Haskel and Wallis (2013). However, this method implicitly assumes that the depreciation rate of R&D is zero, which is not a very realistic assumption. Hence, Elnasri and Fox (2014) use the stock of public-sector R&D as estimated with the

method of Corrado, Hulten and Sichel (2005, 2006).

Figure 10 plots multifactor productivity (MFP) growth, smoothed by a three-year centred moving average, against the Elnasri-Fox capital stock growth of public support for research agencies, higher education, and business enterprise. Productivity and public support for higher education activities move together throughout the period, which gives the appearance of a strong relationship. Similarly, with the exception of the early years, there is co-movement between productivity and research agencies' activities, again suggesting a positive correlation between them. Conversely, the divergent trends in productivity and the public support for the business enterprise sector suggest a negative relationship. However, this casual analysis presupposes a contemporaneous relationship between R&D and productivity; it is more likely that there are lagged effects of R&D expenditure on productivity given that knowledge typically takes time to disseminate. The correlations suggested by the bivariate plots may therefore represent an overly simplistic analysis. There may also be other potential influences on productivity which could be obscuring actual causal relationships. Therefore, to provide stronger evidence of the relationship between productivity and public knowledge, a detailed econometric analysis accounting for other influences is required.

Elnasri and Fox (2014) provide such a detailed analysis, isolating social returns from private returns while controlling for various factors that can affect Australia's productivity performance, such as the provision of public infrastructure, the business cycle, trade openness and the terms of trade. Although restricted by data availability to examine an aggregate of the twelve core market sectors over the period of 1993-94 to 2012-2013, they present extensive results from alternative models and conduct numerous robustness checks.[15] Essentially, the results confirm the relationships apparent in Figure 9.

The conclusions from the Elnasri-Fox analysis can be summarized as follows. There is evidence that private-sector knowledge capital is a source of positive spillover to market-sector productivity. That is, not all benefits of research, innovation and other intangibles are captured privately, but there are "social" benefits which diffuse throughout the market sector.

There is strong evidence of productivity benefits from public spending on Commonwealth research agencies and higher education. However, the results show no evidence of social returns (in excess of private returns) from public support to the business enterprise sector, the multisector category, or defence R&D.

Several reasons can be postulated for this. Health research funding constitutes nearly 50 percent of public expenditures in the multisector category in 2012-13, as shown in Figure 7. Its output is not part of market-sector value added, and any productivity effects are likely to be very long term, through improvements in the health of the workforce and population more generally; hence, there is a bias against finding a positive significant result. Similarly, it is expected that while some select components of expenditures on defence may result in innovations with

---

[15]A longer time series would provide more confidence in the results, but given the lack of historical data this can only be remedied by the passage of time. The sample size is similar to that used in the related study of Haskel and Wallis (2013) for the U.K.

commercial value that appear in the market sector, defence services will not, again biasing the results against finding a positive relationship. The main public support for the research and innovation in the business enterprise sector is the industry R&D Tax Concession,[16] comprising 81 percent of support to the sector in 2012-13. Unlike much of the funding to higher education and research agencies, the allocation of support is based on expenditures rather than on performance. Obviously, there are strong financial incentives for firms to maximise expenditures classified as being related to R&D, potentially biasing the results.[17] In addition, there may be other policy goals of the R&D Tax Concession than raising productivity. Indeed, providing incentives for the establishment of small innovative firms may actually lower productivity, as new entrants often initially have lower productivity compared to incumbents; see, e.g., Baldwin (1995) and Aw, Chen and Roberts (2001).[18]

On the other hand, universities and research agencies are primary sources of knowledge and technology creation and diffusion. While the above analysis has focussed on the aggregate market sector, there is substantial international evidence of the positive impacts of universities and research agencies on firm productivity, through the development of skilled labour and positive externalities (Malecki 1997; Medda *et al.* 2005). Adams (2002) found evidence of academic spillover from U.S. R&D laboratories that induce the clustering of firms with universities and research agencies, while Anselin *et al.* (1997) and Woodward *et al.* (2006) found that R&D-intense production tends to be located close to universities. After controlling for corporate R&D, Jaffe (1989) found that patented inventions at the state level in the U.S. depend significantly on university research.

Such evidence is not restricted to the U.S. For example, Yaşar and Morrison Paul (2012) found more patent activity in Chinese firms with university and research institution connections. In addition, they found that linkages with research institutions in particular raised firm productivity. The introduction of new products, processes, and new businesses was also positively associated with linkages with research institutions.

Hence, if the policy goal is to raise private-sector productivity, the evidence suggests that government research agencies and higher education are the areas with more potential gains from public funding support.

---

[16]Following a change in eligibility rules and allowances, the R&D tax concession was replaced by the "R&D tax incentive" from 1 July 2011: http://www.ato.gov.au/Business/Research-and-development-tax-incentive/.

[17]Thompson (2009, p. 3) notes the following: "However, some have argued that anecdotal evidence does not support the efficacy of R&D tax incentives. Regarding the US experience, a senior correspondent from Business Week describes his experience, speaking, off the record, with corporate executives (Gleckman 2006): 'In 20 years, I've never had a single corporate executive from the pharmaceutical industry or the high-tech industry, or anyplace else tell me that they have done a dime's worth of research that they otherwise wouldn't have done as a result of the R&D credit. They spend lots of time and effort reallocating costs so they can take advantage of the credit, but they don't actually do any more research.' For Australia, survey evaluations of the Australian R&D tax concession (DITR 2005; DITR 2007a) found that approximately 30% of respondents admit that their R&D efforts would not have been smaller or completed at a slower rate in the absence of the concession.

[18]The evidence of the effectiveness of R&D tax concessions in only raising R&D intensity is mixed, without even considering the impact on productivity. In a study of nine OECD countries over a nineteen-year period, Bloom *et al.* (2000) found that tax incentives are effective in increasing R&D intensity. Yet, in a study of Australia using financial data on 500 large Australian firms between 1990 and 2005, Thomson (2009) finds that tax incentives are not an important determinant of a firm's R&D investment decisions.
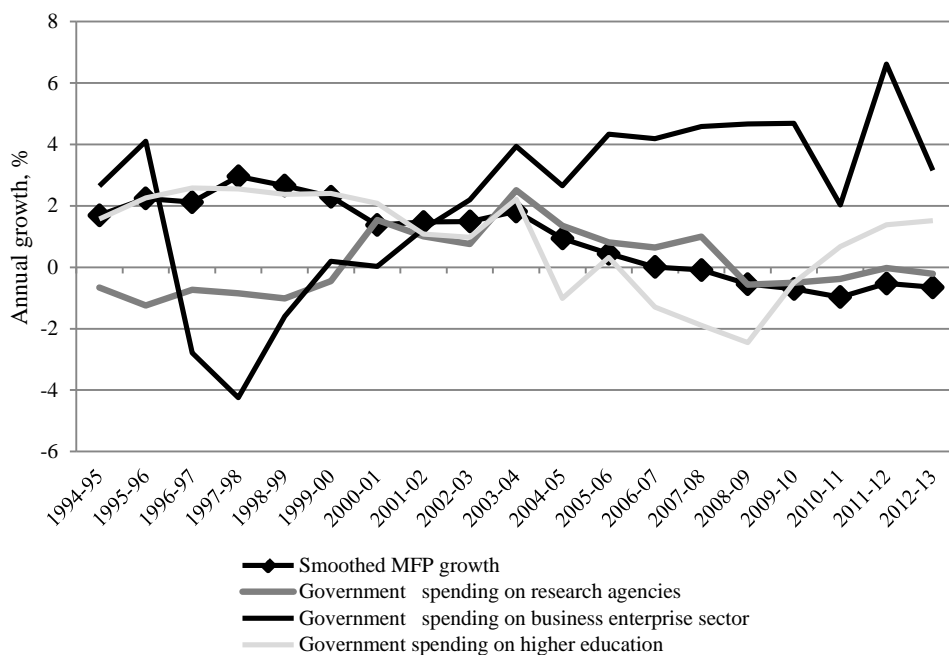
FIGURE 11. MARKET-SECTOR MFP GROWTH AND PUBLIC SUPPORT FOR RESEARCH AGENCIES,
HIGHER EDUCATION AND THE BUSINESS SECTOR (1993/94-2012/13)

VI. Conclusions

Investments in research and innovation (such as information technology, R&D, skills development, design and organisational improvements and other types of intangible assets) are regarded as central drivers of productivity. They create more efficient services and production processes, more effective workplace organisation, and open up new markets. However, it is commonly argued that there are major market failures in the provision of a sufficient amount of such knowledge capital, as knowledge diffuses beyond the control of the innovator. This implies that the private rate of return for research and innovation is lower than its social return, resulting in underinvestment in knowledge capital than would be optimal if all returns were privately captured. Additionally, the high risks involved discourage firms from engaging in such activities.

For both reasons, the amounts invested by firms in research activities in a competitive framework are likely to be below the socially optimal level. This justifies intervention by governments directly to make their own investments in knowledge capital, or indirectly to support the private sector to reduce its costs. However, governments face the stumbling block of a large number of projects competing for tight budgets, raising questions about how available funds can be distributed most effectively to achieve policy goals, such as raising private-sector productivity. This paper makes reference to the international literature and draws on recent empirical research for Australia to provide some policy-relevant insights

related to the role of government in supporting productivity-enhancing research and innovation.

For a better understanding and to improve the functioning of the innovation systems of an economy, it is essential to track, or benchmark, performance. Developing robust and relevant measures of research and innovation is difficult. The intangible nature of research and innovation poses problems for the measurement of spending and the depreciation of spending in defining capital stocks. As such, research and innovation are largely ignored in the National Accounts and in the corporate financial reports of many countries, where they have been only treated as intermediate expenditures. However, excluding investments in these intangible assets means that investments are underestimated, which may distort measures of growth in capital services and, consequently, productivity. Hence, in addressing the role of government funding of research and innovation, this paper has paid significant attention to the fundamental issue of accounting for investments in knowledge capital.

Some key findings can be summarised as follows. First, in the case of Australia, measuring research and innovation by focusing only on the set of assets currently capitalised in the System of National Accounts seems unreliable. Total investment has been found to be under-reported, and this has distorted measures of the growth of capital services and, consequently, productivity. Different countries have capitalised intangibles to different degrees, making international comparisons complicated.

Also in the case of Australia, it was found that the partial capitalisation of intangible assets has lowered the estimates of productivity growth. As the Australian Bureau of Statistics is a leading agency in improving its National Accounts and productivity measurements in this way, it is likely that Australia's relative market-sector performance is better than currently thought.

Second, the accumulation of private-sector knowledge capital is a source of positive benefits (spillover) to market-sector productivity. This implies that innovative activity has broad benefits that diffuse through the economy.

Third, given the pressures on public finances, it is appealing to direct the innovation budget to areas with higher social benefits. Consistent with the findings of Haskel and Wallis (2010, 2013) for the U.K., the results presented in Section 6 and further findings of Elnasri and Fox (2014) for Australia suggest that government research agencies and higher education are areas with more potential gains compared to, e.g., providing firms with tax incentives for investment in R&D.

This remains a fertile field for further research. For example, the standard current approach to the capitalisation of intangibles is that of Corrado, Hulten and Sichel (2005, 2006), which effectively treats intangibles as it treats tangibles. That is, it treats intangible capital (such as knowledge capital) as if it has similar characteristics to a truck, with a finite life during which it depreciates. This approach has benefits in terms of familiarity and, with some brave assumptions about deflators and depreciation rates, the relative ease of implementation. Unfortunately, it is not a very accurate description of what is going on with investments in intangibles; it is unlikely that, in general, an idea depreciates in the same way as a truck. By developing and expanding the approach proposed by Diewert and Fox (2014) in the context of amortizing goodwill (an intangible) for

commercial property, and taking into account the "sunk cost" aspect of investments, it seems possible to develop a significantly more realistic framework with which to address this important problem of appropriately accounting for intangibles.

An additional unresolved issue is the potential difference in the productivity impact from government support for different types of R&D, such as pure basic research versus applied research (see Figure 10). The unavailability of sufficient survey data prevented the further exploration of this important aspect of investment in knowledge capital for Australia.[19]

Finally, it is noted that the apparent persistence of the slowdown in productivity growth in industrialized countries, combined with recent budget concerns arising from less favourable economic conditions, will likely heighten the debate on the role of government innovation policies which raise productivity growth.   While acknowledging the caveats in the existing literature (including the current paper) and the desirability of further analysis if appropriate data becomes available, there appears to be a role for government funding support; the evidence suggests that it is not through direct industry support through tax incentives but rather through support for government research agencies and higher education.

REFERENCES

ABS. 2007. "Experimental Estimates of Industry Multifactor Productivity." Information paper, ABS Cat. No. 5260.0.55.001, Canberra, Australia.

ABS. 2013. "Estimates of Industry Multifactor Productivity, Australian Bureau of Statistics." ABS Cat. No. 5260.0.55.002, Canberra, Australia.

Bell, J., B. Frater, L. Butterfield, S. Cunningham, M. Dodgson, K. J. Fox, T. Spurling and E. Webster. 2014. "The Role of Science, Research and Technology in Lifting Australian Productivity." report for the Australian Academy of the Humanities, www.acola.org.au

Aghion, P., R. Blundell, R. Griffith, P. Howitt, and S. Prantl. 2009. "The Effects of Entry on Incumbent Innovation and Productivity." *Review of Economics and Statistics* 91 (1): 20–32.

Anselin, L, Varga, A and Acs, Z. 1997, "Local Geographic Spillovers Between University Research and High Technology Innovations." *Journal of Urban Economics* 42: 422–448.

Arrow, K. 1962. "The Economic Implications of Learning by Doing." *The Review of Economic Studies* 29: 155–173.

Aw, B. Y., X. Chen and M. J. Roberts. 2001. "Firm Level Evidence on Productivity and Turnover in Taiwanese Manufacturing." *Journal of Development Economics* 66: 51–86.

Baldwin, J. R. 1995. *The Dynamics of Industrial Competition: A North American perspective*, Cambridge University Press, Cambridge.

Barnes, P. and A. McClure. 2009. "Investments in Intangible Assets and Australia's Productivity Growth." Productivity Commission Staff Working Paper, March.

Bloom, N., R. Griffith and J. Van Reenen. 2002. "Do R&D Tax Credits Work? Evidence from a Panel of Countries 1979-1997." *Journal of Public Economics* 85 (1): 1–31.

Connolly, E. and K. J. Fox. 2006. "The Impact of High-Tech Capital on Productivity: Evidence from Australia." Economic Inquiry 44 (1): 50–68.

Connolly, E. and L. Gustafsson. 2013. "Australian Productivity Growth: Trends and Determinants." *Australian Economic Review* 46 (4): 473–482.

Corrado, C., C. Hulten and D. Sichel. 2005. "Measuring Capital and Technology: An

---

[19]However, given the differences in industry structure across countries, it is unlikely that lessons from any one country using such a breakdown by R&D type will be easily transferable to other countries. H owever, if the data were available, the productivity impact of support for different types of R&D and in novation within these sectors could provide new insights for policymakers in any specific country.

Expanded Framework." In *Studies in Income and Wealth* Vol. 65, edited by C. Corrado, J. Haltiwanger and D. Sichel, University of Chicago Press.

Corrado, C., C. Hulten and D. Sichel. 2006. "Intangible Capital and Economic Growth." NBER Working Paper No. 11948, National Bureau of Economic Research, Cambridge, Massachusetts.

Crepon, B., E. Duguet, and J. Mairesse. 1998. "Research, Innovation, and Productivity: An Econometric Analysis at the Firm Level." *Economics of Innovation and New Technology* 7: 115–156.

Criscuolo, C., and J. E. Haskel. 2003. "Innovation and Productivity Growth in the UK: Evidence from CIS2 and CIS3." CeRiBA Working Paper, London School of Economics, London, UK.

Diewert, W. E. and N. Huang. 2011. "Capitalizing R&D Expenditures." *Macroeconomic Dynamics* 15: 537–564.

Diewert, W. E. and K. J. Fox. 2014. "Sunk Costs and the Measurement of Commercial Property Depreciation." University of British Columbia, Department of Economics Discussion Paper No.14-06.

DITR. 2007a. "How R&D Assistance Influences Company Behaviour." Department of Industry, Tourism and Resources, Canberra.

DITR. 2007b. "High Variation in R&D Expenditure by Australian firms." Department of Industry, Tourism and Resources, Canberra.

Elnasri, A. and K. J. Fox. 2014. "The Contribution of Research and Innovation to Productivity and Economic Growth." School of Economics Discussion Paper UNSW.

Gleckman, H. 2006. Transcript of the 2006 Tax Analysts Conference Series, "Tax Incentives-Do they Work, and are they Worth the Cost?" Washington DC, as cited in Rashkin, M. D. (2007). *Practical Guide to Research and Development Tax Incentives*, Federal, State and Foreign, 2nd Ed, Chicago, Wolters Kluwer Business, p.30.

Gordon RJ. 2012. "Is US Economic Growth Over? Faltering Innovation Confronts the Six Headwinds." NBER Working Paper No 18315. http://www.nber.org/papers/w18315

Gorodnichenko, Y., J. Svejnar, and K. Terrell. 2010. "Globalization and Innovation in Emerging Markets." American Economic Journal Macroeconomics: 194–226.

Griffiths, W. and E. Webster. 2010. "The Determinants of Research and Development and Intellectual Property Usage among Australian Companies, 1989 to 2002." *Technovation* 30, 471481.

Griliches, Z. 1981. "Market Value, R&D and Patents." *Economics Letters* 7: 183–187.

Griliches, Z. 1988. "Productivity Puzzles and R&D: Another Nonexplanation." *Journal of Economic Perspectives* 2 (4): 9–21.

Griliches, Z. 1998. *R&D and Productivity: The Econometric Evidence*, University of Chicago Press: Chicago.

Hall, B. H. 2011. "Innovation and Productivity." National Bureau of Economic Research Working Paper No. 17178.

Hall, B. H. and N. Rosenberg. 2010. *Handbook of the Economics of Innovation*, Vol. 1 & 2, North-Holland: Amsterdam.

Haskel, J. and G. Wallis. 2010. "Public Support for Innovation, Intangible Investment and Productivity Growth in the UK Market Sector." IZA Discussion Paper Series No. 4772.

Haskel, J. and G. Wallis. 2013. "Public Support for Innovation, Intangible Investment and Productivity Growth in the UK Market Sector." Economics Letters 119: 195–198.

Isaksson, A. 2007. "Determinants of Total Factor Productivity: A Literature Review." Staff Working Paper No. 02/2007, United Nations Industrial Development Organization.

Jaffe, A. 1989. "Real Effects of Academic Research." *American Economic Review* 79: 957–970.

Janz, N., H. Loof, and B. Peters. 2003. "Firm Level Innovation and Productivity—Is there a Common Story Across Countries?" Mannheim, Germany: ZEW Discussion Paper No. 03-26.

Lichtenberg, F. 1993. "R&D Investment and International Productivity Differences." NBER Working Paper No. 4161, Cambridge, MA.

Loof, H., and A. Heshmati. 2006. "On the Relationship Between Innovation and Performance: A Sensitivity Analysis." *Economics of Innovation and New Technology* 15: 317–344.

Louca, J. 2003. "Multifactor Productivity and Innovation in Australia and Its States." In *Productivity and Regional Economic Performance in Australia*, edited by C. Williams, M. Draca and C. Smith, Collection of Papers prepared by the Office of Economic and Statistical Research, Queensland Treasury.

Mairesse, J., and S. Robin. 2010. "Innovation and Productivity: a Firm-Level Analysis for French Manufacturing and Services Using CIS3 and CIS4 data (1998-2000 and 2002-2004)." Paris, France: CREST-ENSAE.

Malecki, E. J. 1997. *Technology and Economic Development: the Dynamics of Local, Regional and National Competitiveness*, Longman, London.

Medda, G., C. Piga, and D. S. Siegel. 2005. "University R&D and Firm Productivity: Evidence from Italy." *Journal of Technology Transfer* 30 (1/2): 199–205.

Mohnen, P. 2001. "International R&D Spillovers and Economic Growth." In *Information Technology, Productivity, and Economic Growth: International Evidence and Implications for Economic Development*, pp.50–71, edited by M. Pohjola, Oxford University Press, London.

Mowery, D. C. and B. N. Sampat. 2010. "Universities in National Innovation Systems." unpublished manuscript, Haas School of Business, University of California, Berkeley, http://innovate.ucsb.edu/wp-content/uploads/2010/04/Mowery-Sampat-Univ-National-Innovation-Systems.pdf

Nadiri, I. 1993. "Innovations and Technological Spillovers." NBER Working Paper No. 4423, Cambridge, MA.

OECD. 2005. *Oslo Manual: The Measurement of Scientific and Technological Activities—Guidelines for Collecting and Interpreting Innovation Data*, 3rd edition, p.46, OECD, Paris.

Oliner, S. D., D. E. Sichel and K. J. Stiroh. 2007. "Explanation of a Productive Decade." *Brookings Papers on Economic Activity* 1: 81–137.

Parham, D. 2006. "Empirical Analysis of the Effects of R&D on Productivity: Implications for Productivity Measurement?" OECD Workshop on Productivity Measurement and Analysis, Bern, Switzerland, 16–18 October.

Parham, D. 2012. "Australia's Productivity Growth Slump: Signs of Crisis, Adjustment or Both?" Visiting Researcher Paper, Productivity Commission, Canberra.

Phelps. E. 2013. *Mass Flourishing: How Grassroots Innovation Created Jobs, Challenge, and Change*, Princeton University Press, Princeton.

Productivity Commission. 2006. "Potential Benefits of the National Reform Agenda." Productivity Commission Research Paper, Canberra.

Productivity Commission. 2007. "Public Support for Science and Innovation." Productivity Commission Research Report.

Productivity Commission. 2009. "Australia's Productivity Performance, Submission to the House of Representatives Standing Committee on Economics: Inquiry into Raising the Level of Productivity Growth in Australia." September.

Rosenberg, N. 1963. "Technological Change in the Machine Tool Industry, 1840-1910." *Journal of Economic History* 23: 414–443.

Rosenberg, N. 1981. "Why in America?" In *Yankee Enterprise and the Rise of the American System of Manufactures*, edited by O. Mayr and R. C. Post, Washington, DC: Smithsonian Institution Press; Reprinted in Exploring the Black Box, Cambridge: Cambridge University Press, 1995.

See House of Representatives Standing Committee on Economics. 2010. *Inquiry into Raising the Productivity Growth Rate in the Australian Economy*, The Parliament of the Commonwealth of Australia, Canberra, pp.31–57.

Siedschlag, I., Z. Zhang, and B. Cahill. 2010. "The effects of the Internationalisation of Firms on Innovation and Productivity." ESRI Working Paper No. 363, Economic and Social Research Institute, Dublin, Ireland.

Schmookler, J. 1966. *Invention and Economic Growth*, Cambridge, MA: Harvard University Press.

Shanks, S. and S. Zheng. 2006. "Econometric Modelling of R&D and Australia's Productivity." Productivity Commission Staff Working Paper.

Soames, L., D. Brunker and T. Talgaswatta. 2011. "Competition, Innovation and Productivity in Australian Businesses." Methodology Research Papers, Cat. No. 1351.0.55.035, Australian Bureau of Statistics, Canberra.

Syverson, C. 2011. "What Determines Productivity?" *Journal of Economic Literature* 49 (2): 326–365.

Thomson, R. 2009. "Tax Policy and R&D Investment by Australian Firms." Intellectual Property Research Institute of Australia Working Paper No. 05/09, Melbourne Institute of Applied Economic and Social Research, University of Melbourne.

Department of Innovation, Industry, Science and Research. 2012. "Australian Innovation System Report." December.

Webster, E. and P. H. Jensen. 2006. "Investment in Intangible Capital: An Enterprise Perspective." *Economic Record* 82 (256): 82–96.

Wong, M., D. Page, R. Abello and K, Pang. 2007. "Explorations of Innovation and Business Performance Using Linked Firm-Level Data." Methodology Research Papers, cat. No. 1351.0.55.020, Australian Bureau of Statistics, Canberra.

Woodward, D., O. Figueiredo, and P. Guimaraes. 2006. "Beyond the Silicon Valley: University R&D and Hightechnology Location." *Journal of Urban Economics* 60: 15–32.

Yaşar, M. and C. J. Morrison Paul. 2012. "Firm Performance and Knowledge Spillovers from Academic, Industrial and Foreign Linkages: The Case of China." *Journal of Productivity Analysis* 38: 237–253.

KDI Book Membership Information

Exclusive Offer (Members-Only)

- All KDI publications, with the exception of those classified as confidential or limited, are to be mailed to members
- Preferential invitations to special events hosted by KDI including seminars, policy discussion forums, public hearings, etc., are to be mailed.
- A 10% discount on the online purchases of additional copies of the published research monographs (printed-only) from the KDI homepage.

KDI Publications

- Publications include books, research monographs, policy studies, KDI policy forums, KDI FOCUS, research papers and policy-information materials.
- Three types of periodicals are available:
  - Monthly: KDI Monthly Economic Trends, KDI Review of the North Korean Economy, Economic Bulletin, Narakyungje, click-Economic Education
  - Quarterly: KDI Journal of Economic Policy
  - Biannual: KDI Economic Outlook

Annual Fees

- Individual Purchase: 100,000 KRW
- Institutional Purchase: 300,000 KRW

Sign-Up

- You may sign up for membership via KDI homepage. Please register on the homepage by completing and submitting the registration form. Possible payment methods are as follows:
  - Bank-Transfer: Woori Bank, 254-012362-13-145 (account holder name: Korea Development Institute)
  - GIRO System: No. 6961017 (Credit Card and Mobile Payments available)
  - Direct Payment to the Research Outcome Dissemination Unit of KDI Division of External Affairs.

Contact

- Publication personnel in charge: Research Outcome Dissemination Unit, Division of External Affairs, KDI.
  - Tel: 82-44-550-4346 / Fax: 82-44-550-4950 / E-mail: book@kdi.re.kr
- Sales Distributors
  - Kyobo Bookstore (Gwanghwamun Branch: Government Publications Section)
  - Tel: 82-2-397-3628
- Yongpoong Bookstore (Jongno Branch: Policy & Economy Section)
  - Tel: 82-2-399-5632